Wireless Technology Application to Nuclear Power Plants

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1. Introduction

Wireless technologies are getting widely used in various industrial processes for equipment condition monitoring, process measurement and other applications. In case of Nuclear Power Plant (NPP), it is required to review applicability of the wireless technologies for maintaining plant reliability, preventing equipment failure, and reducing operation and maintenance costs. Remote sensors, mobile technology and two-way radio communication may satisfy these needs. The application of the state of the art wireless technologies in NPPs has been restricted because of the vulnerability for the Electromagnetic Interference and Radio Frequency Interference (EMI/RFI) and cyber security. It is expected that the wireless technologies can be applied to the nuclear industry after resolving these issues which most of the developers and vendors are aware of. This paper presents an overview and information on general wireless deployment in nuclear facilities for future application. It also introduces typical wireless plant monitoring system application in the existing NPPs.

2. Review of Wireless Technology for NPPs

Table 1 illustrates typical standards for industrial application. Wi-Fi is a kind of Wireless Local Area Networks (WLANs) standard. The others in Table 1 belong to Wireless Personal Area Networks (WPANs) standards. In this section, three wireless standards of Wi-Fi, ZigBee and WirelessHART in widespread today are briefly described for nuclear application.

Table 1. Typical Industrial Wireless Standards

Wireless Standards		Typical Vendors
IEEE 802.11 (Wi-Fi)		Most Network Vendors
IEEE 802.15.4 (ZigBee)		Emerson, Honeywell, SIEMENS, Cirronet, Sensicast, Others
IEEE 802.15.4 (WirelessHART*)		Emerson, Honeywell, ABB, SIEMENS, Others
ISA100**		Emerson, Honeywell, ABB, Others
Proprietary	OneWireless	Honeywell
	IWLAN	SIEMENS
	ION Network	Invensys & Apprion

* WirelessHART is a part (ISA100.12) of ISA100
** Still in development

Table 2 summarizes the characteristics of these protocols [1]. The protocols in the table are not compatible with others. So, the protocols should be determined according to their application environments.

Table 2. A Typical Comparison of Wireless protocols

Features	Wi-Fi	ZigBee	WirelessHART
Nodes	5bit node	16bit node	16bit node
Range	100M	70~300M	70M
Data Rate	54/300Mbps	250Kbps	250Kbps
Operating Frequency	2.4GHz	2.4GHz	2.4GHz
Security	128bit AES	128bit AES	128bit AES
Fastest Sampling Rate	192KHz	10Hz	8Sec
Optimum Battery Life	Hours	1~5Yrs	1~10Yrs
Extensibility	Roaming possible	Yes	Yes

2.1 Wireless LAN - IEEE 802.11(Wi-Fi)

Wi-Fi enabled devices such as a laptop or smart phone can connect to the designated server within a range of wireless network of the plant LAN. The only recommended areas to deploy Wi-Fi would be non-safety monitoring of equipment and audio/video/data services due to the link reliability and the non-deterministic nature of wireless communications. Table 3 shows the IEEE 802.11 variants [1].

Table 3. Summary of IEEE 802.11 WLAN Technologies

IEEE Standard	Max. Data Rate	Frequency Band
802.11a	54 Mbps	5 GHz (UNII)
802.11b	11 Mbps	2.4 GHz (ISM)
802.11g	54 Mbps	2.4 GHz (ISM)
802.11n	300 Mbps	2.4 GHz (ISM)

* UNII (Unlicensed National Information Infrastructure)
* ISM (Industrial, Scientific and Medical)

2.2 Wireless PAN - IEEE 802.15.4 (ZigBee)

ZigBee includes three different types of devices that are coordinator, router and end device. ZigBee is a superset of the IEEE 802.15.4 standard, one of the leading WPAN standards. This technology is characterized by low-cost, low-power wireless devices that self-organize into a short-range wireless communication network to support relatively low throughput applications such as distributed sensing and monitoring. Because ZigBee can sleep most of time, average power consumption can be very low, resulting in long battery life [1].

2.3 Wireless PAN - IEEE 802.15.4 (WirelessHART)

Each WirelessHART network includes three main elements which are wireless field device, gateway and the network manager [2]. Each device in the mesh network can serve as a router for messages from other devices. This extends the range of the network and provides redundant communication routes to increase reliability. The network manager determines the redundant routes based on latency, efficiency and reliability.

3. Wireless Technology Application to NPPs

3.1 Potential Applications in NPPs

The followings are potential non-safety application areas of wireless technology for enhancement of operability and maintainability in the NPPs. [3]

- Voice communication over network
- Visual monitoring using wireless cameras
- Handheld device, Personal Digital Assistant (PDA) and laptop applications for maintenance
- Wireless sensors and data transmission equipment to implement condition-based maintenance
- Data collection and management
- Sensor monitoring
- Facilities monitoring
- Rotating Equipment
- Communication infrastructure for mobile computing
- Electronic personal teledosimetry system
- Wireless barcode scanning system
- Wireless access to information via wireless LANs for retrieval of manuals, drawings, and procedures by personnel in the field
- Real-time wireless communication between work-order software and scheduling software
- Radio Frequency Identification (RFID) for tracking parts into and out of inventory

3.2. Implementation of Wireless Technology in Plants

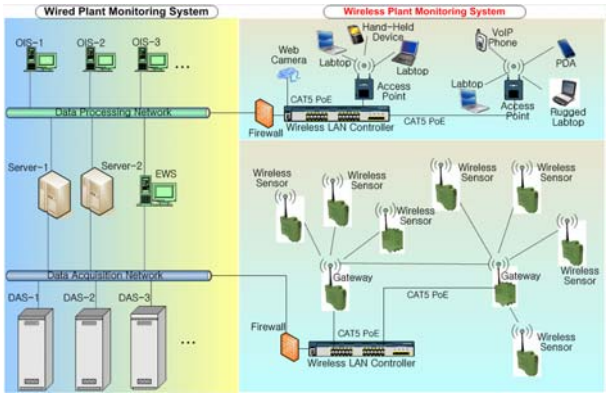

Figure 1. Typical Wireless Plant Monitoring System

Figure 1 shows a typical configuration of wireless plant monitoring system that can expand the operating plant operability and maintainability using both the wireless data acquisition network (DAN) and wireless data processing network (DPN) layers. The wireless DAN layer uses the ZigBee standard which is one of the industrial standards, while the wireless DPN employs the one of commercial standards which is IEEE 802.11 Wi-Fi. WirelessHART could be selected for the wireless DAN layer depends on the requirement of NPPs. This configuration integrates the wired and wireless domains using wireless LAN Controllers, Wireless Access Point (WAP) and wireless gateways to provide a single scalable infrastructure. Power over Ethernet (PoE) technology is used to transfer electrical power safely along with data to remote WAP and wired sensors over standard category 5 cable in the Ethernet network. To maximize uninterrupted wireless coverage numerous WAP should be installed throughout the plant. Clients on wireless DPN are most commonly laptops, web cameras, VoIP phones and data collection devices that plant staff members can use in their daily roles. It is clear that voice and data communication is currently the most prominent application in plants. Handheld devices are used for the installation, configuration, monitoring, and maintenance of all kinds of wireless DPN clients. Wireless DAN clients may be sensors monitoring plant equipment or sensors looking for hazardous plant conditions.

4. Conclusions

As the results of review for the state of the art wireless technologies, it is concluded that variety of applications can be applied to nuclear plant environment, including online equipment monitoring for condition-based maintenance, two-way radio communication, the VoIP phone, mobile computing and remote video monitoring. This paper proposes potential non-safety applications of the wireless technologies using the most prominent wireless protocols. The advantages of the wireless plant monitoring system with these technologies are as follows:

- Expanded operability and maintainability
- Equipment monitoring to evaluate performance
- Enhanced redundancy and diversity
- Reduced radiation exposure of workers
- Easy to extend or replace facilities
- Efficient access to information in remote area
- Reduced cable connection costs
- Improved voice communication
- Enabled mobile computing

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