Design and Preliminary Implementation of an IoT-Based System for Ocean Observation Buoys

Si Moon Kim, Woon Hyun Lee, Hyuk Jin Kwon, Jeongchang Kim[1]
Division of Electronics and Electrical Engineering, Korea Maritime and Ocean University
Busan 606-791 South Korea
E-mail: ehdaudwjdqh0@naver.com, dnsgus6035@naver.com, gurws0813@gmail.com, jchkim@kmou.ac.kr

Abstract: In this paper, we propose an IoT-based system for ocean observation buoys. The proposed system consists of various sensor modules, a gateway, and a remote monitoring site. In order to integrate sensor modules with various communication interfaces, we propose a CAN-based sensor data packet and a protocol for the gateway. The proposed scheme supports the registration and management of sensor modules so as to make the buoy system easier to manage various sensor modules.

1. Introduction

Information and communication technologies are evolving with internet of things (IoT) technologies. IoT technologies have been applied to various IoT services such as smart city, smart home, smart factory, smart vehicle, and health care. In the ocean, it is difficult to utilize the IoT technology due to environmental limitations such as communication coverage, power supply, and maintenance. Nevertheless, the importance of the ocean observation is recently increasing due to the natural disasters, such as earthquake and tsunami, in the ocean.

In order to monitor ocean environments, buoy systems are widely utilized. In [1], DART (deep-ocean assessment and reporting of tsunamis) buoys were developed to improve the capability for the early detection and real-time reporting of tsunamis in the open ocean. In [2], Mooring Systems, Inc. developed a wide range of surface buoys designed for meteorological and oceanographic instrumentation platforms.

Since ocean sensors have various input/output (I/O) interfaces, it is difficult to integrate with a single unified system. Furthermore, the buoy system operates on a faraway ocean. Hence, it is also difficult to manage the system when the buoy system is damaged and/or modified.

In this paper, we propose an IoT-based system for ocean observation buoys. The proposed system consists of sensor modules, a gateway, and a remote monitoring site. In order to integrate sensor modules with various communication interfaces, we propose a controller area network (CAN)-based sensor data packet and a protocol for the gateway of the buoy system. The CAN-Bus is widely used in the vessels and cars. It is well known that the CAN-Bus is a robust, low-cost, and simple event-triggered technology for connecting electronic control devices in manufacturing industries and vessels [3]. Hence, the CAN-based system can be utilized to maintain the compatibility with existing systems or devices for the vessel.

The proposed scheme supports the registration and management of sensor modules so as to make the buoy system easier to manage sensor modules. By utilizing the proposed scheme, we can develop a unified platform for a buoy system.

2. System Configuration

Fig. 1 shows the block diagram of the proposed buoy system. In practice, various sensors can be used for the ocean observation. In this paper, in order to implement a prototype of the proposed system, we consider most widely used ocean observation sensors such as a conductivity/temperature (CT) sensor and a weather sensor. The CT sensor measures various oceanic data such as the conductivity, temperature, and conductance in the sea. The weather sensor measures various weather conditions such as the direction and speed of the wind over the sea. The global positioning system (GPS) is used to seize the position of the buoy.

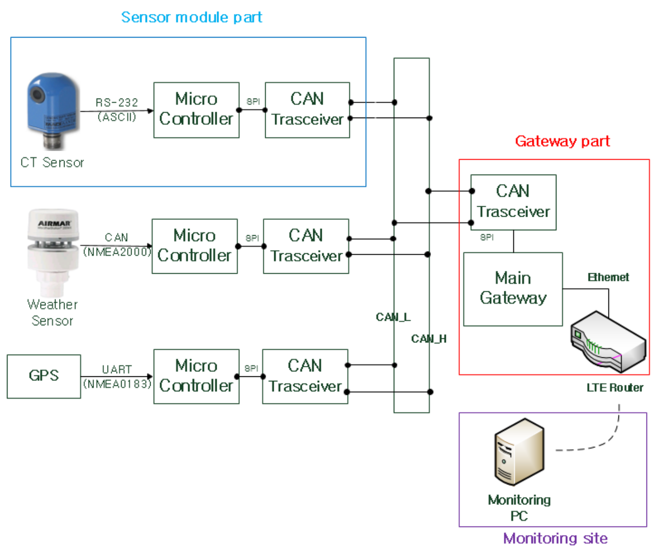

Figure 1. Block diagram of the proposed buoy system.

The proposed system is consists of three parts. The first part is the sensor module that consists a sensor unit and micro-controller unit. The variety of sensor units have various interfaces with external devices such as NMEA (national marine electronics association) 0183, NMEA2000, and UART (universal asynchronous receiver/transmitter). The micro-controller of each sensor module parses the necessary

[1] Corresponding author: Jeongchang Kim

information such as conductivity, temperature, conductance, and speed and direction of the wind, and then the CAN transceiver reshapes the parsed data into a CAN frame. Finally, the resulting frame is transmitted to the gateway via CAN-Bus.

The second part is the gateway that is received the reshaped CAN frame from sensor modules. Also, the gateway supports the registration and management of the sensor modules. Each sensor module broadcasts its data with a unique CAN-ID (identification) to all devices including the gateway via the CAN-Bus [4]. Then, the gateway receives and stores data from all sensor modules. The gateway transmits the collected data to the monitoring site on the ground using LTE (long term evolution) communication.

The third part is the monitoring site on the ground. The received data from the gateway of the buoy is stored on the database (DB) server.

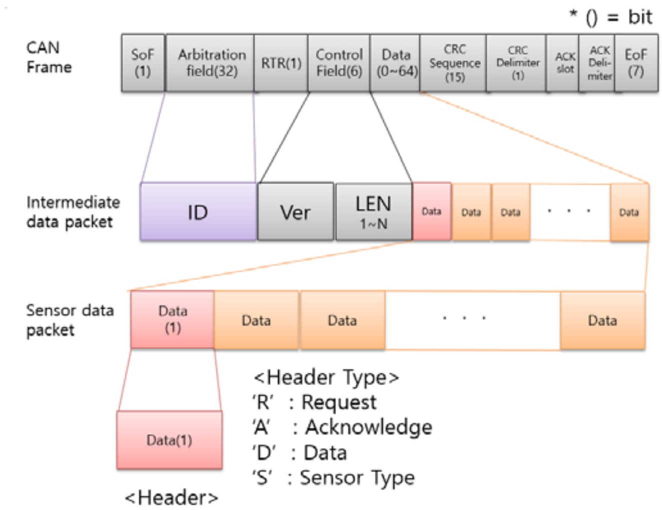

Figure 2. Data packet structure for the proposed protocol.

Fig. 2 shows the data packet structure for the proposed scheme. For the micro-controller of the sensor module, the measured data of the sensor unit is formatted into a data packet with one byte header. Then, the data packet is transferred to the CAN transceiver with 6 bytes header, which is referred to as intermediate data packet. The header of the intermediate data packet consists of 3 fields such as ID, Ver, and LEN. ID field means the unique CAN-ID assigned to each information of the sensor module. For example, the conductivity and conductance of the CT sensor are transmitted with different CAN-IDs. By using unique CAN-ID for each information, the proposed system can distinguish various information in a sensor module and the measured data in a sensor module can be classified by the CAN-ID. Ver field informs whether the CAN-ID is the standard version or extended version. In this paper, we consider the extended version since the extended version supports both NMEA2000 and NMEA0183 formats. LEN field determines the number of bytes in the data field where the maximum value of LEN field is 8. The CAN transceiver forms the CAN frame [5] with the intermediate data packet and transmits the CAN frame to the gateway via CAN-Bus [6].

3. Experiment Result

Figs. 3(a) and 3(b) show the hardware configurations of the proposed system. The internal hardware of the proposed system is composed of the micro-controllers, the CAN-transceivers, the LTE module, some batteries, and the interface board as shown in Fig. 3(a). These components are installed in the waterproofed aluminum box which are stacked with two-layer form and arranged near the wall to deconcentrate the heat generated by various modules including batteries. Also, the interface board including CAN-Bus provides the communication between sensor modules and the gateway. On the other hand, the external hardware contains a camera module, GPS antenna, and LTE antenna as shown in Fig. 3(b). The camera module supports the 5 megapixel resolution with a fixed focus lens onboard and utilizes the dedicated camera serial interface which is capable of extremely high data rates for maritime surveillance.

(a)

(b)

Figure 3. Hardware configurations of the proposed system. (a) internal configuration. (b) external configuration.

Data from each sensor are transmitted to the DB server of the remote monitoring site and are monitored at the server PC and/or the mobile phones. It can be arranged in a time order to show the variation of the sensor data according to the time. Also, the location of the buoy is tracked on a web-based map. Hence, we can monitor the ocean information with the proposed buoy system at a glance.

4. Conclusion

In this paper, we designed the gateway for the buoy system and proposed the integrated ocean platform for the buoy system. We developed the gateway which integrates the observed data from each sensor module with a single protocol. The transferred data to the gateway are transmitted to a remote monitoring system, stored at a database server, and monitored by PCs or smartphones. It is possible to integrate various interfaces and manage the sensor modules. Hence, we can easily manage and maintain the buoy system and observe the ocean data in real-time. Also, by applying the proposed system to the conventional buoy, it is possible to make the buoy system easier to manage various sensor modules.

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