XBee dispatcher プログラムを用いた放射線ドーズモニタの機能向上

UPGRADED RADIATION DOSE MONITOR SYSTEM WITH XBEE DISPATCHER PROGRAM

Min Yang[#, A)], Noboru Yamamoto [B)], Norihiko Kamikubota [B)]
[A)] The Graduate University for Advanced Studies (SOKENDAI)
[B)] J-PARC Centre, KEK and JAEA

Abstract

The prototype of real-time radiation dose monitor system in J-PARC was developed to realize real-time feedback of exposed radiation dose upon individual worker in radiation environment. It consisted of a supervisor part and a sensor part, which communicate with each other wirelessly using XBee® modules. The prototype system can only accept one sensor part. To realize the wireless monitoring of multiple sensor parts, an upgraded system with an XBee dispatcher program has been developed. With the XBee dispatcher, we can realize the communication between many sensor parts and a supervisor part. Therefore, the radiation doses of many workers can be supervised simultaneously. The details of the upgraded system with XBee dispatcher, and test results of the system are presented in the paper.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator facility. It consists of a 400 MeV Linac (linac), a 3GeV Rapid-Cycle Synchrotron (RCS), a 30 GeV Main Ring (MR) synchrotron, and three research facilities (Materials and Life science Facility, Neutrino facility, and Hadron facility). Using MW-class high power proton beams, generated secondary particles (neutrons, muons, neutrinos, and mesons) are used for various advanced studies [1, 2]. J-PARC MR is a slow-cycling synchrotron. It is the furthest downstream and physically the largest accelerator at J-PARC [3].

The prototype system of real-time radiation dose monitor system, consisted of one sensor part and one supervisor part, was developed and tested in the J-PARC MR accelerator tunnel in 2019 [4]. Figure 1 shows the demonstration of the prototype system in the J-PARC accelerator tunnel. It realized the monitoring and collection of real-time radiation doses to an individual worker in a radiation environment. The wireless communication between the sensor part and the supervisor part was stable. But one drawback of the prototype system is that it can only accept the monitoring of one radiation sensor.

In order to realize the wireless monitoring of multiple radiation sensors, an upgraded system with a dispatcher program has been developed. With the upgraded system, radiation doses of many workers can be supervised simultaneously.

This report describes the limitation of the prototype system, the software and hardware details of the upgraded system, and a report of system demonstration in an accelerator tunnel, followed by a discussion.

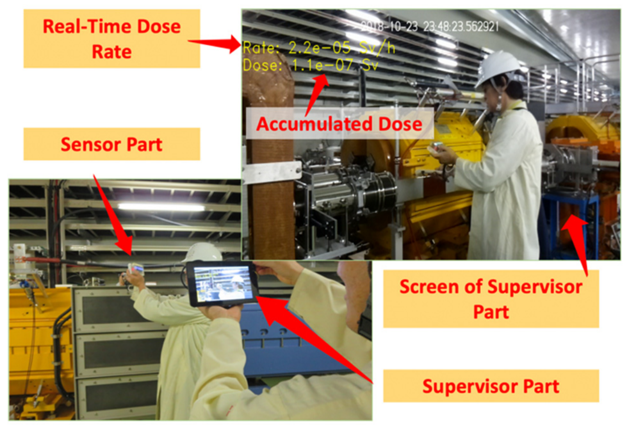

Figure 1: Test of the prototype system in J-PARC MR accelerator tunnel.

LIMITATION OF PROTOTYPE SYSTEM

To realize the real-time monitoring of radiation dose remotely, we adopted two modern technologies in the prototype system: Raspberry Pi® and ZigBee wireless scheme with XBee® modules. Raspberry Pi® is a mobile device and was used for a core processor for dose measurement, as well as for a local PC. XBee® modules realized short-term wireless communication between the sensor part and the supervisor part of the prototype system. In the prototype system, we choose the transparent mode operation of the XBee assuming the single monitor operation. This should be reconsidered to handle multiple sensors.

In general, the XBee® modules working in the transparent mode cannot identify the source of a received wireless message. If we add more sensor parts to the prototype system, we will get mixed data as shown in Fig. 2.

[#] yangmin@post.kek.jp

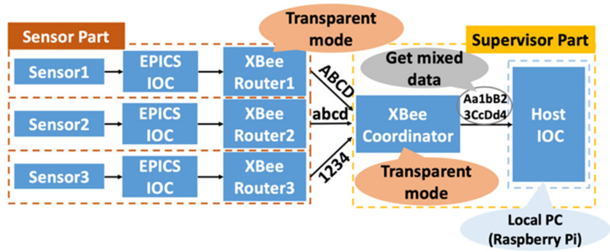

Figure 2: The limitation of prototype system with multiple sensor parts.

In order to overcome the limitation in the transparent mode, the XBee® module can be operated in an Application Programming Interface (API) mode. The API mode provides a structured interface where data is communicated through the serial interface in organized packets and a determined order [5].

In addition to changing the XBee® operation mode, we also need a dispatcher to allocate the received data to the specified interface. The XBee dispatcher is described in detail in the next section.

UPGRADED SYSTEM

The Software of the System

The software of the upgraded system is almost the same as the prototype system, except the dispatcher. The structure of the upgraded is shown as Fig. 3.

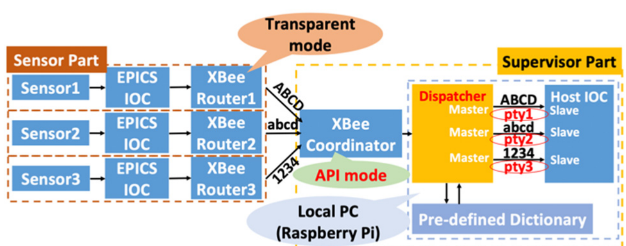

Figure 3: The structure of the upgraded system with XBee dispatcher.

The IOCs, both in the sensor parts and in the supervisor part, have been developed based on EPICS (Experimental Physics and Industrial Control System). Many modules of EPICS, such as StreamDevice, procServ, and devgpio, are also employed to realize the communication between sensor, Raspberry Pi®, and local PC.

To monitor multiple radiation sensors in real-time, an XBee dispatcher with a pre-defined dictionary has been developed by python program. The pre-defined dictionary is shown as Table 1.

Table 1: The Pre-Defined Dictionary

MAC Address	Self-defined Path	Serial Port	Master	Slave
0013A200...	../sensor1	tty001	3	4
0013A200...	../sensor2	tty002	7	8

The “MAC Address” is the physical address of the XBee® Router modules that allows us to distinguish the source of the data. The “Self-defined Path” is a path set in advance that is used to establish a symbolic link with “Serial Port”. The “Serial Port” here means the name of the serial port where dose data is being transferred on the local PC (The operating system is Raspbian which is Debian based Linux for Raspberry Pi). The “Master” and “Slave” are two ends of a bidirectional communication channel provided by a pseudo-terminal (pty). Anything that is written to the “Master” side can be read on the “Slave” side. And the “Slave” end corresponds to a real serial port in the system.

The “MAC Address” and “Self-defined Path” are already set up in the pre-defined dictionary before the dispatcher runs. The information of “Serial Port”, “Master”, and “Slave” is appended to the dictionary after the dispatcher runs.

When the dispatcher starts running, it first checks the source of the received data (MAC address of the XBee® Router) by referring to the pre-defined dictionary. If the MAC address is not in the dictionary, an error message appears, and the program exits. If the MAC address is in the dictionary, then a pty is created for sending the received differentiated data to the host IOC. The “Master”, “Slave”, and corresponding “Serial Port” are added to the dictionary at the same time. However, every time we create a new pty, we might get a different “Master” and “Slave”, and get a different occupying serial port. To avoid resetting the serial port of the received data each time in the host IOC, a symbolic link between the serial port and the “Self-defined Path” is made after the pty creates.

Finally, the received differentiated data is sent to the host IOC and displayed on the interface of the local PC.

The Hardware of the System

The hardware design of the upgraded system is shown in Fig. 4.

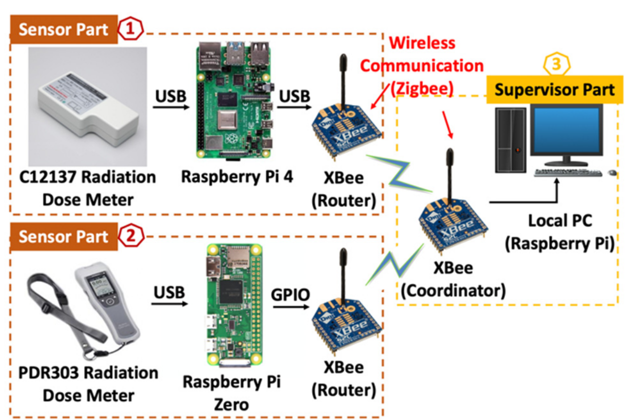

Figure 4: The hardware design of the system.

There are three parts of the system: two sensor parts and a supervisor part. Compared with the prototype system, we added the sensor part 1 as a new radiation sensor part. The real implementation is shown in Fig. 5. The left picture shows the new sensor part. The right side shows the original sensor part and the supervisor part.

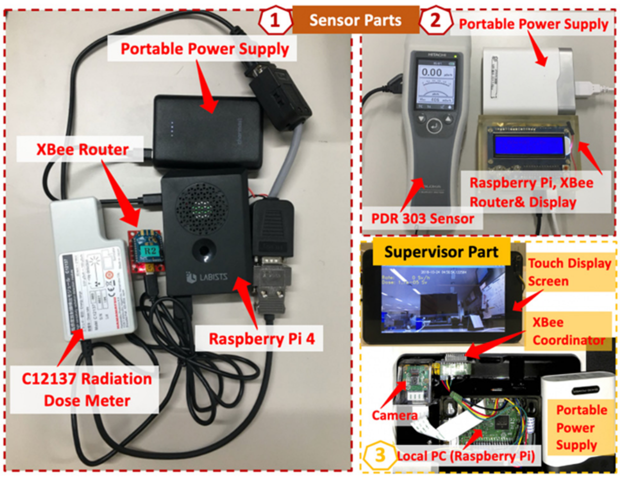

Figure 5: The real implementation of the system.

The new sensor part includes a Hamamatsu radiation sensor (C12137-00D), a Raspberry Pi® 4, an XBee® Router module, and a portable power supply. The Hamamatsu radiation sensor sends data to the Raspberry Pi® every second. After the Raspberry Pi® receives dose data and temperature of the meter through a USB port, it sends the data to the supervisor part using the XBee® Router module.

The other sensor part includes a commercial radiation dose meter (PDR303), an integrated package with a two-line indicator, and a portable power supply. Inside the package, the Raspberry Pi® Zero and another XBee® Router module are included. Details are given in [4].

The supervisor part includes a Raspberry Pi® 3, an XBee® Coordinator, a camera, a touch display screen, and a portable power supply. With the upgraded system, the screen shows the received data from two sensor parts and the temperature of the sensor (Fig. 6).

DEMONSTRATION

We tested the upgraded real-time radiation dose monitor system in the J-PARC MR tunnel in August, 2020. When two workers, each with a radiation sensor part, approached two possibly radiated components respectively, the supervisor person with the supervisor part could monitor the real-time doses of the workers.

Figure 6 shows a short distance test of the system. Short distance wireless transfer of dose data and monitoring of the sensor parts in the accelerator tunnel were demonstrated successfully.

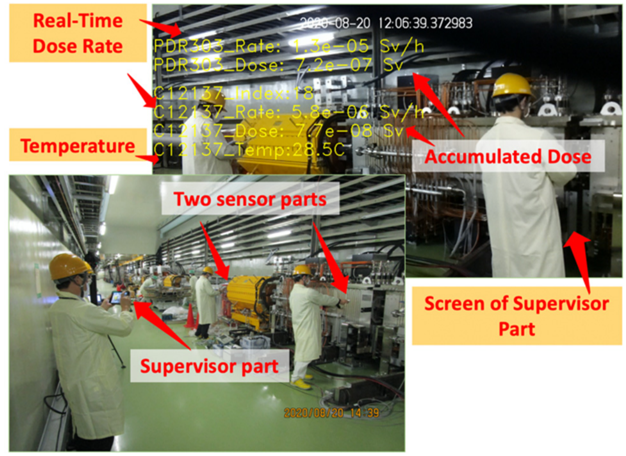

Figure 6: Short distance test of the system.

Figure 7 shows a long-distance test of the system and the picture of the supervisor part. Two workers with two sensor parts arrived at 20 meters away from the supervisor person. The long-distance wireless transfer of radiation dose was stable. The monitoring doses on the supervisor part were demonstrated successfully.

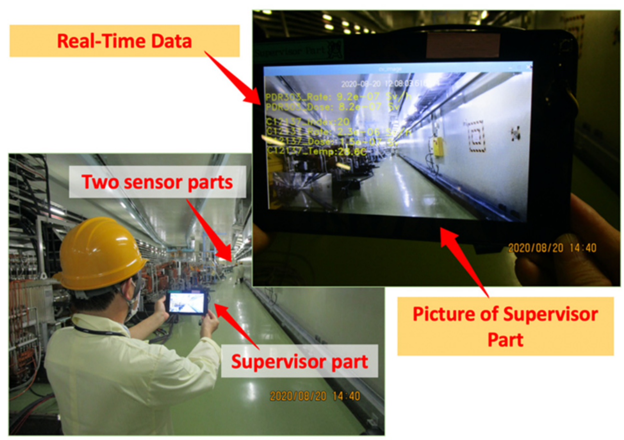

Figure 7: Long-distance test of the system.

DISCUSSION

Advantages of Upgraded System

Based on the development and demonstration, the upgraded system exhibits good performance and some special advantages.

- The system implements monitoring with multiple sensors. More sensor parts can be easily added.
- The short-term wireless communication between multiple sensor parts and supervisor part is stable.
- The camera can save the status of workers together with the observed dose rates.
- The whole system is portable and can be carried anywhere, especially in the accelerator tunnel.
- The core hardware of the system is cost-effective, such

as Raspberry Pi® and XBee® module.

Future Plan

Based on experience and test results during the demonstration, some improvements will be made in the future.

- Find smaller and cheaper radiation sensors. The sizes of the Hamamatsu sensor (C12137-00D) and PDR303 radiation sensor are slightly large. In addition, the cost of the Hamamatsu sensor and PDR303 radiation sensor is high (C12137-00D costs 260,000 JPY and PDR303 costs 90,000 JPY).
- Increase more sensor parts. The system currently has only two sensor parts.
- An alarm system is preferable. When the XBee® Router and XBee® Coordinator are disconnected from each other, an alarm should arise.

SUMMARY AND OUTLOOK

An upgraded real-time radiation dose monitor system with an XBee dispatcher program has been developed and tested in the J-PARC MR tunnel. The system realizes monitoring with multiple radiation sensors simultaneously. Therefore, the radiation dose of many workers can be monitored synchronously.

In the future, we will improve the system to an operational model. The system can be helpful for radiation workers to avoid unexpected radiation during the whole radiation work.

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