

Wireless Technology for Industrial Applications “Opportunities and Challenges”

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Abstract

Wireless networking technologies are gaining rapid acceptance in many industrial sectors because of its cost effectiveness, improved reliability, fast deployment and flexibility. This technology could be used for industrial applications, such as monitoring remote machines, equipment, and giving operators easy access to remote information from anywhere in the plant for managing remote operations [1]. Several wireless technology standards have been developed to address industrial applications, such as ISA100, WHART, ZigBee, IEEE802.11a,b,g,n, WiMax, etc. Moreover, many users are convinced of its reliability, satisfied with its performance and are ready to use it for different applications in large-scale and more complex wireless networks. Although, there are several challenges that hinder the adoption of this technology. In this paper, the authors will provide an overview of industrial wireless technologies, industrial requirements and will address some key opportunities and challenges that would impact the development and deployment of wireless technology for industrial applications.

Introduction

Wireless technology provides cost-effective and efficient connectivity solutions for several industrial operations. Many remote facilities, processes and field operations can benefit from the last mile wireless access to connect to the corporate networks and this would result in improving productivity, reducing downtime, faster and more accurate data collection and reduced capital and operating expenditures, Fig. 1.

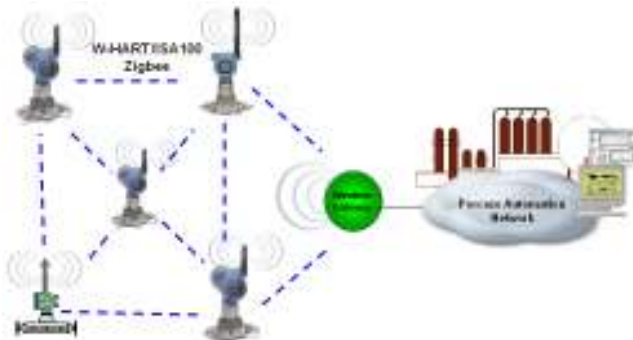


Fig. 1. Plant wireless network. [6]

The new smart wireless sensors technology opens the door for the industry to meet the demands of increased competitiveness. This technology enables real-time data acquisition throughout a facility, increase operation efficiency and productivity and reduces costs [5,6].

In general, industrial wireless technologies can be classified into three main categories [5] based on their coverage area and bandwidth as shown in Fig. 2.

- Wireless Sensors Networks:
 - 10 m ~ 100 m
 - Covers the Wireless Personal Area Network (WPAN - ISA100, WHART, Zigbee, Bluetooth, etc.)
- Plant Wireless Network
 - 100 m ~ few kilometers
 - Covers the Wireless Local Area Network (WLAN) – WiFi Technology (IEEE802.11a,b,g,n)
- Wireless Backhaul Connectivity
 - Wireless Metropolitan Area Networks (WMAN) and Wireless Wide Area Networks (WWAN)
 - 1 km ~ 100s km
 - WiMAX (IEEE802.16), Cellular Network (2G, 3G), VSAT, Long-Term Evolution (LTE), etc.

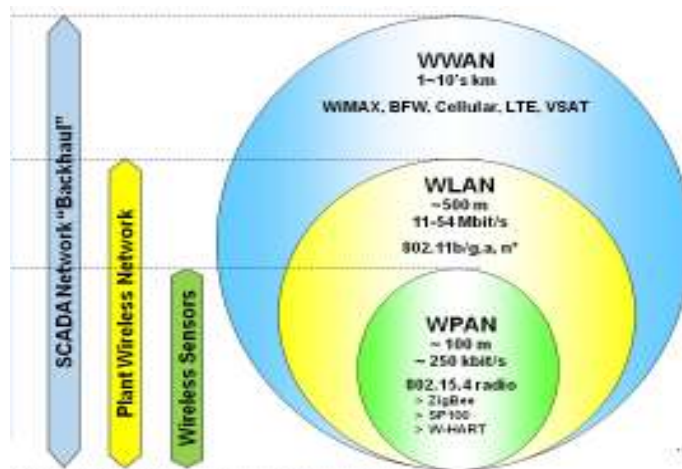


Fig. 2. Wireless classifications. [5,6]

Business Drivers

Wiring and cabling have traditionally dominated the cost and practice of industrial communications. These wires and cables are used as a communication medium between field sensors and controllers, controllers and servers, and between remote sites and business headquarters. This common practice resulted into high installation costs, high

maintenance costs and difficulty in troubleshooting. Therefore, wireless technology is becoming an alternative solution that can result in:

- Lower installation and maintenance costs.
- Ease of replacement and upgrade.
- Reduced connector failure.
- Greater physical mobility and flexibility.
- Faster installation and commissioning.

Currently, wireless technology is being used in most of the industrial applications to perform monitoring applications, Fig. 3, rather than control, due to remaining security and performance issues [5,6]. Improvements in the wireless technology will greatly expand monitoring and control functionalities. Industrial end-users must feel confident in the solutions before they entrust control functionality to a wireless system supporting mission-critical industrial system requirements.

Application	Application Classification
Safety	Class 0: Emergency action (avoids impact)
	Class 1: Closed loop regulatory control (often critical)
Control	Class 2: Closed loop supervisory control (usually non-critical)
	Class 3: Open loop control (human in the loop)
	Class 4: Alerting (Short-term operational consequence (e.g., event-based maintenance))
Monitoring	Class 5: Logging and downloading/uploading (No immediate operational consequence (e.g., history collection, sequence-of-events, preventive maintenance))

Fig. 3. Industrial applications classifications. [5,6]

Industrial Applications

The Wireless Sensors Network technology is an appropriate solution for in-plant process interconnectivity, such as connecting scattered sensors, controllers, instruments and machines wirelessly. On the other hand, WiFi, BFW, Cellular, VSAT can provide potential cost saving by eliminating the need to deploy physical cabling (optical fiber) between different facilities and plants, Fig. 4 [4]. Moreover, it can provide adequate bandwidth and throughput in a point-to-point and point-to-multi-point configuration that fulfills the requirement of current and future industrial application requirements, including:

- Oil/Gas well heads automation.
- Pipeline monitoring.
- Cathodic protection monitoring and control.

- Energy management.
- Waste water management.
- Vibration monitoring.
- Power Monitoring System.
- Condition-based maintenance.
- Remote surveillance and alerting solution.
- Power monitoring.
- Micro-seismic sensing application.

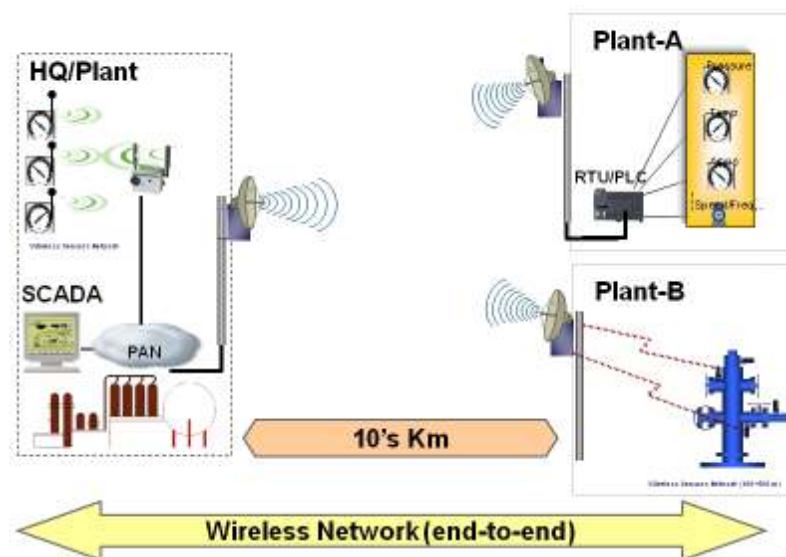


Fig. 4. Integrated wireless network.

Key Requirements for Industrial Wireless System

Figure 5 shows key factors required in the industrial wireless solution to be effectively utilized for process automation in the industrial applications[4]:

- Support real-time applications (deterministic).
- Offer reliable radio channel “reliability.”
- Use open standards interfaces and protocols “interoperability.” This provides protection for investment (interoperability between different vendors).

- Be as secure as a wired network “security.”
- Uses robust and certified industrial products.

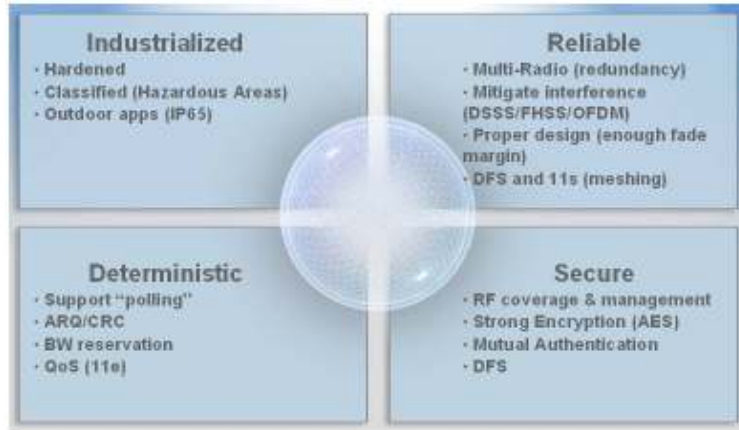


Fig. 5. Industrial requirements.

Industrial, Scientific and Medical (ISM) Band

The industrial, scientific and medical (ISM) radio bands were originally defined by the ITU Telecommunication Standardization Sector (ITU-T) and reserved internationally for the use of RF electromagnetic fields for industrial, scientific and medical purposes other than communications [7]. Currently, there are two dominant ISM bands, which are the 2.4 GHz - 2.5 GHz (center frequency 2.45 GHz), and 5.725 GHz - 5.875 GHz (center frequency 5.8 GHz).

The rapidly growing development and use of the 2.4 GHz and 5.8 GHz radios for communication applications motivated end-users to use off-the-shelf standard based products to provide efficient and cost-effective connectivity options for various industrial applications, such as wireless sensors (ISA100, WHART, Zigbee), WiFi (11a,b,g,n), BFW and others that can be used as a backhaul wireless connectivity in a point-to-point and point-to-multipoint topology.

Key Challenges

There are three key challenges in realizing adding wireless connectivity.

- 1) **Spectrum Regulation:** Since most industrial wireless systems operate at the ISM bands (2.4 GHz and 5 GHz), it is very essential and crucial to ensure flexible government regulation that allows the industry to use this frequency band. Currently, most countries – worldwide - allowed end-users to utilize these bands for indoor and outdoor applications without the need to obtain licensing from the spectrum regulator. This is not the case in some countries, e.g., Saudi Arabia, which hindered the development and deployment of wireless technology, especially for backhaul applications.
- 2) **End-User Perspective:** End-users need to build the confidence on the use of wireless technology for industrial applications. This can be achieved by selecting proper wireless technology for the domain and use it for data acquisition application “monitoring of non-critical applications.” Furthermore, the rapid

development in wireless technology may cause a challenge to some end-users; in such case, a standard based solution with a proper migration plan should be considered whenever wireless technologies became mature and field-proven.

3) **Technology:** There are two technological key challenges that faces industrial wireless technology:

- **Standard-Based:** A key issue currently limiting wireless deployment in industry involves compatibility among wireless components from different suppliers, generally referred to as interoperability. Some industrial end-users are wary of becoming locked into a proprietary system that might later hinder system upgrades as technology advances. Full compatibility and compliance with the standard-based among components would also provide end users with the flexibility to connect highly specialized, high-end sensors with best-in-class wireless interface devices.
- **Co-Existence:** Almost all recent wireless sensor technologies (ISA100, WHART, Zigbee, etc.) were developed based on IEEE802.15.4 MAC and physical layer, which uses 2.4 GHz band. However, several technical papers highlighted some coexistence “issues” between Wireless Sensors (IEEE802.15.4 based radios) and WiFi (IEEE802.11a,b,g,n*). Unfortunately, these technical papers did not reach consistent results which can be summarized as follows:
 - a) **Pessimist Camp:** WiFi and wireless sensors (IEEE 802.15.4 based radios) cannot coexist at the same field/working area and WiFi (with low duty cycle) will hinder IEEE 802.15.4 based radios operations!!! Quote “IEEE 802.11 even with small duty cycle (10%) can have a significant impact.”
 - These results raise a major concern about the reliability of 802.15.4 based radios to be used for industrial/process applications.
 - Some “pioneers” suggested to prohibit the use of 2.4 GHz WiFi at the field for IT applications because it will hinder/block 802.15.4 radios devices.
 - b) **Optimist Camp:** WiFi and wireless sensors (IEEE 802.15.4 based radios) coexist seamlessly and there is no major degradation in wireless performance (both WiFi and IEEE 802.15.4 radios). Quote “Our tests of this architecture under real-world conditions demonstrate that coexistence issues are in fact minimal, even in an extreme deployment scenario.”

Any wireless solution that operates in the ISM band shall be designed to be immune to noise and should be able to coexist with other systems that share the same frequency band. Moreover, Spread Spectrum technology (Frequency Hopping, Direct Sequence), OFDM, Mesh, power control and dynamic frequency selection are some features that allow coexistence between wireless devices at the same location without causing severe performance degradation.

Future Trends

There is intensive research within the telecommunications industry to overcome the fundamental shortfalls of the current wireless networks [2]. The industry has lately realized that these wireless systems do not have homogeneous architectures and they also undergo limited and poorly allocated radio spectrum. One example is the PMR, SCADA and WLANs. These wireless technologies cannot share resources, due to their heterogeneous architectures and the allocated spectrum. While it is understood that each of these systems was built for a unique purpose, which

mandated the construction of a different architecture, this alone was not the reason behind the current inefficient use of different frequency bands. Rather, it was due to the lack of available frequencies assigned by the regulator bodies.

The static assignment of the frequencies results in inefficient usage of the spectrum. The utilization of the spectrum can be as low as 10% in some systems and as high as 90% in others. There is nothing that can currently be done to balance this situation. If there was a unified technology to allow these different wireless systems to share the same frequency band, this will certainly maximize the use of allocated resources and ultimately reduce operator running costs.

The current spectrum allocation model in use today is believed to be obsolete. First, due to its inherent principle of fixed resource allocation that leads to an apparently spectrum insufficiency, which is later revealed to be inefficient utilization. Second, it comes into play the need of introducing new wireless applications and services, which grew exponentially during the past few years. This increasing growth for wireless services cannot be met with the current situation. It is also very difficult to obtain approval from the regulatory bodies for additional frequencies to meet the rising demand for wireless services.

Both scenarios motivate the use of dynamic spectrum access. This lends itself to cognitive radio oriented wireless networks, an enabling technology that will benefit several types of and help to implement a more efficient approach regarding spectrum requirements in the future. A cognitive radio network is the new paradigm shift for wireless communication worldwide. This technology calls for the development of customized methods, algorithms and applications for exchanging spectrum sensing data between wireless devices. In this theme, either the network or the wireless node changes its transmission or reception parameters to communicate efficiently avoiding interference with licensed or unlicensed users. This alteration of parameters is based on the active monitoring of several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior, and network state. In other words, the radio will have the ability to think and make informed decisions as opposed to the current radio devices, which can only be characterized as operational radios.

Cognitive radio is a topic of great interest and holds much promise as a technology that will play a strong role in communication systems of the future. With this new emerging technology, it will be possible to borrow free space in other frequency bands to relieve congestion and offer more services. The idea is that a cognitive radio can act as a secondary client that utilizes the frequency of a primary, e.g., approved by the regulatory body while that channel is not used. It will certainly provide a cost effect alternative to the costly spectrum licensing model. The other advantages that this technology will allow are spectrum sensing, mobility, sharing and management of radio resources. The vast majority of research and development work taking place in the wireless field is currently devoted to cognitive networks. This is because regulators, operators and manufactures have realized that no matter what capacity improvement is built in the current network architectures, the scarcity of allocated spectrum will always be a bottleneck for the unprecedented rising demands for wireless services.

Conclusion

The Industrial Wireless solution provides rapid network connectivity deployment that is cost-effective and efficient for various industrial applications. It is very crucial to ensure reliable guaranteed access for time critical applications in a point-to-point and point-to-multi-point/mesh architecture. Moreover, providing redundant links “radio” and complying with hazardous area’s classifications is necessary to ensure the reliability of wireless connectivity and safety of industrial operations. Currently, there are several standard-based wireless technologies that can be used for industrial applications, such as ISA100, WHART and ZigBee, for the field sensors networking. Furthermore, WiFi, WiMAX/BFW, VSAT and cellular network (GSM/TETRA), are considered as a potential backhaul wireless

connectivity solution and service providers shall consider “industrial requirements” to ensure reliable, secure and cost-effective wireless deployment.

The recent industrial wireless development standard mandates the use of ISM bands (2.4 GHz and 5 GHz) as operating frequency. This makes frequency de-regulation a prime requirement to ensure development and deployment of wireless technology for the industrial sector. Advanced Spread Spectrum technology (Frequency Hopping, Direct Sequence), OFDM, Mesh, power control and dynamic frequency selection are some features that allow coexistence between wireless devices at the same location without causing severe performance degradation.

Cognitive radio oriented networks is being foreseen as the ultimate merger platform for many of the fragmented radio architectures currently in operation. The technology is still in its research stage, but it holds much of the promise to resolve several issues of the current static frequency allocation model used by many of the spectrum regulatory bodies.

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