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Brief Communication

Networking strategy for data-driven management in a ship: Requirements and applications

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Abstract: Data-driven management in ships to improve efficiency and safety increasingly requires a networking solution that should satisfy the requirements of a ship. The mandatory regulations in the International Maritime Organization (IMO) requirements require recording voyage data to assist in accident investigations. However, most intra-communication devices in a ship are built based on wired communication, such as Ethernet, which causes problems with initial installation cost and scalability. Internet of Things (IoT) technology interconnects many sensor nodes to collect data and allows them to be used intelligently. Considering wireless sensor networks for IoT in a ship, techniques to reduce the energy consumption of distributed devices and extend communication coverage are significant issues to collect various data in a ship and ensure the accuracy of the collected data. The long-range wide area network (LoRaWAN) protocol for IoT was introduced as a promising solution for IoT because it is a data link layer with a long range, low power, and suitable bit rate for IoT applications. This paper discusses the suitability of the LoRaWAN protocol as a potential networking strategy for ships and proposes its use cases for data-driven vessel management.

Keywords: Internet of Things (IoT), LoRaWAN, Data-driven management, Voyage Data Recorder (VDR)

1. Introduction

Owing to the growth of Internet of Things (IoT) technologies, the scale of issues and applications has increased in various areas. For better network connectivity, many studies have been conducted to determine the optimal power consumption strategies to increase the lifetime of each node **[1]**. With IoT technologies, a massive number of nodes equipped with communication devices and sensors require access to the internet and long-distance communication with limited energy.

Recently, data control and analysis of ships have been required to improve efficiency and safety. Data-driven management in a ship increasingly needs a networking solution that should satisfy the requirements of a ship. Passenger and non-passenger ships of 3000 gross tonnages and upwards constructed on or after July 1, 2002, must carry voyage data recorders (VDRs) to assist in accident investigations under regulations adopted in 2000, which entered into force on July 1, 2002 **[2]**. The VDR is a data recording system designed for all vessels required to comply with the IMO's International Convention Safety of Life at Sea (SOLAS) Requirements (IMO Res. A. 861 (20)) to collect data from various sensors onboard a vessel **[3]**.

New challenges arise from maintaining a stable connection in a ship for IoT-based data-driven management while reducing energy consumption and extending communication coverage. Therefore, there have been limitations in the application of legacy short-distance wireless communication methods, such as Wi-Fi and Bluetooth. To satisfy the requirements of IoT networking, many studies on low-power wide area networks (LPWAN) have been actively conducted. As a result, several approaches, such as LoRaWAN, Sigfox, narrowband Internet of Things (NB-IoT), and long-term evolution (LTE) machine-to-machine (M2M) (LTE-M), are commercially available.

Figure 1: LoRaWAN network architecture

LoRaWAN **[4]-[5]** is a promising candidate for use in many applications in ships. **Figure 1** shows an example of the LoRaWAN network implementation for data-driven management in a ship. This paper focuses on presenting suitable standard

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protocols as IoT solutions for data-driven management in a ship and proposes an application strategy that considers these requirements.

This paper is organized as follows: Section 2 explains the applicable solutions for IoT in a ship. In Section 3, the IoT strategy for ships is described. In Section 4, candidate technologies are compared and discussed to propose a more suitable onboard IoT technology. Finally, concluding remarks are presented in Section 5.

2. Applicable solutions for IoT in a ship

Wireless communication technologies proposed for IoT are classified into licensed and unlicensed band technologies. The first category includes the LoRaWAN and Sigfox, and the second category includes NB-IoT and LTE-M **[6]**.

2.1 IoT technologies with licensed bands

In 2016, Narrow Band (NB)-IoT was introduced to intend for sensing and data collection applications as a 3rd Generation Partnership Project (3GPP)) IoT initiative. It can satisfy the requirements of non-latency-sensitive and low-bit-rate applications **[6]**.

LTE-M is intended to satisfy the requirements of IoT devices based on existing LTE carriers **[6]**. It was designed to rely on existing LTE networks to reduce the compatibility problems of M2M applications and lower the production costs of communication modules **[7]**.

2.2 IoT technologies with unlicensed bands

LoRa/LoRaWAN is one of the most common LPWAN technologies that works on the unlicensed band, which is provided by Semtech **[6]**. It enables massive IoT scenarios that offer advantages in terms of cost and power consumption.

Sigfox is provided by the Sigfox company that provides network devices with ultra-narrowband technologies **[8]**. It aims to create a new communication technology with low power consumption and cost **[6]**. Sigfox is a suitable choice when IoT devices only need to send small and infrequent bursts of data **[7]**.

3. IoT strategy in a ship

3.1 Requirements in the relevant regulations

Regarding international regulations, the IMO stipulated that existing cargo ships engaged in international navigation services built before July 1, 2003, must have VDRs installed in accordance with SOLAS Revision V/20.2.

According to these regulations, VDR installation and operation are currently active in large ships and when a ship accident occurs the data stored in the VDR are analyzed and utilized to analyze the accident situation and cause of the accident. According to the international convention, the subject of the application is only passenger ships on international voyages and cargo ships of 3000 tons or more, but not coastal passenger ships. The data requested to be recorded include speed, heading, radar data, and status of all propulsion thrusters **[10]**.

3.2 Challenge for data-driven enhancements

The ongoing pressure to improve efficiency and increase safety will drive the need for ship digitization **[11]**. The challenge that the maritime industry will face for many years to come is to optimize and support the operation and decision of a ship using data. The transformation into data-driven management of a vessel can achieve the benefits of digitalization, such as cost reduction, enhanced safety, efficient decarbonization, improved decision making, technical management, etc. **[11]**.

4. Discussion and proposal

Table 1 presents the features of several LPWAN technologies that consider the best solution for data-driven management of a ship.

Table 1: Comparison among LPWAN technologies **[1]**

Feature	LoRaWAN	Sigfox	NB-IoT	LTE-M
Modulation	SS Chirp	GFSK/ DBPSK	UNB/ GFSK/ BPSK	OFDMA
Data rate	290bps – 50kbps	100bps	100bps	200kbps – 1Mbps
Battery lifetime	8-10 years	7-8 years	7-8 years	1-2 years
Power efficiency	Very high	Very high	Very high	Medium
Range	2-45 km	3-50 km	1.5-40 km	35-200 km

Regarding the data rate requirement, power efficiency, and communication coverage, **Figure 2** shows a comparison of the features of each technology. NB-IoT and Sigfox show almost the same performance levels, whereas LTE-M and LoRaWAN technologies show superior overall performance. Although LTE-M supports the highest data rate, its performance is inferior to that of the other technologies in terms of power efficiency. The supported data rate of LoRaWAN is lower than that of LTE-M. However, it satisfies the interface requirements for VDR, such as IEC

61162-1 and IEC 61162-2. In terms of power efficiency, it exhibits excellent performance, which makes it suitable for IoT applications.

Although there are tradeoffs between LTE-M and LoRaWAN in terms of data speed and power efficiency, LoRaWAN can be said to be a more suitable technology for onboard IoT, considering the communication bands of LoRaWAN and LTE-M and the in-ship environment. IoT communication methods with unlicensed spectra can conflict with other business flows with respect to channel collisions **[9]**. However, unlicensed band communication technologies within a ship are relatively free from the problem of collisions between heterogeneous communication technologies.

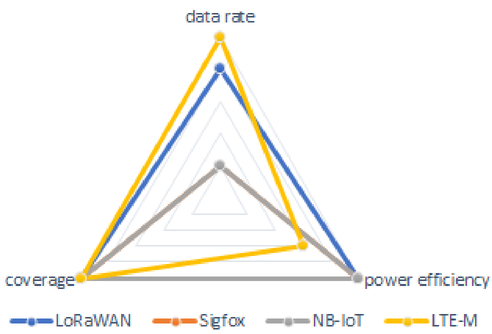

Figure 2: LoRaWAN network architecture

Potential use cases in ships using LoRaWAN are as follows: in domestic use cases, smart leakage detectors of gas and water using LoRaWAN have been installed in cities such as Seoul, Busan, and Daegu. Germany and Switzerland applied LoRaWAN to monitor containers at ports. By analyzing these application cases, data-based vessel management will become possible by applying LoRaWAN to the part that collects and monitors the ship's engine system or various navigation information.

5. Conclusion

This study analyzes several promising IoT technologies for data-driven enhancement in ships. Considering requirements such as the IMO regulations, data rate, power efficiency, cost reduction, etc., and the onboard communication environment, LoRaWAN is suitable technology for onboard IoT. Because the LoRaWAN protocol has been applied in various areas and meets the requirements for safety and efficiency, it can easily be adopted in the onboard IoT strategy.

Author Contributions

Conceptualization, Y. -I. Joo; Methodology, Y. -I. Joo; Writing-Original Draft Preparation, Y. -I. Joo; Validation, Y. -I. Joo; Writing-Review & Editing, Y. -I. Joo.

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