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Internet of Things in Maritime Industry

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ABSTRACT

The Internet of things (IoT) refers to devices, both everyday devices and commercial technology, that communicate with each other over the Internet. It is transforming various aspects of maritime operations by providing real-time data that can be used to improve ship management, increase engine efficiency, decrease maintenance costs, and reduce the frequency and severity of breakdowns. The maritime industry is increasingly integrating the IoT to enhance operational efficiency, safety, and sustainability. IoT brings several benefits to maritime operations, from optimizing vessel performance to ensuring the safety of seafarers and the environment. This paper explores the world of IoT in the maritime industry.

KEYWORDS: *Internet of things, IoT, industrial Internet of things, IIoT, maritime industry*

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INTRODUCTION

Seas and oceans cover about 70% of the earth's surface. Sea vessels are loaded with packed cargo containers to be prepared and signaled for transit across the world. Issues can arise at sea, and maintaining contact with rescue services and authorities is essential. This is where the Internet of things (IoT) comes into play, addressing the fundamental needs of the maritime sector: ensuring safe navigation and facilitating communication of daily activities. The barriers to information flow at sea can be addressed by the power of the IoT [1].

In recent years, the importance of IoT has been recognized by the world's major trade industries, including maritime. IoT devices are wireless sensors attached to shipping containers to sense any change in the external environment. These devices are anchored with sensors and software technologies to collect and exchange and share data on multiple devices and systems using the Internet. IoT encompasses everything connected to the Internet. With the invention of IoT, anything can become a computer. Your kettle at home is no longer a kettle, it is a computer which just happens to specialize in boiling water. Your fridge is now a computer which just happens to keep things cool. In a maritime context, each box on a container ship is no longer just a box, but a computer which specializes in safely carrying goods around the world. With IoT, a ship is no longer a ship. It is a network of thousands of connected computers which specialize in moving thousands of tons of cargo safely and efficiently across the oceans [2]. Ships have become bigger and sophisticated logistic assets. The complexity of the maritime environment is shown in Figure 1 [3].

Using IoT devices, shippers can get real-time data about the whereabouts and health of the shipping containers and cargo. Internet of things (IoT) solutions are gaining importance in the shipping industry thanks to the huge number of distributed cameras and sensors in modern ships, cargoes and sea ports, which can be exploited to improve safety, costs, and productivity.

OVERVIEW ON INTERNET OF THINGS

The concept of the Internet of things (IoT) has been around since the late 1990s, but it gained momentum in the 2000s with the rise of Internet-connected

devices. The Internet began with some military computers in the Pentagon called Arpanet in 1969. It expanded throughout the 1980s as a set of four parallel military networks, each at a different security level. The core technology which gives the Internet its particular characteristics is called Transmission Control Protocol/Internet Protocol (TCP/IP), which is essentially a set of rules for communication [4].

Internet of things (IoT) is a worldwide network that connects devices to the Internet and to each other using wireless technology. These devices contain hardware such as sensors and electronics which give them the ability to interact with other objects and to be monitored and controlled from afar. The idea is that the physical devices with sensors or the ability to capture data, shares that data with websites. The information is then used or analyzed in real time or at a later time, to create efficiencies. IoT is expanding rapidly and it has been estimated that 50 billion devices will be connected to the Internet by 2020. These include smart phones, tablets, desktop computers, autonomous vehicles, refrigerators, toasters, thermostats, cameras, alarm systems, home appliances, insulin pumps, industrial machines, intelligent wheelchairs, wireless sensors, mobile robots, etc. Figure 2 illustrates the Internet of things [5].

There are four main technologies that enable IoT [6]: (1) Radio-frequency identification (RFID) and near-field communication, (2) Optical tags and quick response codes: This is used for low cost tagging, (3) Bluetooth low energy (BLE), (4) Wireless sensor network: They are usually connected as wireless sensor networks to monitor physical properties in specific environments. Communications technologies in Internet of things are portrayed in Figure 3 [7].

IoT technology enables people and objects to interact with each other. It is employed in many areas such as smart transportation, smart cities, smart energy, emergency services, healthcare, data security, industrial control, logistics, retails, structural health, traffic congestion, manufacturing, and waste management. The Internet of things is extensively developed world-wide with a focus on civilian applications such as electric power distribution, intelligent transportation, healthcare, industrial control, precision agriculture, environmental monitoring, etc.

INDUSTRIAL INTERNET OF THINGS

The growth of the internet of things (IoT) is drastically making impact on home and industry. While the IoT affects among others transportation, healthcare, or smart homes, the Industrial Internet of Things (IIoT) refers in particular to industrial environments. IIoT is a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine-human collaboration to improve productivity, efficiency and reliability. It is bringing about a world where smart, connected embedded systems and products operate as part of larger systems [8].

The industrial Internet of things (IIoT) refers to the application of the Internet of things (IoT) across several industries such as manufacturing, logistics, oil and gas, transportation, energy/utilities, chemical, aviation and other industrial sectors. A typical industrial Internet of things is shown in Figure 4 [9].

IIoT is often used in the context of Industry 4.0, the Industrial Internet and related initiatives across the globe. Industry 4.0 describes a new industrial revolution with a focus on automation, innovation, data, cyber-physical systems, processes, and people [10]. With Industry 4.0, the fourth industrial revolution is set on merging automation and information domains into the industrial Internet of things, services, and people. The communication infrastructure of Industry 4.0 allows devices to be accessible in barrier-free manner in the industrial Internet of things, without sacrificing the integrity of safety and security [11]. Figure 5 shows a typical representation of IoT [12].

MARITIME IOT

The maritime industry has undergone a technological transformation in the past few years, implementing cutting-edge technologies to enhance efficiency, safety, and sustainability. One such revolutionary force is the Internet of things (IoT), a network of interconnected devices and sensors that communicate seamlessly. The Internet of things is revolutionizing the maritime industry. IoT refers to the interconnectedness of devices, such as sensors and cameras, that are able to collect and share data with one another. IoT devices are transforming our approach to shipping logistics, vessel monitoring, and marine life conservation. They are making the maritime sector safer, more efficient, and more sustainable. Smart connected vessels reap the benefits of the IoT in a variety of ways, from driving down costs by scaling maintenance time to decreasing fuel consumption [13]. Maritime IoT is represented in the Figure 6 [14].

APPLICATIONS OF MARITIME IOT

The Internet of things (IoT) is transforming the maritime industry by enabling smart, connected systems for various applications like navigation, cargo management, and operational control. IoT solutions provide real-time data for monitoring, predictive maintenance, and optimized operations,

impacting areas like cargo tracking, environmental monitoring, and port management. The applications of the Internet of things in the maritime domain are numerous. Figure 7 shows some applications of IoT for shipping [15]. Common areas of applications of maritime IoT include the following [15-17]:

- *Fleet Management:* The implementation of IoT in maritime operations enables comprehensive fleet management. Ship operators can track the location, speed, and status of each vessel in their fleet in real time. Real-time tracking of vessels helps shipping companies to optimize routes, monitor fuel consumption, and minimize operational delays. Understanding not only what parcels need to be moved, but where they need to go, helps with fleet management. IoT sensors can interact with transportation management software to help with route optimization. Vehicles can share information with fleet managers about fluid levels, tire pressure, and other maintenance issues, to predict problems before they occur. GPS sensors can allow managers to know where vehicles and freight is without having to make a phone call. The manager can also monitor driving behavior.
- *Real-Time Monitoring:* Shipping companies that are investing in IoT technology believe monitoring shipments more closely will help them to make better decisions about their goods. Given the sheer size of many vessels, the monitoring of holds and decks for dangers related to fire or flood reduces labor costs associated with staffing patrols. More comprehensive monitoring provides real-time information such as cargo temperature, gas emissions, and other important data that can help optimize operations, reduce maintenance costs, and increase the safety of the entire ecosystem. IoT sensors on ships can monitor engine performance, fuel consumption, and other critical parameters, allowing for immediate adjustments to optimize operations and reduce fuel costs.
- *Cargo Monitoring*: Is your cargo at the right temperature and humidity? What forces is it experiencing? Where is it, and when will it get to the destination? IoT devices provide real-time tracking and monitoring of cargo, ensuring its safety and integrity throughout the journey. Shipping containers can be equipped with IoT sensors to monitor factors such as temperature, humidity, and vibration. This is particularly important for perishable goods like pharmaceuticals and fresh food.
- *Autonomous Shipping:* IoT devices are key to making autonomous vessels a reality. IoT sensors can provide data about environmental conditions, onboard systems, and even nearby vessels, which can help autonomous ships to navigate safely and efficiently without human intervention. These technologies could help shipping companies to lower labor costs, reduce human error, and increase the overall efficiency of maritime transportation.
- *Internet of Ships:* The recent emergence of Internet of things (IoT) technologies in mission-critical applications in the maritime industry has led to the introduction of the Internet of Ships (IoS) paradigm. IoS is a novel application domain of IoT that refers to the network of smart interconnected maritime objects, which can be any physical device or infrastructure associated with a ship, a port, or the transportation itself, with the goal of significantly boosting the shipping industry towards improved safety, efficiency, and environmental sustainability. Three major IoS application domains are smart ships, smart ports, and smart transportation. A typical IoS environment at sea is shown in Figure 8 [18].
- *Underwater IoT:* IoT technologies allow the implementation of new models of underwater research in the tasks of underwater archaeology, seabed mapping, natural resources search, and many other applications. There are three steps for implementing underwater Internet of things (UIoT). The first step is to implement a dynamic, continuous, comprehensive and intelligent real-time perception of the underwater environment. The second step in the implementation of IoUT is the transmission of large amounts of underwater data in real time. The third step in IoUT implementation is the intelligent processing of massive underwater data. The IoUT market segment for industrial applications in fisheries and aquaculture, which deals with fish farming in confined spaces, can be singled out separately.
- *Predictive Analytics:* Predictive analytics powered by IoT can help forecast component failure, thus improving maintenance scheduling and reducing operational costs. IoT aids in the implementation of predictive analytics for risk assessment, ensuring proactive measures are taken to avoid potential hazards. For example, data analysis can be used to predict ship arrival times, which can help to better plan the use of cranes and other cargo handling equipment. This can help to reduce congestion and delays at ports,

which can ultimately lead to cost savings for shipping companies.

- *Predictive Maintenance:* Normally, we replace or maintain equipment at fixed intervals whether it needs it or not. With IoT components, ships can carry out predictive or condition-based maintenance instead. Predictive maintenance uses ML models to compare current data with similar data from before a known failure of the equipment. The models identify patterns and alert us when we need to repair or replace the component. AI algorithms predict equipment failures, scheduling maintenance only when needed, thus avoiding unnecessary checks. Data analysis from IoT devices can help predict potential equipment failures, enabling proactive maintenance and preventing costly breakdowns.

BENEFITS

There are several advantages of embracing the Internet of things in the maritime industry. The main benefits are greater efficiency in operations, a reduction of human error, minimizing risk (both safety and security), and being able to offer a better quality of service overall. The latest advancements in IoT are revolutionizing the maritime industry by enabling smarter shipping, enhancing port operations, facilitating predictive maintenance, supporting environmental monitoring, and improving safety and security. Other benefits of IoT in the maritime industry include the following [19]:

- *Automation:* Shipping is constantly becoming the main field of automation and digitalization. To gain a competitive advantage, companies in the maritime industry need to move with the times, digitize, and automate. IoT enables automation of various ship functions, from navigation and engine control to cargo handling, leading to greater efficiency and reduced reliance on manual labor. Automation in warehouses is growing, from the use of robotic picking and packing, to automated sortation. Automation helps in regulating temperature, humidity, and airflow in containers.
- *Cost-effectiveness*: The on-time handling and repairs help reduce extra and unnecessary handling and maintenance charges. It prevents incurring heavy losses that may be caused due to damage to cargo. IoT analyses and offers the best and most efficient routes for shipment, thereby leading to the consumption of less fuel and resources. With the help of IoT-based solutions, the marine sector is eyeing on reducing the administrative costs of regulatory compliance and enhancing security and safety.
- *Increased Efficiency*: The use of sensors will provide an excellent opportunity to improve the efficiency and safety of ships and related equipment. In terms of increasing efficiency and slashing process times and costs, the IoT provides a way to supply automatic real time shipping updates throughout the entire supply chain process. Everything from a shipment's whereabouts, the estimated time of a delivery, and even the reasons for a delayed delivery will help organizations plan smarter routes and be more responsive to customers. In other words, they will be able to run a tighter ship. The process's efficiency helps lower operating costs.
- *Better Decision Making:* The wealth of data generated by IoT devices in maritime operations empowers stakeholders to make informed decisions. IoT solutions help operators make better decisions through the use of predictive analytics. The ability to make data-driven decisions enhances overall business performance and competitiveness in the maritime industry.
- *Preempting Maintenance:* Preemptive maintenance is another area in which the Internet of things is hitting it out of the park. Not only does pinpointing and addressing potential and small issues before they become big problems save money on repairs and downtime, but it also increases the safety of the crew onboard. The IoT sensors are installed on maritime equipment and collect data on performance metrics, allowing for predictive maintenance strategies. IoT technology is also useful for predictive maintenance, to alert users or a supply chain manager when a piece of machinery is nearing maintenance needs.
- *Reducing Fuel Consumption:* The maritime industry is under pressure to reduce fuel consumption and the Internet of things is proving to be a force for change in this area too. IoT-based smart meters, monitors and sensors onboard vessels collect performance data and accurately track fuel consumption. This results in shipowners not only saving money but allows them to also operate in a more environmentally friendly manner by reducing carbon emissions.
- *Enhanced Port Operations:* When it comes to life on land, smart ports are becoming the norm and are increasingly utilizing IoT devices to monitor and manage port activities in real-time. A smart port refers to a technologically advanced port that uses digital tools, IoT, automation, and data-driven systems to enhance the efficiency, sustainability, and security of port operations.

- *Environmental Monitoring*: The environment is a huge issue in the world of shipping and logistics and it is no surprise to find that the Internet of things is being used to help make the maritime industry more eco-friendly and sustainable. IoT technologies assist in monitoring environmental parameters such as water quality, emissions, and weather conditions. This information is crucial for compliance with environmental regulations and for implementing sustainable practices within maritime operations.
- *Improved Safety and Security:* An important issue in shipping is security - that of vessels, their cargo, and of course seafarers themselves. The increasingly unstable situation in the Red Sea has led to an increase of terror attacks by certain organizations and the issue of piracy is never far from mind. Therefore, the deployment of IoT devices to enhance maritime safety is a welcome one.
- *Customer Service:* Knowing where cargo is in ocean shipping or where supplies are with global IoT tracking can alert customers about the status. That takes the pressure off the company and provides solid information that can be used in planning. IoT devices can sometimes also alert customers about final delivery, or about product quality – if a sensor shows the product went out of temperature range, for example.

CHALLENGES

Since everything is governed online, hacking and personal information misuse are high risks. Deploying IoT devices on shipping containers or transport modes is costly and time-consuming. Other challenges of IoT in the maritime industry include the following [20]:

- *Maritime Safety*: Safety is paramount in maritime operations, and IoT plays a pivotal role in enhancing it. Sensors monitor various safety-critical parameters such as weather conditions, sea state, and the structural integrity of the vessel. IoT-based monitoring systems on ships can help with early detection of hazards such as fire, flooding, or equipment malfunction. Whether it is tracking cargo shipments, ensuring safe passage through difficult or dangerous areas, managing fleets of boats, or monitoring the proper functioning of ships, IoT is a powerful and indispensable ally for maritime safety. Figure 9 shows maritime safety and security [21].
- *Protection Against Piracy*: Piracy remains a significant threat to maritime shipping. IoT-enabled surveillance devices, such as satellite tracking systems, cameras, and radar, can provide real-time location data and imaging to help shipping companies to adjust routes and provide updates to security forces, minimizing the risk of piracy-related incidents.
- *Cybersecurity:* The main advantage of IoT solutions is also one of the biggest threats. The open ecosystem for development means that exploits discovered in one set of devices can be used for hacking products of multiple other manufacturers. Increased connectivity heightens the risk of cyber attacks, which could lead to significant operational disruptions. While IoT enhances safety, it also introduces new cybersecurity risks. IoT devices can also assist with regulatory compliance, cargo monitoring, and enhance safety and security measures. Robust security measures like encryption, firewalls, and adherence to international standards are crucial for protecting sensitive data and preventing disruptions.
- *Sustainability:* The maritime industry faces increasing pressure to reduce its environmental footprint. IoT is helping to promote sustainability in the maritime industry. IoT technologies contribute to sustainability efforts by enabling precise monitoring of fuel consumption and emissions. This data allows ship operators to optimize routes and adopt fuel-efficient practices, ultimately reducing greenhouse gas emissions. IoT facilitates compliance with environmental regulations by providing accurate reporting on emissions and other environmental impacts.
- *Regulatory Compliance*: Every year, the regulatory environment for ships becomes more stringent, requiring ever-increasing measurements and records. Sulphur caps, emissions requirements, oily water separators, security, and cybersecurity requirements are a few of the more recent requirements. IoT helps prove compliance while reducing the administrative burden on the crew.

CONCLUSION

The Internet of things is the network of physical objects that have been embedded with the computing power required to collect, process, and transmit data. The importance of IoT in the maritime industry is based on its versatility, flexibility, and reliability offered to its consumers. The main objective of utilizing IoT and its applications is to achieve better efficiency in terms of operations, minimize human errors and risks, and hence enhance quality service.

The Internet of things is a growing trend that introduces a huge network connecting physical

devices digitally to help in providing real-time data. It is helping the maritime industry to improve the safety of ships, ports, and the overall industry. As the maritime industry advances, IoT becomes an innovation that brings unprecedented efficiency, safety, and sustainability. More information about Internet of things in the maritime industry can be found in the books in [21,22] and the following related journals:

- IEEE Internet of Things Journal
- Journal of Marine Science and Engineering
- Journal of Shipping and Trade

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Figure 1 The complexity of the maritime environment [3].

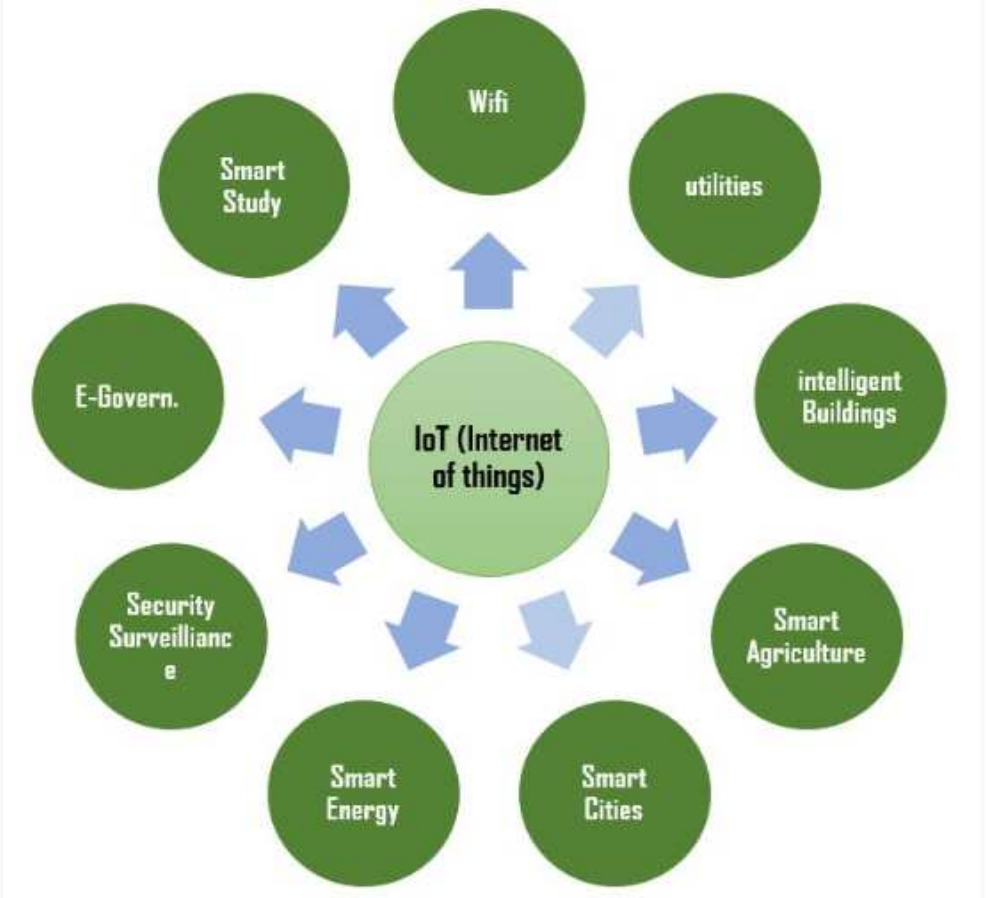

Figure 2 The Internet of things [5].

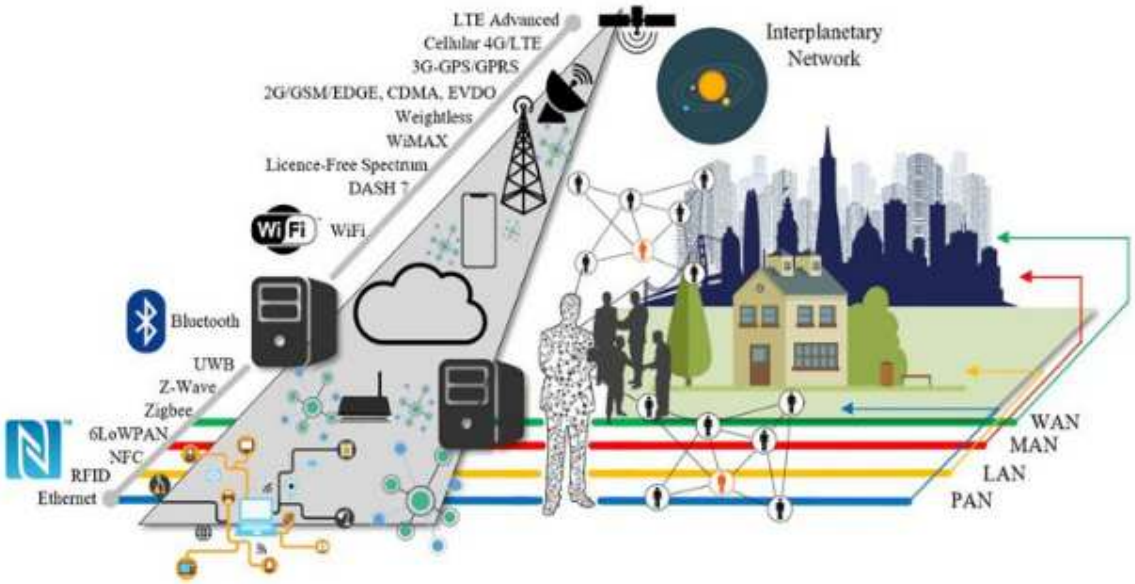

Figure 3 Communications technologies in Internet of things [7].

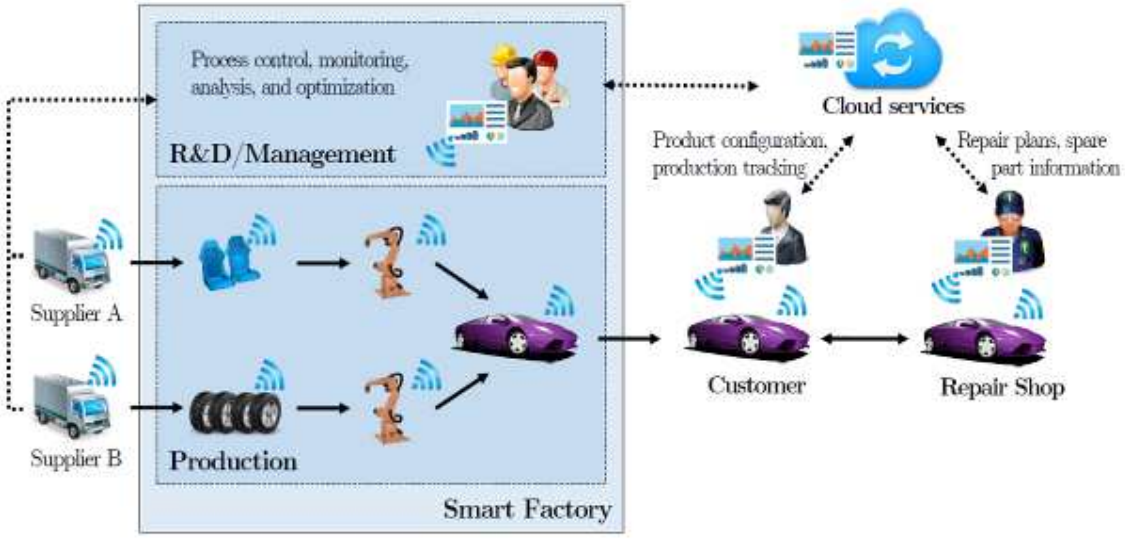

Figure 4 A typical industrial Internet of things [9].

Figure 5 A typical representation of IoT [12].

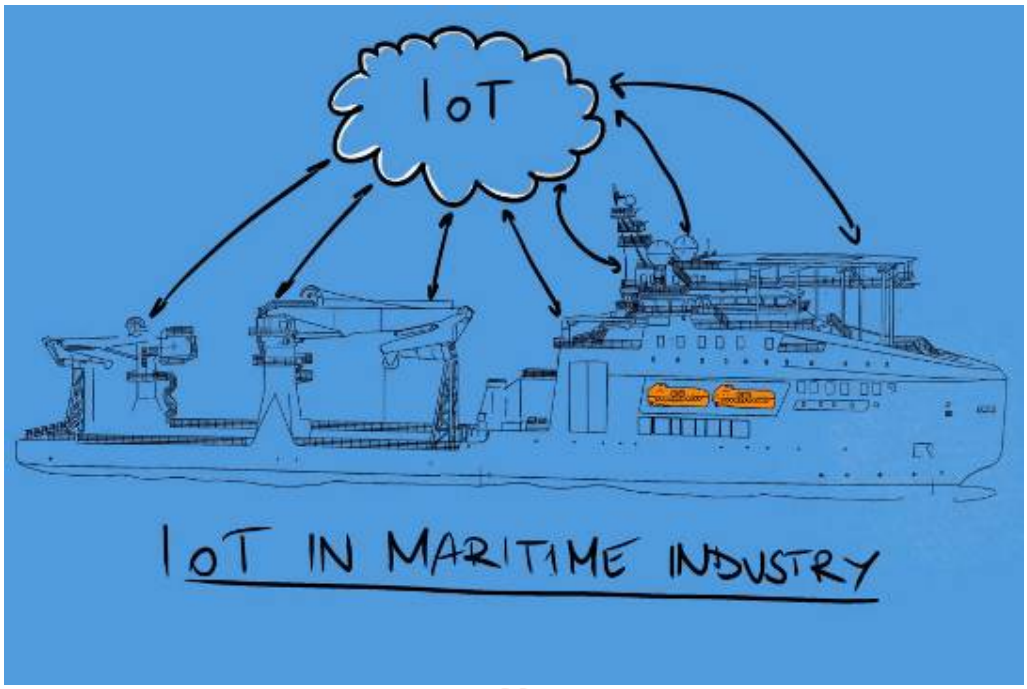

Figure 6 Maritime IoT [14].

Figure 7 Some applications of IoT for shipping [15].

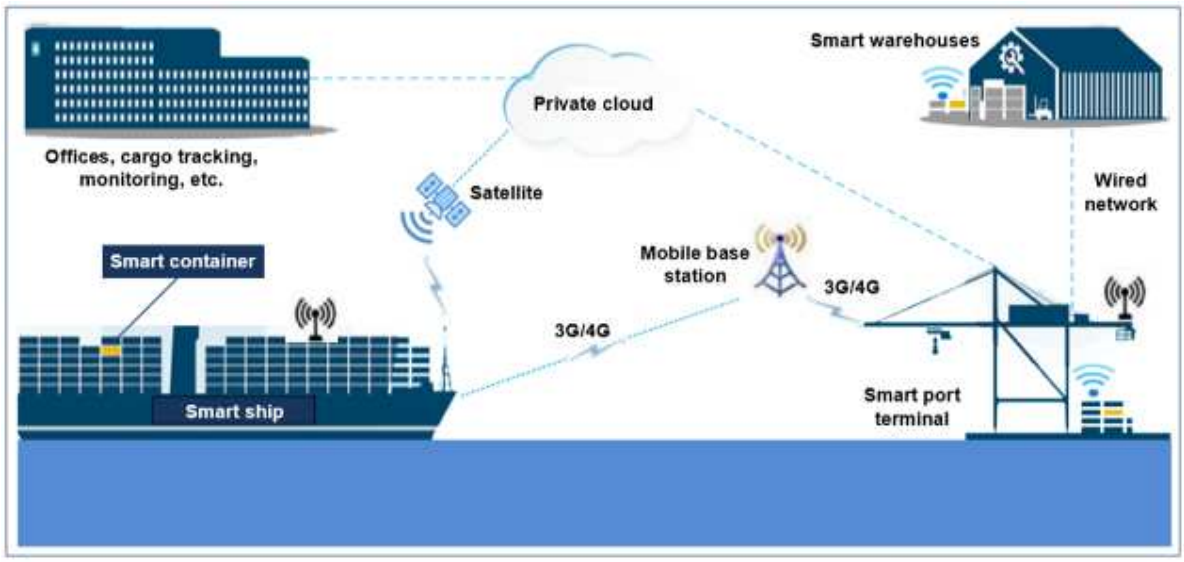

Figure 8 A typical IoS environment at sea [18].

Figure 9 Maritime safety and security [15].