Automatic Identification Monitoring System for Fishing Gear Based on Narrowband Internet-of-Things Communication Systems

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***Abstract*—Lost and derelict fishing gear is devastating for the marine environment, causing marine accidents and decreasing the catch of fish. Therefore, South Korea is attempting to reduce this lost and derelict fishing gear by developing a new monitoring system that can track the location of fishing gear and manage this type of debris. This monitoring system will use what is known as the Narrowband Internet of Things (NB-IoT) for marine communication. Marine communication encounters a signal strength problem when a wave invades the first Fresnel zone. This article suggests relaying by drones to solve this problem and extend the coverage of communication modules.**

Keywords—Marine communication; Fishing gear; Narrowband Internet of Things; First Fresnel zone; Drone; Relaying

I. INTRODUCTION

Various types of fishing gear are used in the fishery and aquaculture industries both in nearshore and offshore locations. In particular, 131,000 tons of fishing gear are used each year in South Korea, which is surrounded by seas on three sides [1]. Lost and derelict fishing gear is causing great damage to marine environments, and marine accidents caused by derelict fishing gear are threatening the safety of fishermen. This devastation of the marine environment due to these debris decreased the catch of fish by an estimated 10% in 2016 in South Korea. Derelict fishing gear sometimes causes marine accidents in South Korea. Currently, fishing boats have become larger and use advanced fishing methods. However, the productivity of fisheries in nearshore and offshore locations has decreased. It is assumed that this decrease is caused by overfishing, ghost fishing (a term referring to lost and derelict fishing gear), and illegal fishing. Therefore, fishing gear management laws, monitoring systems, closed seasons, and resource management efforts have been considered. The FAO (Food and Agriculture Organization) of the United Nations has promoted the development of a management plan to maintain marine resources and to guarantee their efficient use. However, some feel that the efforts of the FAO will decrease productivity of fisheries. The Code of Conduct for Responsible Fisheries of the FAO recommends the marking of fishing gear during the operation of a fishery, emphasizing the importance of developing new technologies or new fishing methods to minimize ghost fishing [2].

South Korea revised the rule to permit fisheries and to register them, also introducing a real-name fishing gear system to prevent the overuse of fishing gear in nearshore and offshore areas. However, these regulations, despite much sympathizing with them, were not followed closely due to perceived inconvenience and unfairness. Therefore, South Korea suggested the necessity of developing a new real-name fishing gear system, a monitoring system to manage fishing gear, new technology to handle derelict fishing gear, and technology by which derelict fishing gear can be collected. In certain more advanced countries, such as Norway, Canada, and France, technology to check the condition of fishing gear on fishing boats and to monitor fish catches is being developed based on marine communication and navigating technology. However, no country can monitor all fishing gear around the world. South Korea, which has implemented a real-name fishing gear system, is attempting to adopt a new automatic identification monitoring system using NB-IoT [3], one of the latest IoT technologies, in cooperation with a mobile communication company to reduce the amount of lost and derelict fishing gear.

Section 2 outlines the current knowledge on automatic identification monitoring systems. Section 3 discusses several issues, including the decline of signal strength levels caused by the invasion of first Fresnel zone area related to antenna buoys and wave heights. Drones for relaying are then suggested as a solution for the signal strength and coverage issues of NB-IoT modules. Section 4 concludes this article.

II. AUTOMATIC IDENTIFICATION MONITORING SYSTEM FOR FISHING GEAR BASED ON NB-IOT

A. Narrowband Internet of Things

The IoT as the next generation of mobile communication has been developed rapidly by mobile communication companies and manufacturers. NB-IoT, a form of the IoT, uses low-power wide-area (LPWA) communication technology. Related to this, 3GPP approved NB-IoT based on narrowband LTE including OFDMA/SC-FDMA and it was included as a working item (WI) in Release 13 of Radio Access Network (RAN) #70 to cope with issues related to LPWA, LoRa, and Sigfox. NB-IoT can communicate via small amounts of data on a bandwidth of 180 kHz in the licensed LTE frequency domain. NB-IoT has three operation modes, the guard-band, in-band, and stand-alone modes, as described in

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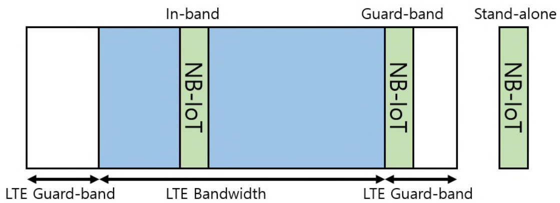

Figure 1. Operation modes of NB-IoT

TABLE I. SUMMARY OF NB-IOT

	NB-IoT
Deployment	In-band & guard-band LTE, stand-alone
Coverage	164dB for standalone, FFS others
Downlink	OFDMA, 15kHz tone spacing, 1 Rx
Uplink	Single tone, 15kHz and 3.75kHz spacing SC-FDMA, 15kHz tone spacing, Turbo code
Bandwidth	180kHz
Peak rate (DL/UL)	DL: ~200kbps UL: ~200kbps
Duplexing	HD, FDD
Coverage	~15km
Modulation	QPSK/16QAM
Power saving	PSM, ext. I-DRX, C-DRX
Power class	23dBm

Figure 1. Table 1 presents the specifications of NB-IoT. RAN #72 approved an enhanced NB-IoT (eNB-IoT) which requires additional improved technology as specified in the WI of Release 14 [3].

NB-IoT has several advantages. First, the NB-IoT modules are typically small and therefore inexpensive. Second, NB-IoT uses existing LTE base stations, which are already widespread in South Korea. Therefore, this technology allows communication everywhere in South Korea. Third, the batteries used in NB-IoT modules are expected to work for ten years because NB-IoT uses LPWA. Thus, maintenance is also inexpensive. NB-IoT is thus clearly suitable for small data communications.

B. Concept of the automatic identification monitoring system

The automatic identification monitoring system as a new system developed by the government attempts to prevent lost and derelict fishing gear from causing harm to marine environments while also maintaining a safe environment for fishermen by attempting to prevent marine accidents which are caused by the derelict fishing gear, among other tasks. The government wants to successfully manage fishing gear near the shore and in offshore areas. The monitoring system can always track the positons of fishing gear and judge whether or not these items are lost. Furthermore, the real-name fishing gear system serves to prohibit the overuse of fishing gear and to control fish catches. Above all, these measures motivate fishermen to maintain control over their fishing gear. The adoption of IoT technology for communication between fishing gear and the base station, between the base station and management ships, and between the base station and fishing boats is the key aspect of this monitoring system. The monitoring system utilizes NB-IoT communication technology, broadcasting on empty bandwidth segments of the licensed LTE frequency domain.

The automatic identification monitoring system for fishing gear based on NB-IoT consists of satellites, buoys, fishing gear, base stations, integrated base station on land, management ships, and fishing boats. Figure 2 shows the concept of this monitoring system. A satellite provides a global positioning system (GPS). Buoys, management ships, and fishing boats use GPS to determine current positions. Buoys form a connection to the fishing gear components and send information which includes the current position and data pertaining to the connections between buoys and these fishing gear components to the base station on land. These processes require very little data; therefore, NB-IoT, a type of LPWA, can handle these tasks. The integrated base station can receive data from all buoys in nearshore and offshore locations and track the positions of all of the fishing gear. The integrated base station sends all data to the management ships after accumulating data from the buoys. However, communication between the integrated base station and the management ships uses existing LTE because the data from the integrated base stations are in the form of multimedia information including image data, such as positions of fishing gear, marine maps, and bathymetric charts. NB-IoT cannot handle this data, which is considered to be ‘big’ data.

Buoys have global navigation satellite system (GNSS) antennas for GPS, RF antennas for NB-IoT, communication modules for LPWA, and modules to identify fishing gear. The buoys float on the surface of the sea while maintaining a connection to the fishing gear. Fishing gear components, located underwater, typically have acoustic transmitters. When fishing gear becomes lost and/or detached, the fishing gear identification module detects the loss and sends information pertaining to the loss. At the same time, the acoustic transmitter in the fishing gear starts to work. The velocity of sound waves is 340 m/s in air and about 1500 m/s in water. Sound waves are elastic waves, which transfer energy more rapidly in a dense material. Therefore, they offer an advantage when used in water. The integrated base station sends the loss information to the fishing boat that originally installed the lost fishing gear after receiving information about the lost fishing gear. Fishing boats should have wireless nodes for NB-IoT communication. The fishing boats and management ships have acoustic receivers, allowing the fishing boats to move to the position of the lost fishing gear and receive the signal sent from the acoustic transmitter. Due to the use of an acoustic receiver, fishing boats can track the exact position of the fishing gear and collect it even when moved by sea currents.

III. ISSUES OF THE AUTOMATIC IDENTIFICATION MONITORING SYSTEM FOR FISHING GEAR

A. First Fresnel zone and wave height

The automatic identification monitoring system for fishing gear uses NB-IoT. Communication is mainly

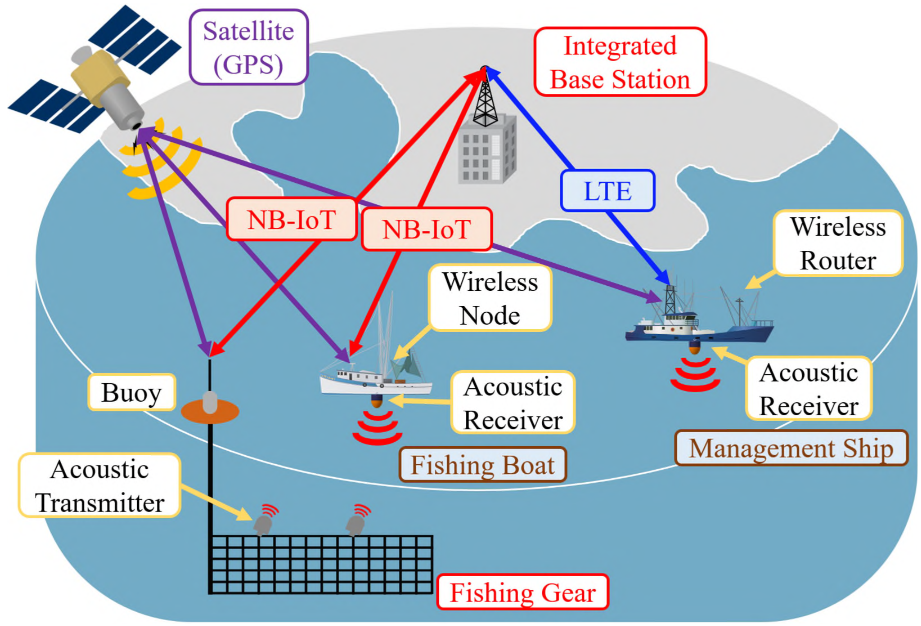

Figure 2. The automatic identification monitoring system for fishing gear based on NB-IoT

between buoys and the base station, which is on land. NB-IoT uses the licensed frequency domain. LTE is a type of wireless communication; therefore, it has the same characteristics as electromagnetic waves. A certain amount of empty air space is necessary for electromagnetic waves to propagate from the transmitter to the receiver without a decline of the signal strength.

Energy in space cannot arrive at a receiver in a straight line. Electromagnetic waves require an ellipsoid space following the minimum distance between the transmitter and the receiver. This space is called the Fresnel zone. In fact, it is possible to extend the space of the Fresnel zone infinitely. In principle, the first space, known as the first Fresnel zone, contributes to transfer the greatest amount of energy of a wave. The signal strength can decrease when obstacles exist in the first Fresnel zone. This weak signal strength increases the loss of transmitted data and the probability of errors. The first Fresnel zone is an ellipsoid space formed by the electromagnetic wave arriving at the receiver with following the shortest distance, which has a path difference of λ/2. Here, λ is the wavelength of the electromagnetic wave. The electromagnetic wave passing through the first Fresnel zone arrives at the receiving point after being superposed. Propagation loss in the first Fresnel zone becomes close to the theoretical value of the empty space. Therefore, good signal strength is guaranteed when no obstacles exist in 60% of the radius of the first Fresnel zone [4].

$$F_1 = \frac{1}{2}\sqrt{\lambda D} = \frac{1}{2}\sqrt{\frac{cD}{f}} \qquad (1)$$

Equation (1) is used to determine the radius of the first Fresnel zone. F_1 is the radius of the first Fresnel zone, D is the distance between the transmitter and the receiver, f is the frequency of the transmitted signal, and $c \simeq 2.997 \times 10^8$ m/s is the speed of light in air. According to (1), the radius of the first Fresnel zone is wide when the distance is long or the frequency is low. A small radius of the first Fresnel zone offers a low probability to lose the signal.

The automatic identification monitoring system for fishing gear based on NB-IoT requires a marine communication environment. The surface of the sea continually changes due to waves. For example, the radius of the first Fresnel zone of a buoy with a 1.8GHz electromagnetic wave with a distance of 1km is 6.452m. In this case, 60% of the radius is 3.871m, indicating that the buoy should have an antenna which is longer than 3.871m to ensure an empty first Fresnel zone. However, obstacles such as waves and other ships likely exist between the buoy and the base station. It is difficult to make the antenna longer when the size of the buoy is considered. Of course, the base station on land is located at a high altitude. The radius of the first Fresnel zone of the buoy with 850 MHz electromagnetic waves and with a 15 km distance is 36.362m, and 60% of the radius is 21.817m. This radius must encounter obstacles as those shown in Figure 3. Therefore, the communication between the buoy and the base station will not always be smooth.

B. Using drones for relaying

Using drones for relaying has been suggested to solve first Fresnel zone problem on the sea. The automatic

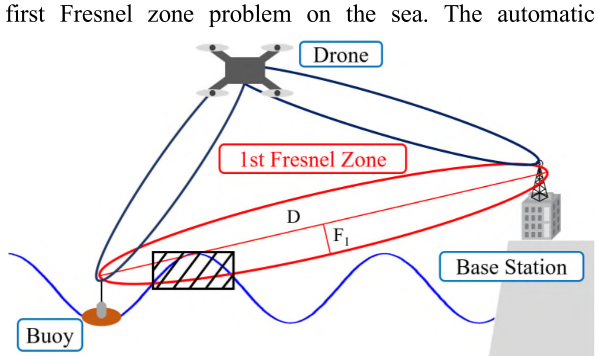

Figure 3. The first Fresnel zone and relaying by drones

identification monitoring system for fishing gear operates on management ships. These ships have drones that have NB-IoT communication modules and signal amplifiers for relaying. The management ship flies the drone through the air. The signal from the buoy is then transmitted to the base station via the drone, as shown in Figure 3. It is possible to remove obstacles and to communicate smoothly when the drone is in the air at an altitude in the tens of meters. Furthermore, relaying by drones is able to extend the communication coverage of NB-IoT between the buoy and the base station via the signal amplifier [5].

IV. Conclusion

This article briefly introduces a new automatic identification monitoring system for fishing gear based on NB-IoT communication that is being developed in South Korea. Some issues are discussed related to the realization of this monitoring system. The problem of the decreased signal strength arises when the wave height invades the first Fresnel zone. Therefore, relaying by drone was suggested to solve this signal strength problem and to extend the coverage of NB-IoT communication. The objectives of this monitoring system are to track the locations of lost and derelict fishing gear components with the real-name fishing gear system and to collect these items. Furthermore, the system can prevent lost and derelict fishing gear from devastating marine environments and can reduce ghost fishing and marine accidents caused by this fishing gear. In several years, this automatic identification monitoring system for fishing gear will be developed and will hopefully contribute to marine environment preservation efforts and to better fishery practices in many parts of the world.

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