

Recent R&D trends on wireless technology for nuclear power plants

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1. Introduction

KAERI (Korea Atomic Energy Research Institute) is developing wireless technology that can be applied to the nuclear power plant (NPP) [1]. Due to the environmental specificity, the wireless technology for NPPs has limitations, as compared with the ones developed for IT industry. For example, the use of wireless devices to systems supporting category A and category B is excluded, whereas the use to category C is permitted (category A functions that play principal role in NPP safety, B play a complementary role to A, and C play an auxiliary or indirect role). It is expected that the application of wireless technology will become an essential element in the new-generation reactors including small modular reactors (SMR). To apply wireless technology to NPPs, NRC R.G. 1.180 and IEC TC45 SC45A standard must be satisfied. Here, we analyze the wireless technology, the regulations and international standards related, and recent R&D trends on wireless technology appeared during NPIC-HMIT 2023.

2. Wireless technology, regulations and international standards

Representative wireless technology in other industry includes Bluetooth, Zigbee, Wi-Fi, LoRa, WirelessHART, and Terahertz. From NPP's perspective, each technology has its own advantages and disadvantages. Under the NPP environment, the wireless technology must meet the required code, standard and regulatory guide. The wireless technology and related documentation is listed in Table 1 [2]. To satisfy regulatory guide for the wireless technology (e.g., NRC R.G. 1.180 and IEC TC45 SC45A), a difference of 8 dB must be maintained from the safety and protection relevant instrumentation and control (I&C) system.

Table 1. List of wireless technology used

Technology	Document
802.11a/b/g/n/ /ac/ad/h/i (Wi-Fi)	IEEE 802.11-2016, IEEE Standard for Information Technology — Telecommunications and

	Information Exchange Between Systems — Local and Metropolitan Area Networks — Specific Requirements — Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
802.15.1 (Bluetooth)	IEEE 802.15.1-2005, IEEE Standard for Information Technology — Local and Metropolitan Area Networks — Specific Requirements — Part 15.1a: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPAN)
802.15.3 (UWB WiMedia)	IEEE 802.15.3-2016, IEEE Standard for High Data Rate Wireless Multi-Media Networks
802.15.4	IEEE 802.15.4-2015, IEEE Standard for Low-Rate Wireless Networks
Zigbee	Zigbee Document 05-3474-21: Zigbee Specification
WirelessHART	IEC 62591:2016, Industrial Networks — Wireless Communication Network and Communication Profiles — WirelessHART
ISA-100	International Society of Automation (ISA) ISA-100.11a, Wireless Systems for Industrial Automation: Process Control and Related Applications
ISA-100	IEC 62734:2014, Industrial Networks — Wireless Communication Network and Communication Profiles — ISA 100.11a
802.16 (WiMAX)	IEEE 802.16-2012, IEEE Standard for Air Interface for Broadband Wireless Access Systems

For the radiation field operating area of 10 V/m (140 dB μ V/m), the radiation field emitted from the wireless devices within the restricted area should be limited to 4 V/m (132 dB μ V/m). Thus, the wireless technology can only be applied to the NPPs, when the minimum separation distance for the wireless devices from the I&C system is ensured.

3. Wireless technology in NPIC-HMIT 2023

Last July, American Nuclear Society (ANS) held Nuclear Plant Instrumentation, Control and Human-Machine Interface Technologies (NPIC-HMIT) 2023 meetings [3]. Among 45 sessions in technical sessions of NPIC-HMIT 2023, at least 7 were closely related to use of wireless technology in NPP. The tiers of wireless communication includes a three-tier sensing and communication strategy, *i.e.*, tier 1 (In-core: data signal from in-core to outside the pressure vessel), tier 2 (Containment building: data from containment building to balance of plant network), and tier 3 (Balance of the plant network: transmit to the data cloud and control room). Each tier has examples of wireless technology application including pressurized pipeline setup with a harmonic radio frequency (RF) sensor tag, passive in-vessel monitoring using acoustic transmission through structures, and wireless vibration sensors installation across circulating water system pumps, motors and associated bypass valves. In wireless technology, “one size fits all” is difficult to achieve, thus different types of data transmission is required. Network elements include distributed antenna system (DAS), long range wide area network (LoRaWAN), and industrial, Scientific, and medical (ISM) band. The coverage and connectivity via co-existence wireless technologies in ISA (2.4 GHz) band includes ZigBee, Bluetooth, and Wi-Fi. The need to integrate information transmitted from different sensor nodes using different wireless technologies requires a multiband heterogeneous network architecture. Most of the wireless application is in the balance of plant (BOP). From regulatory perspective, NRC activities related to I&C support follows: new sensor technologies are applicable for both modernizing the operating reactor fleet as well as advanced reactors, and sensors are the center of I&C system designs. Current branch research, sensor-intensive activities, includes the field of artificial intelligence & machine learning (AI/ML) research for cybersecurity, remote monitoring, and wireless safety and security.

4. Conclusions

Wireless technology in NPPs includes technologies relevant to wireless devices, wireless communication, and regulations/standards related. There are on-going efforts to expand the use of wireless technology towards nuclear facilities. We analyzed wireless technology,

regulations and standards related, and recent R&D trends through NPIC-HMIT 2023. Our work will support wireless technology applications for operating and/or constructing NPPs, as well as new-generation reactors including small modular reactors (SMR).

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