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A Study on the Navigation Aids Management Based on IoT

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Abstract

Nowadays, most cargoes for export/import are processed through maritime transportation. Large-scale and high-speed vessels make maritime transportation more and more complex, which causes frequent maritime accidents.

The risk of these maritime accidents can be reduced by providing systematic and appropriate safety information about them. For this, navigation aids are actively being used. However, because navigation aids are managed and maintained by using a manager's visual observation, as well as by using a lighthouse and a buoy tender, checking the position error of a mooring buoy and its real-time condition becomes impossible. In accordance with this, conducting an overall review and an advance research on maritime transportation system on coastal waters should be conducted to systematically manage maritime transportation conditions, which makes it is necessary to develop a method of systematic management and efficient operation of navigation aids to help guarantee safe navigation on coastal waters.

As a solution, this study analyzed the problem of current navigation aids management by conducting a literature study and an interview with relevant field experts. It suggests a method to manage navigation aids, which is applicable to IoT (Internet of Things) technologies.

Keywords*: IoT, AtoN (Aids to Navigation), Navigation Aid, Navigation Aid Management*

1. Introduction

At present, cargoes are being imported and exported globally through maritime transportation. However, the increase of ship spaces and cargo volumes, resulting from the increase of large and high-speed vessels, makes maritime traffic increasingly complicated [1-]. In particular, based on the analysis on maritime accidents, a higher rate of accidents on coastal waters where vessel entry and departure frequently occur [4] has been observed. Consequently, this causes serious problems such as maritime environmental pollution and fatal damage to human lives.

In the case of Korea, a country that is topographically characterized by having a complex coastline and a large tidal range, there is always a lot of potential causes of maritime accidents [5].

The risk of such maritime accidents can be reduced by providing systematic and appropriate safety information to vessels that approach the land [6]. At present, the navigation aids are actively used to provide maritime information [7, 8], and maritime transportation is also being managed through Vessel Traffic Services (VTS) [9, 30]. Besides, IALA (International Association of Lighthouse Authorities) strongly recommends AIS AtoN that applies AIS (Automatic Identification System) [3].

However, Korea has not actively introduced AIS AtoN and the systematic management of navigation transportation using VTS. In addition, navigation aids has not been sufficiently conducted. To systematically manage maritime transportation conditions,

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conducting an overall review and research on maritime transportation system on coastal waters shall be conducted in advance. In particular, the systematic management of navigation aids that can act as a guide for safe navigation of vessels is urgently needed [5].

This study suggests an efficient method of navigation aids management based on IoT technologies. IoT means an intelligent platform that makes free data communication, information exchange, and mutual communication possible between humans and things and between things and other things by intellectualizing and networking them based on ICT.

This study also analyzes the current status of navigation aids management and its system through a literature study and interview with relevant field experts. Moreover, this study suggests an application and utilization method through the development of navigation aids management scenarios and services.

This paper is composed of five chapters. Chapter 2 briefly introduces the navigation aids and IoT. Chapter 3 introduces the service scenarios and major functions for navigation aids management. Lastly, Chapter 4 summarizes the matters that shall be further studied in the future.

2. Theoretical Background

2.1. IoT

The future Internet enables us to obtain not only the data, information, and knowledge created and processed by humans but also the information produced from everyday items around us, with functions on sensing and actuation. Moreover, these items will interact with the world through computing and communication using their own identifiers [10, 11, 12]. IoT is a concept that was suggested by Kevin Ashton, the former director of MIT Auto-ID Center in 1999 [13], and it is diversely defined in academic and industrial circles.

ITU argues that while the existing ICT enables humans and things to give and receive information "anytime, anywhere," IoT is a technology that makes the connection and communication between humans and things, as well as between things and other things, possible by adding a new concept of "anything" as shown in Figure 1 [14, 15] below. This "anything" includes not only the specific things on physical space but also the information identified and stored on cyberspace [16].

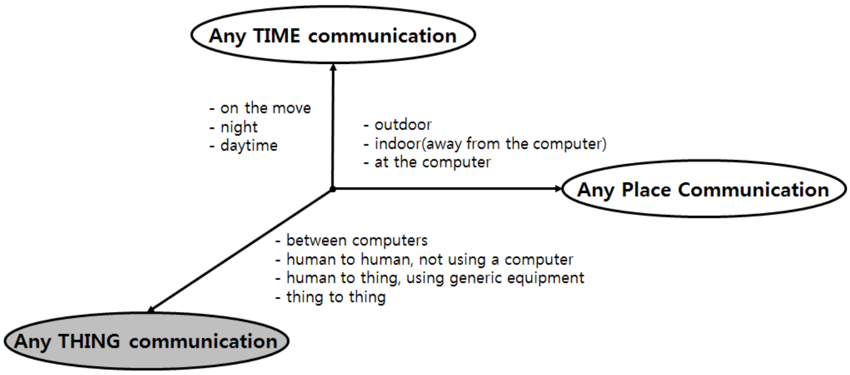

Figure 1. The Concept of IoT [16]

EU stipulates that IoT refers to all the things that can connect and communicate with their ambient environmental factors through an interface that is intellectualized with their own identifiers and cyber personalities [17]. The Korea Communications Commission (KCC) defines IoT, a similar concept as M2M, as "a future broadcasting-and-communication-fusing ICT infrastructure that can use intelligent communication services between humans to things and between things and other things safely and conveniently on a real-time basis anytime, anywhere [18].” However, the difference between IoT and M2M lies in the entity of connection. While the entity of M2M is “machine,” the entity of IoT is “environment” that includes all things connected to humans.

Nowadays, IoT is rapidly evolving from the concept of M2M, which makes anenables the intelligent communication between humans and things and between things and others things possible using a mobile communication network, to the concept of interaction with all information in real and virtual worlds, including the information on things by expanding its area to the Internet [19]. In other words, M2M, which makes the intelligent communication between humans and things, as well as between things and other things, possible and on a real-time basis anytime at any place, is expanding its area to IoT while connecting with all things around it through the medium of Internet.

Taken together, IoT can be defined as “an intelligent platform that makes free data communication, information exchange, and mutual communication between humans and things, as well as between things and other things, possible by intellectualizing and networking them based on ICT.”

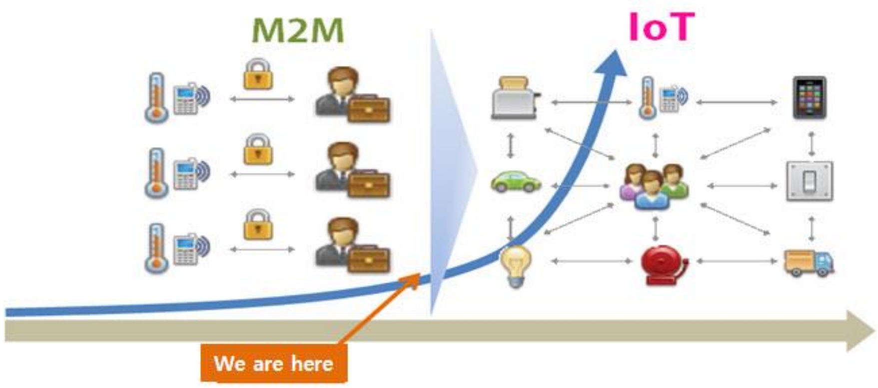

Figure 2. Concept Changes of M2M and IoT [19]

2.2. Current Operation and Management Status of Navigation Aids

Port facilities are defined as the entire facilities that are necessary to meet the function of ports, including the anchorage, wharf, structures, and facilities attached to them. Among these, navigation aids are artificial facilities installed to ensure the safety of ships and maritime transportation with improved navigation efficiency [7]. They are classified by communication channels such as lantern light, shape, color, sound, and radio wave. The location of a vessel should always be identified for safe navigation of vessels. In accordance with this, various communication channels are used to indicate its location even at night or in severe weather. IALA classifies navigation aids into visual signals, including visual aids and shape signal; radio beacon such as Racon, GNSS, AIS, and VTS. Korea Association of Aids to Navigation classifies navigation aids as shown in Table 1.

Table 1. Kinds of Navigation Aids

Type	Definition	Kinds
Visual aids	Navigation aids with the same structure with daytime beacon, which indicates the location using the light at night	Lighthouse, light beacon, leading light, spot lighting light, direction light, light staff, bridge light, light buoy, and light vessel
Shape signals	Navigation aids that indicate the location using shape and color in the daytime	Beacon, leading mark, and buoy
Audible aids	Navigation aids that indicate the location to a vessel by creating sound waves and sending out acoustic signal when visibility is poor because of bad weather	Air siren, electric horn, diaphone, motor siren, and bell
Radio beacon	Navigation aids that work as an indicator for vessels or aircrafts using straightness, isokinetic, and reflexibility that are characteristics of radio wave	Radio beacon, radar beacon, Raymark Beacon, Loran, Decca, ShodaVision, Omega, radio, and radar station
Special signal mark	Navigation aids that provide vessels at sea with navigation data about the traffic volume of vessels or the direction of tidal current in narrow straits, waterway, and others using radio wave or shapes, day and night	Traffic control signal mark, tidal signal mark, and weather signal

The navigation aids that are installed in Korea as of 2014 are summarized in Table 2 [20] below. A total of 4,633 units have been installed in the ports. Among them, 2,790 units are owned by the state, accounting for around 66% of the total units. The number of the private navigation aids is 1,843, which is equivalent to around 66% of the state-owned units. Navigation aids are concentrated in West Sea regions such as Incheon and Yeosu that have complex coastlines [21] and Busan with much maritime transportation.

Table 2. Number of AtoN in Regional Maritime Offices

Port / Classification	Total	Busan	Incheon	Pyeongtaek	Donghae	Daesan	Gunsan
Total	4,633	792	234	658	519	528	178
State-owned	2,790	646	171	253	288	314	83
Private	1,843	146	63	405	231	214	95
Port	**Mokpo**	**Jindo**	**Yeosu**	**Pohang**	**Masan**	**Ulsan**	**Jeju**
Total	186	204	319	283	233	171	328
State-owned	128	123	198	185	145	106	150
Private	58	81	121	98	88	65	178

The major function of navigation aids are to guarantee the safety of the ships and prevent large maritime accidents, which are subject to the following two basic conditions. First, they should always be firmly installed at certain places to enable people to easily identify their locations. Navigation aids should be exactly operated at constant locations, because they should be easily identified by anyone. Second, they should allow people to check their conditions for immediate inspection and use. In other words, people should be able to immediately ignore the navigation aids at normal times or use them as the occasion demands. The stability and reliability of navigation aids can help navigators depend on them by eliminating the risk factors in maritime safety [22].

However, because of the characteristics of their installation and operational environment, it is difficult for them to keep their constant places. The light buoys are sometimes lost because the fastening devices that maintain their places are damaged because of ship collisions and high winds. Furthermore, the light beacons sometimes cannot properly function because they have reached the end of their service lives or because they are damaged even if the light buoys are able to keep their places. The Korean government operates an integrated navigation aids management system by taking in consideration the characteristics of the current monitoring and management method for each navigation aid, as well as the features of widely distributed facilities. The current integrated navigation aids management communication system performs the function of navigation aids management by monitoring the information about the location and the condition received by a relay center or an integrated management center via VHF and UHF networks from the navigation aids or lighthouses [23, 24]. However, because these methods also have many limitations, different opinions are currently suggested and discussed with regard to the methods of operation and communication [24, 25].

Regular container shipping carriers have recently pursued the economies of scale based on the increase of large containers. As a result, it is expected that hub ports will decrease to a few ports and the placement of feeder container ships will increase because the volume of cargoes will sharply increase as vessels become larger and larger. Therefore, maritime traffic volume will increase rapidly and traffic congestion will get worse. In addition, the navigation aids that do not work properly may cause fatal maritime accidents. At present, the management as well as the repair and maintenance of navigation aids are mostly dependent on the “lighthouse and buoy tender,” which checks the function of navigation aids and carries out management activities such as repair and maintenance. However, this method cannot check the real-time condition of maintenance aids. Moreover, visual observation can create errors in location identification. The information on any separation or failure of navigation aids is difficult to be properly transmitted using the current methods. Moreover, it is difficult to obtain information about their conditions because it is not easy to monitor the electric power condition or consumption with a remote control. Recently, a system [8, 27, 28] was introduced to allow an application to check the location of navigation aids through the installation of a GPS or a DGPS receiver [26], or to control and monitor [4] the navigation aids using wire and wireless remote control devices. However, this system is not actively used because of communication problems and high operational costs [29].

3. Service Development to Manage Navigation Aids

3.1. Requirements and Application Scenario

To derive the requirements and scenarios for navigation aids management, this study conducted an analysis through a literature study and an interview with relevant field experts. It also took in consideration the technological aspects of IoT, including their environmental characteristics. As described above and shown in Figure 3 below, it is necessary to check the locations and real-time operating conditions of navigation aids for their safety and efficient operation.

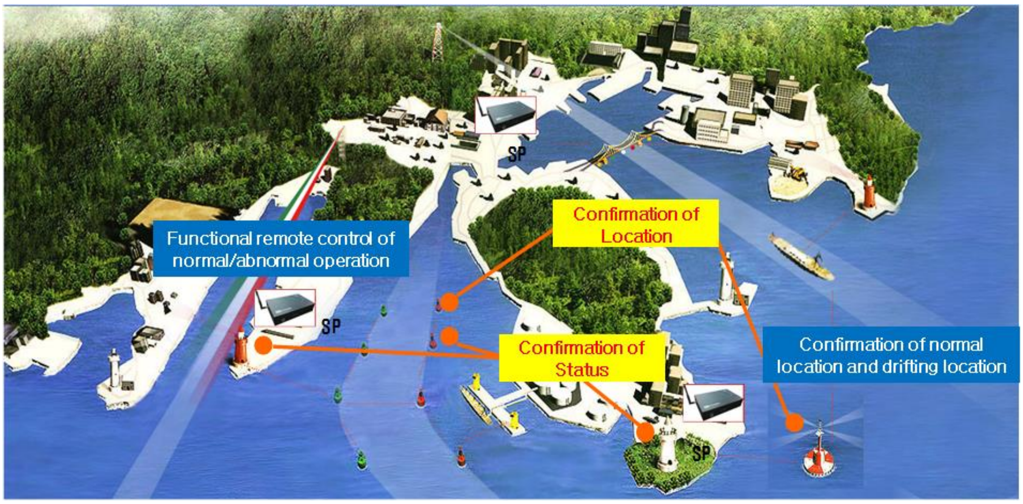

Figure 3. Requirements for Navigation Aids Management

In accordance with the result of an interview with relevant field experts and a managing agency, the manager directly identified each location of the buoys through naked eye observation.

Auxiliary aids for navigation are generally fastened at their locations through the installation of sinkers at the seabed. However, they sometimes drift from their location because of high winds and collision, and it is hard to identify their locations by only using naked eye. The managers sometimes monitor the location of the buoys by installing a DGPS receiver at the aids, but this can also create problems because of the high installation and operation expenses. In the current maintenance and repair management, the relevant agency measures various functions using a vessel, as well as conducts maintenance and repair. While navigating within the effective range of radio aids, the agency measures the positioning of each system and checks the status of the receiving radio waves. Besides, it also measures the effective luminous intensity and visibility status of the visual aids of each system and identifies the storage battery, the solar battery, the electric bulb, and the charge and discharge conditioner. However, real-time checking of the status and immediate action are not conducted when any problem occurs.

Based on these problems, this study created a scenario by taking in consideration two aspects: 1) location management through identification and tracking of navigation aids; and 2) equipment management through remote control and collection of state information. First, for the identification of navigation aids, their current exact location can be identified by identifying the location of each navigation aid that has been installed, as well as by perceiving its movement during its entry into a nearby IoT network, even if it deviates from its normal position. At this time, the manager can directly receive information that he/she needs from the IoT equipment on the navigation aids or check the location of the lost equipment.

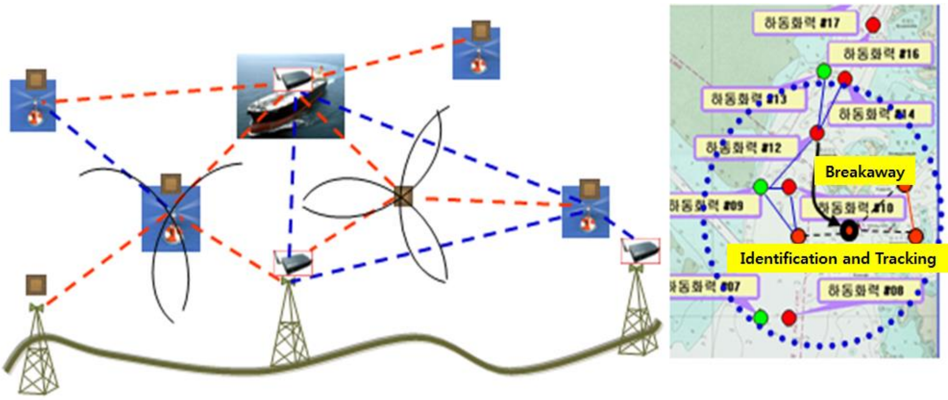

Figure 4. Identification and Location of the Navigation Aids

Second, the function control remotely controls the movement of the installed navigation aids and the functions of lighting and lights-out, the flickering cycle, as well as the luminous intensity. Using the sensor, the state information related with the movement of the facilities or their function can be collected and delivered to the manager on a real-time basis in case an abnormal situation occurs. The major information collected includes communication state, lamp state, battery state, brightness, temperature, collision state, *etc.*

Such application scenario works based on the process shown in Figure 5 below.

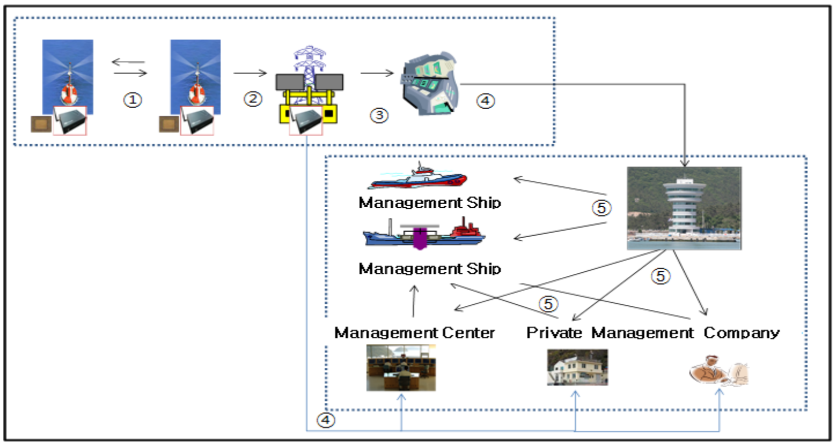

Figure 5. Procedures of Application Scenario

① Exchange of state information between IoT equipment installed in navigation aids

② Controls the navigation aids or transmits the location information to a ground station (or communication terminal) using control technology or an IoT equipment

③ Transmits information from the ground station to the control center

④ Provides transmitted information to navigation aids-integrated management center and navigation aids installer or the entrusted management company

⑤ Immediate notification in line with the management of ships for inspection and repair of the relevant navigation aids in case of functional or equipment problem

3.2. Service Functions and Major Contents

For the management of navigation aids using IoT technology, scenarios and services were developed under the assumption that an IoT equipment or a communication terminal is installed in navigation aids. Through the installation of the IoT equipment, a network can be constructed on coastal waters as an infrastructure that can be used for relevant scenarios or systems, such as coastal waters traffic control and management of aqua farm facilities and fishing gears, as shown in Figure 6 below.

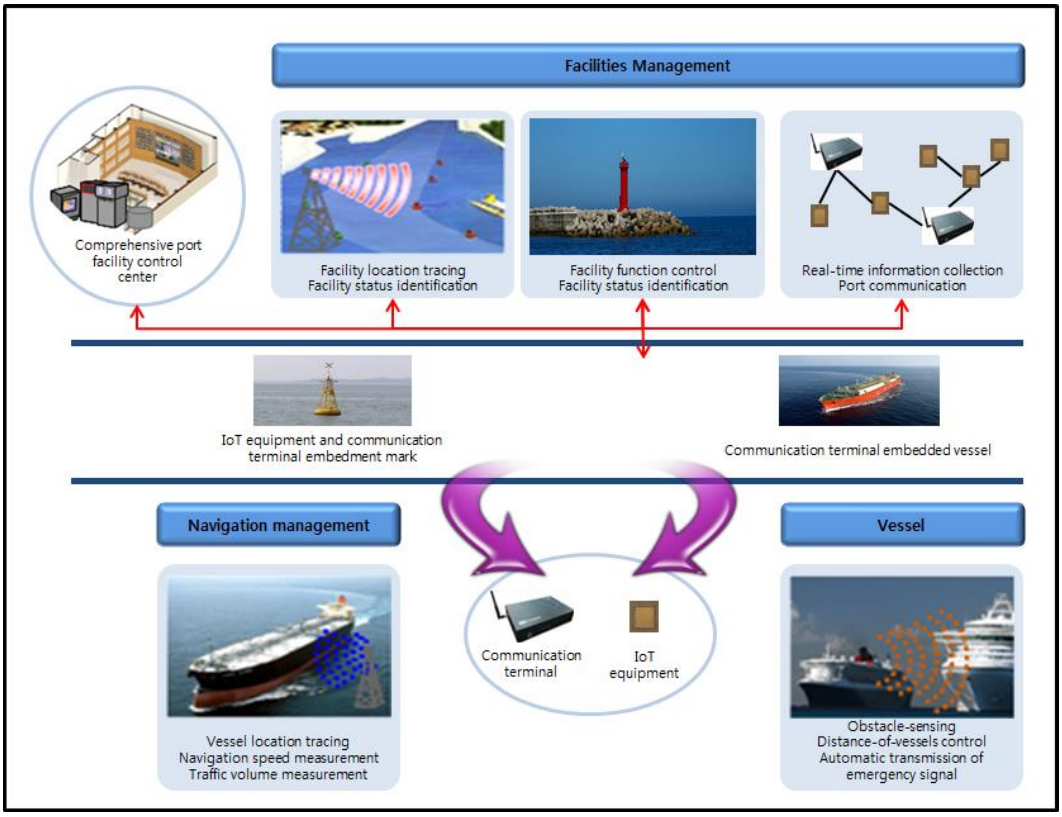

Figure 6. IoT Scenario Application

Figure 7 below shows the configuration diagram of navigation aids management system using IoT technology. IoT-based navigation aids management system, operated under the control of general port facilities control center, can be used for production and utilization of various additional services. Apart from the navigation aids operation and state information collected on real-time basis, various maritime environmental information can be collected and provided through public cloud. A more detailed maritime state and weather information than the present can also be provided through data analysis.

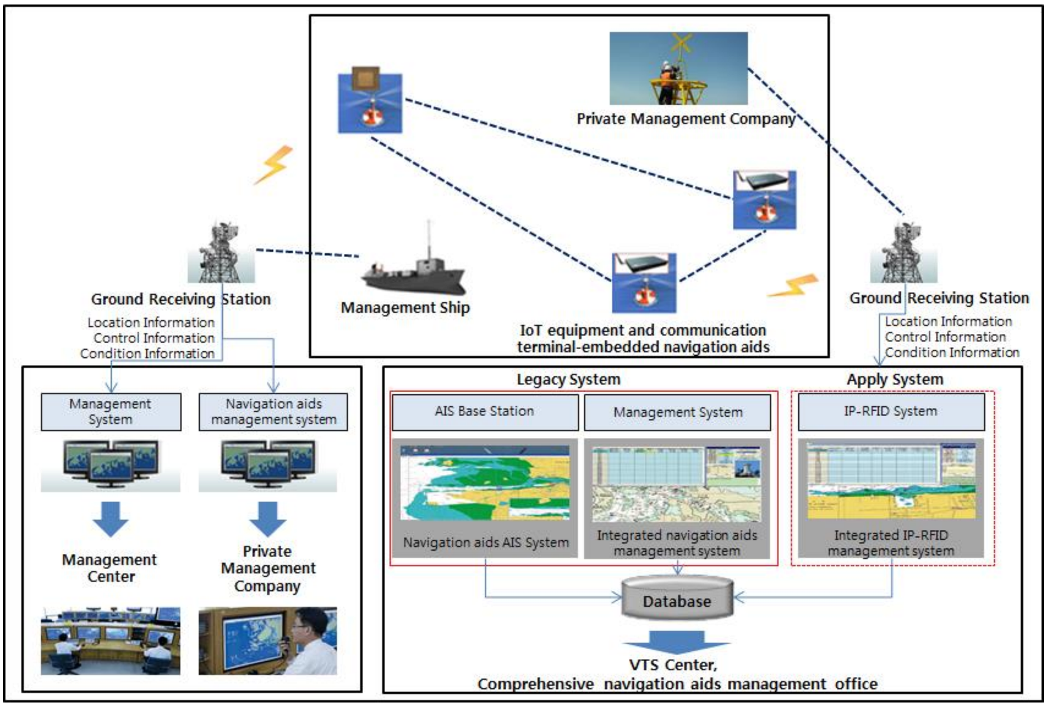

Figure 7. Configuration Diagram for IoT-based Navigation Aids Management System

The IoT-based navigation aids management system provides relevant data to comprehensive navigation aids management center and maritime traffic control center. It also provides relevant data to major relevant entities, such as navigation aids management office, private navigation aids installation company, and trust management company, thus enabling them to manage the navigation aids on a real-time basis. As shown in Table 3 below, the contents of services are classified into two categories and into five subcategories.

Table 3. Detailed Contents of Each Major Service

Category	Subcategory	Contents
Real-time information delivery service	Identification service	Can check which IoT device is attached to navigation aids using its unique identifier and can carry out the management of each different navigation aid
	Location identification/tracing service	Can trace the location by applying the technologies of RTLS or communication between the IoT equipment and the facilities with communication terminal
	Operation status notification service	Can directly deliver information to the relevant entities that manage vessels (comprehensive management office, management office, installer, trustee) using an IoT equipment and a communication terminal
Remote control management	Remotely controlled function service	Can carry out the remote control function of the navigation aids equipment
	Malfunction and problem text notification service	Can detect any problem in the movement of navigation aids, the luminous intensity of beacons, the collisions of vessels, floating matters, and the battery condition by using IoT equipment sensors

4. Conclusion

The navigation aids, VTS, AIS, and AtoN are currently used to manage maritime traffic. However, various problems arise because of highly technological devices that have not been sufficiently introduced and the management system that is not accurately operated. In accordance with this, it is necessary to develop different methods to improve the navigation aids that act as a guide to the vessels that are navigating on coastal waters.

As a method of real-time management and efficient operation of navigation aids, this study developed application scenarios that used IoT technologies and suggested a system configuration method as well as other relevant services.

This study applied IoT technologies for real-time monitoring and remote control of the navigation aids that were pointed out as the problems in navigation aids management based on previous studies and by condcuting an interview with relevant field experts.

This study also suggested the identification service, the location identification and tracing service, as well as the operation status notification service, as the detailed service for real-time information delivery service. The remote control function service and the malfunction and problem text notification service were also suggested for remote control management.

Through this method, time and expense for the repair and maintenance of navigation aids—which can be directly related with large-scaled maritime accidents—are expected to be reduced through the use of IoT technologies that are currently in active development through various ways. In addition, the reliability and stability of the navigation aids will be improved because relevant information can be directly delivered to the managers and users of the navigation aids on a real-time basis, thus contributing to the safety of ships and the prevention of maritime accidents.

As such, this study suggests that a research on IoT equipment installation and communication network configuration on the navigation aids should be conducted. Moreover, a research on processing, analysis, and utilization of the various data collected using an IoT equipment should also be carried out on a real-time basis in the future.

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