Development of high reliable IoT Wireless Network for Decommissioning NPPs

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1. Introduction

Wireless communication within a nuclear power plant has been limited in use for various reasons such as the safety of the power plant[1]. However, the use of wireless communication has become an essential technology for real-time location recognition and radiation level measurement of workers in the field of decommissioning nuclear power plant (NPP). The most widely used wireless communication methods include wi-fi, cellular, ZigBee, Bluetooth (BT), Bluetooth Low Energy (BLE), and Low Power Wide Area (LPWA) IoT Network[2]. Each wireless communication method has its own advantages and disadvantages. Classification in terms of communication distance and data rate can be summarized in Figure 1. Considering the poor wireless communication environment such as nuclear power plants, it can be seen that LPWA, which can communicate over long distances and consumes less power, is an excellent choice.

In this paper, we discuss the LPWA communication network designed according to the IEEE 802.15.4e Deterministic and Synchronous Multi-channel Extension (DSME) standard[3].

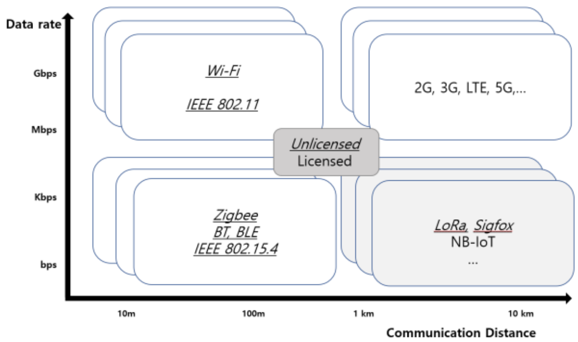

Figure 1. Comparison of Wireless Communication method

2. Design and Results

2.1 Communication Network Design

At the decommissioning site of a nuclear power plant, which is a poor communication environment, multi-hop/high-reliability transmission technology is required to minimize shadow areas. Although there are many ways to reduce the radio wave propagation shadow area, the synchronous multi-channel extension method has advantages in terms of fast connection of end nodes and energy saving by shortening the network search time.

IEEE802.15.4e DSME-based LPWA network consists of network server, mobile node, and fixed node. The mobile node connected to the sensor transmits the information acquired through the AP to the network server. Mobile nodes in the radio shadow area transmit information through fixed nodes. If it is difficult to transmit information even with two hops in a wireless environment, a wireless link is implemented through multiple hops. The clustering configuration including this multipath can be expressed as Figure 2.

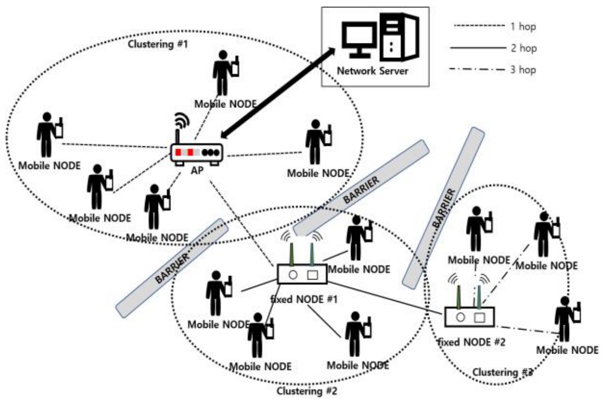

Figure 2. LPWA communication network

2.2 NODE Design

Based on Cortex-M3, IEEE PHY is designed for mobile node to be applicable to 802.15.4g PHY and sx1262 chip. IEEE 802.15.4e DSME protocol S/W is loaded and the frequency used is ISM band, 920 MHz band. Wireless communication range is over 1km in line of sight (LOS) environment, and the maximum data rate is 62.5 k bits per second(bps).

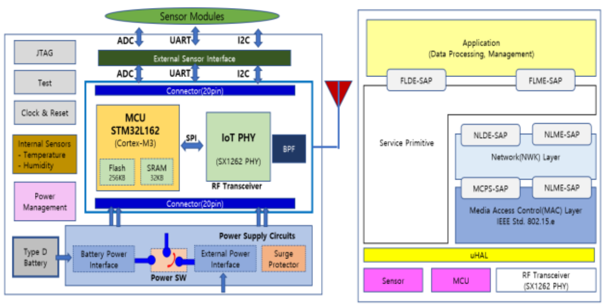

Figure 3 Mobile node H/W and S/W block diagram

UART and I2C interfaces allow connection to external sensors such as dosimeters. Figure 3 shows the H/W and S/W block diagram of Mobile Node.

A fixed node has the same structure as a mobile node. It delivers information of nodes in the radio shadow area to the AP.

2.3 AP Design

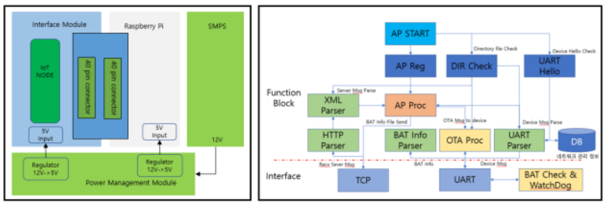

Figure 4 IoT AP H/W and function block diagram

Raspberry-pi 4B+ based IoT AP is composed of interface module, Switched-Mode Power Supply (SMPS), and power management module. Simple configuration technology for efficient installation and management is applied. In addition, cluster topology auto-configuration, timeslot allocation, and automatic handoff are applied. IoT AP H/W and function block diagram are shown in Figure 4.

2.4 Results

Due to the practical difficulties of testing the LPWA communication network in a nuclear power plant, it was first tested in a factory with a similar communication environment.

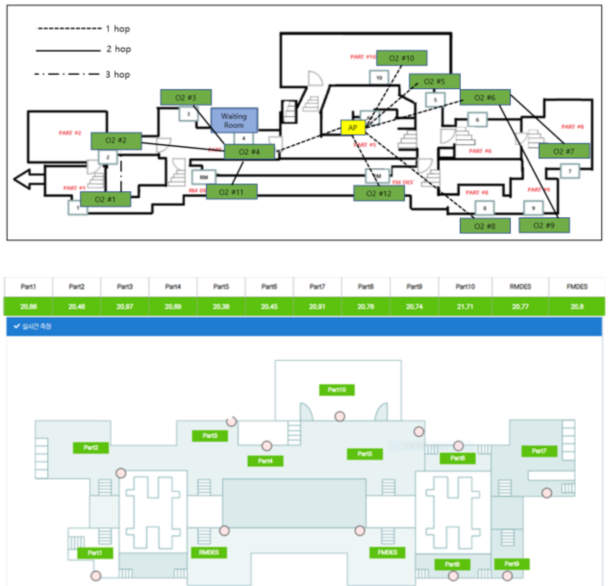

Figure 5 Test result of proposed IoT Network

The underground space of the POSCO plant, the subject of the experiment, is approximately 200m x 40m. The communication environment is an enclosed space with a steel structure and a space separated by a grid wall. A total of 12 oxygen sensor nodes were installed in the enclosed underground space, and a single AP was applied to connect them to a total of 3 hops. Figure 5 shows that the oxygen concentration is transmitted to the production server in real time.

3. Conclusions

The use of wireless communication in existing nuclear power plants has many limitations. However, when dismantling a nuclear power plant, a wireless communication network is an essential element for real-time management of radiation exposure of workers.

In this paper, an LPWA communication network supporting multi-hop is proposed to minimize radio shading. It was confirmed by experiment that real-time measurement information was updated in a factory with a steel structure similar to that of a nuclear power plant communication environment. The next step is to confirm the usefulness of the system by applying it to decommissioned nuclear power plants.

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