Acceptance of Wireless technologies in Automation

An Abstract

"Wireless technologies are challenging automation for new products and services. Like it happened in the past with Ethernet, the growing popularity of wireless among the general public is lowering the costs of wireless equipment. In the same way that Ethernet is being more and more spread in automation networking, wireless solutions are starting to find their place in automation networking, in spite of some scepticism about their robustness in a industrial environment."

Introduction

1. In today's industrial environment, systems and equipment must perform at levels thought impossible a decade ago. Global competition is forcing industry to continuously improve process operations, product quality, and productivity with fewer people than ever before. Production equipment must deliver unprecedented levels of reliability, availability, and maintainability as plant managers seek ways to reduce operational and support costs and to eliminate/minimize capital investments. In short, industry must invoke new measures to improve production performance and safety while minimizing costs and extending the operational life of new and aging equipment. Wireless sensor systems can revolutionize industrial processing and help industry meet the demands of increased competitiveness. Intelligent wireless sensors built for ubiquitous use in industrial environments will enable real-time data sharing throughout a facility to increase industrial efficiency and productivity. Wireless sensor technology offers reliable, autonomous process control to improve product quality, increase yield, and reduce costs.

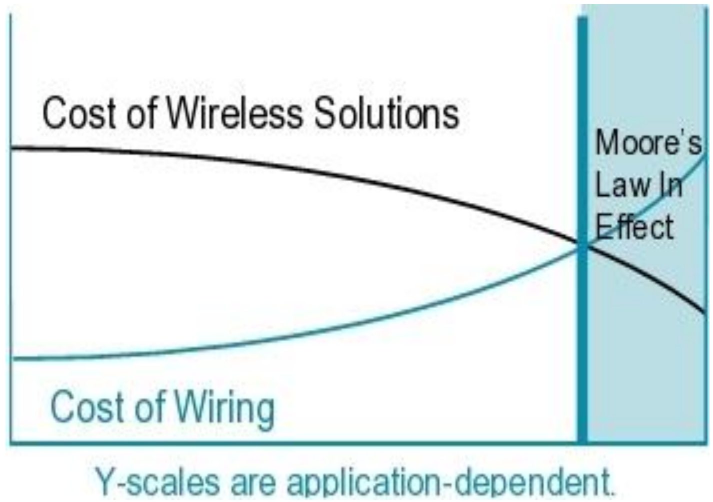
Advantages

2. By using electromagnetic waves as their transmission medium, wireless systems avoid the limitations of wired networks and offer competitive advantages in terms of cost, flexibility, and ease of use. These include:-

(a) **Lower Costs:** The costs associated with installing, maintaining, troubleshooting, and upgrading wiring have escalated while costs for wireless technology have continued to drop, particularly in the areas of installation and maintenance. As wires age, they can crack or fail. Inspecting, testing, troubleshooting, repairing, and replacing wires require time, labor, and materials. Wireless systems obviate any costs associated with running new wires and eliminate associated downtime.

(b) **Reduced Connector Failure:** Most failures in any network occur at the connectors; wireless sensors eliminate this problem.

(c) **Improved Flexibility.** Without the constraint of wires, plant managers can better track materials and more easily reconfigure assembly lines to meet changing customer demands. Freedom from wires also allows greater flexibility in sensor placement, particularly in the case of mobile equipment.



(d) **Exploitation of MEMS:** Micro-electromecha-nical systems (MEMS) offer a rapidly expanding wealth of sensing capabilities. Integrated wireless sensors with built-in communications capabilities can avoid the failures.

(e) **Rapid Commissio-ning:** Simple wireless sensor systems can rapidly organize and configure themselves into an effective communications network. Self calibration and verification are on the horizon, opening the possibility of deploying ad hoc systems to explore a range of production scenarios.

(f) **Wireless Systems Create Value:** Significant technological advances exist at bench-scale in labs across the country. These technologies need to be brought forward and integrated with other emerging technologies to realize the full potential of wireless systems. Low-cost, high-performance, easily deployed wireless devices will change the way end-users view sensors and sensor systems.

(g) **Reliability:** Emerging wireless sensor systems can offer built-in redundancy and capabilities for anticipatory system maintenance and failure recovery.

(h) **Ease of Use:** Integrated wireless sensor systems with distributed intelligence can enable operator-independent control of industrial processes.

(j) **Security:** Manufacturers and industrial companies have become increasingly concerned about threats of industrial espionage and cyber terrorism. New strategies for encrypting and even hiding wireless data transmissions promise a level of security that equals or surpasses that of wired systems. Upgradeability is essential to maintain security as technologies evolve and new threats emerge.

(k) **Robust Design:** Recent advances in materials technology should enable integrated wireless sensor systems to meet durability and reliability requirements in harsh industrial environments.

(l) **Open Architecture:** With the wide range of potential applications and broad diversity of physical devices, the software components will need to be highly modular and efficient. Generic development architecture should allow specialized applications from a wide spectrum of devices without requiring cumbersome interfaces. This will also enable connection to existing sensors and easy upgrades to incorporate more advanced modules in the future.

The Time Is Right

3. Advances in a number of technologies at the beginning of the 21st century are collectively paving the way for the growth of wireless industrial sensor systems. The phenomenal explosion of the personal communications market has dramatically reduced costs and increased the quality of the underlying radio components and technologies. Continued reductions in the costs of computational capabilities also support a distributed architecture for these systems. Embedded intelligence reduces the bandwidth requirements for communications and lowers power requirements, both critical issues for wireless sensors. The technology will also benefit from continuing progress in sophisticated modulation techniques, emerging standards, miniaturization of sensors, and enhanced system reliability and robustness. Continued technology development and the use of a collaborative, multidisciplinary approach to solving common challenges in a cooperative environment can signal a new era in productivity.

4. Orientations in Wireless Technology to gain a competitive advantage, many industrial companies are demanding greater amounts of information, faster methods of processing it, and the means to distribute it to more locations. They seek more devices to collect better information on the physical world, assess its meaning, and communicate it. Often over longer distances, increasingly, industry is turning to systems composed of distributed intelligent devices that communicate via digitized data streams. These systems can move the human-machine interface, monitoring, and control functions closer to the production process, enhancing performance while reducing wiring and cable costs. Wireless sensor technology is now moving rapidly into niche applications in plants and other industrial environments where it can deliver cost advantages and increase flexibility. Wiring and cable have traditionally dominated the cost of industrial communications, but a new dynamic is now in effect High-speed, license-free and low-cost wireless devices that have dramatically altered the equation. Not surprisingly, distance exerts a strong influence on the choice of communications technology. Key industrial wireless markets can be grouped into the following three areas according to their typical distance requirements (from shortest to longest): factory automation, process automation, and supervisory control and data acquisition (SCADA) or telemetry. Hurdles to wider use of wireless systems currently include a range of limitations imposed by both the industrial

environment and the state of the technology. Industrial end-users must feel confident in the solutions to these issues before they will entrust control functionality to a wireless system supporting mission-critical industrial system requirements.

Interoperability

5. A key issue currently limiting wireless deployment in industry involves compatibility among wireless components from different suppliers, generally referred to as interoperability. Full compatibility among components would also provide end users with the flexibility to connect highly specialized, high-end sensors with best-in-class wireless interface devices. The issue becomes how to guide the development of interoperability in the least restrictive manner to encourage creative and unbound solutions. As a framework, the International Standards Organization (ISO) has developed a network model composed of seven different levels or layers. By standardizing these layers and the interfaces between them, portions of communications protocols can be adjusted as needed to accommodate new technologies or altered system requirements. The seven layers are as follows:-

7 Layer OSI Model

Attainment of the long-sought goal of interoperability will depend upon how wireless suppliers implement interfaces among the seven layers of the ISO model. Numerous standards now exist or are under development to promote the compatibility of these interfaces.

Standards

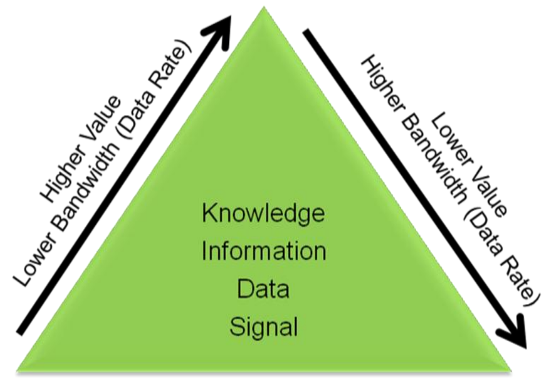
6. The move toward networking of industrial wireless applications is relatively recent. Most of the millions of wireless devices currently used in industrial applications are neither networked nor standards-based. Instead, they pass digitized data transparently or solutions using the license-free bands. Today's networking standards typically address the physical layer and the lower portion of the data link layer (also known as the medium access controller, or MAC, sub

layer). The physical layer addresses modulation (encoding data onto an electromagnetic waveform), frequency use, and transmission. The MAC layer refers to access points and maintains the order of signal flow to avoid signal collision and cancellation. Two of the most widely used standards today were originally designed for office or in-building wireless systems. They are known as **802.11b**, issued by the Institute of Electrical and Electronics Engineers (IEEE), and **Bluetooth**, which was developed by a group of commercial companies. Both of these standards use the unlicensed 2.4 GHz band. The same band is also used for microwave ovens and industrial heating. The 60 GHz unlicensed band has also recently become available and holds promise for reducing interference in short-range applications. Wireless devices that operate in these license-free bands can allow immediate, real-time commissioning of a network, avoiding the delays associated with installing wiring or cables. By spreading data transmissions across the available frequency band in a prearranged scheme, spread spectrum encoding technology makes the signal less vulnerable to noise, interference, and snooping.

7. Spread spectrum technology helps overcome this problem and allows multiple users to share a frequency band with minimal interference from other users. Although there are three spread-spectrum schemes suitable for industrial wireless systems, the two most common are Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS). Bluetooth uses FHSS, in which the transmission hops in pre-defined patterns from channel to channel across the entire 83.5 MHz spectrum. 802.11b uses DSSS, which divides the spectrum into overlapping 22-MHz channels and sends all the information through those swaths. The popularity of both of these standards has increased interoperability among wireless products from different vendors, but the two standards have the potential for spectrum conflict. The third spread-spectrum technique, Ultra-Wideband (UWB), broadcasts on many frequencies simultaneously, distributing its signal across a vast bandwidth. The idea is that the signal is spread so thinly that interference will be negligible in any one frequency. Instead of spread spectrum, both of these recently ratified standards employ the relatively power-intensive, wideband orthogonal frequency division multiplexing (OFDM) signaling technique. OFDM, which was not originally designed for industrial applications, offers higher throughput in areas without intervening walls or other obstructions, but is less power efficient than most other data-transmission schemes due to its requirement for high radio frequency linearity. Unlike FHSS, it uses all channels at once, boosting throughput but increasing the likelihood of interference with other wireless devices in the area.

8. **Spread-Spectrum Encoding Techniques:** As the speed of data transmission (throughput) increases, radio frequency signals supply less energy per bit, adversely affecting reliability. Suppliers to the commercial market for personal communications devices tend to value throughput over reliability (generally higher frequencies), and they exert a strong influence on emerging standards. Developers of wireless industrial sensor systems, on the other hand,

tend to value reliability over throughput (generally lower frequencies). Greater flexibility is needed in making these tradeoffs as appropriate to the application.



Relation between Data Value and BW

9. **Bandwidth Availability / Regulation:** Data throughput is adversely affected by distance and the amount of noise or interference in the area. If too many wireless devices are operating in the same vicinity, they can interfere with each other, restricting network capacity.

If insufficient spectrum is available for interfaces among the wireless devices, communication can become difficult or impossible. Many of today's wireless systems contain provisions for collision avoidance and packet retransmission in the event a signal is blocked by interference. Users can also block out frequencies that experience continuous interference, thereby sidestepping offending signals. These techniques, combined with the use of maximum permissible transmit power and highly sensitive receivers; can yield a reliable transmission even over longer distances. On the down side, these solutions are energy-intensive and can generate interference for other systems. Spread-spectrum technology is based on interference avoidance techniques, but if outside transmission does disrupt communications, users can only switch to another frequency or block out channels occupied by the interferer. In short, users of license-free bands are responsible for reestablishing communications. Rapid growth of wireless devices has generated increasing concern about future overcrowding of the ISM bandwidth.

10. **Power:** Since industrial applications increasingly employ miniaturization and require longer intervals between scheduled maintenance, the power source and power conservation strategies are key issues for wireless sensor systems. Some of today's wireless systems rely on solar panels, but many require batteries that require periodic replacement. Although this is an important power source issue, maintenance requirements have been greatly reduced by today's more power-efficient wireless devices and recent gains in battery performance. Many current wireless systems require regular attention to the power source, necessitating a scheduled outage every 3 to 18 months. Techniques such as exception reporting and power management can extend battery life for multiple years. Even when maintenance is required, shutting down a networked wireless site need not cause disruption to the remainder of the network. Auto-discovery techniques will recognize the site when it is brought back online, and operation will continue. Frequency hopping (FHSS) provides greater range by transmitting short signal bursts, but this uses higher peak power. In contrast, direct sequencing (DSSS) uses available power to spread the signal thinly over multiple channels, resulting in a wider signal with less peak power.

11. Transmitting over longer distances and overcoming interference increase the power demand. Bidirectionality and the need to transmit waveforms similarly drive up power requirements. One power conservation strategy is to minimize the duty cycle, the interval between measurements. This strategy can be applied only when the measured process parameter changes relatively slowly. In applications where power consumption must be kept to a minimum, many of today's networks report by exception rather than the traditional polling scheme used in multiple address systems. Rather than requiring the wireless device to transmit at regular intervals (whether it has new data to report or not), transmissions are made only when a user-definable condition is met. One potential problem with this approach is that the network may be flooded with reports if the process suddenly goes awry. Another power conservation strategy is to use process gain, an encoding technique that involves spreading the signal over a wider bandwidth than is strictly necessary to recover the signal from background noise or interference. DSSS, for example, can sample every bit 63 times, which has the same effect as amplifying the signal without actually using power to do so. Process gain can increase the reliability of transmission and avoid the need for retransmission or use of higher power to overcome interference (in effect, reducing power demands without sacrificing reliability).

12. **Manageability:** When a network experiences drop-outs, outages, or reduced throughput, end-users need tools that can help locate the problem and prevent recurrences. Some of today's systems include tools that allow early detection of problems before they pose a threat to network operations. In distributed networks, these tools can also help minimize or eliminate trips to wireless sites to change configuration parameters.

13. **Functionality:** Most of today's wireless systems incorporate sensors and communications interface components that are physically separate devices, and the systems require configuration by the installer or the user. In the future, however, system developers envision networks of integrated components that configure themselves and perform a host of other functions that will make for rapid system commissioning and unprecedented ease of use. The technology is progressing rapidly. Today, several developers of industrial wireless sensors are advertising self-organizing, self healing, wireless networks. Some feature intelligent, mesh-based topology (allowing every node to communicate with every other node) designed for scalability into the tens of thousands of nodes.

14. **Security:** Spread-spectrum technology presents unintended receivers with challenges: they must know the specific frequency band, modulation technique, and spreading code. Well-designed wireless networks also provide encryption tools to keep transmissions secure. Many of today's systems have 128-bit encryption with dynamically generated, rotating encryption keys, that are also password-protected and have mechanisms in place to prevent eavesdropping and unauthorized access. These systems also provide report generation for network activity, including logins/logouts and attempted access by rogue users. For maximum security, separation of internal network precautions from those implemented in the wireless layer are strongly recommended,

including firewalls and virtual private networks- VPNs. These are essential to maintaining a secure network, whether wired or wireless.

15. **Reliability:** Many of today's standards-based solutions offer a consumer-grade mean time between failures (MTBF), which may not be adequate for industrial applications. Harsh industrial environments, in particular, can adversely affect reliability. Some of today's systems can operate within some industrial environments. Reliability also includes avoidance of interference or noise from other devices and the ability to receive weak signals reliably in the presence of such interference. Consequences of failure are not trivial. Industrial applications entail the risk of substantial losses through equipment damage, personnel injuries, loss of raw materials, and environmental pollution. In most industrial applications, reliability is far more important than throughput.

Collaboration

16**.** **R&D Funding:** The required development and integration work will require substantial research and development (R&D) involving expertise in communications, sensors, industrial applications, and commercial computer systems. Most organizations will be unable to tackle this challenge alone and will require collaborative R&D by a variety of organizations working in these fields. Sources for funding and mechanisms for facilitating the development of collaborative R&D partnerships or teams must be identified.

17. **Scale-Up:** A formal process is needed for scaling up many promising technologies now at the bench-scale. Anecdotal information indicates that exciting new developments may be stalled in small laboratories around the country. Initial developers may lack access to funding or channels for finding partners who can help them take the next steps. Mechanisms are needed to foster the development of business partnerships that can advance these technologies.

18. **Integration of components:** Many system developers today tend to specialize in a single technology area. Successfully integrated wireless sensor systems will develop a multidisciplinary perspective (including sensors, communications, information technology, and end-user applications). System developers need a strategy for fostering cooperation among diverse companies and organizations to achieve their technical objectives.

Culture

19. **Work force/corporate attitudes:** Changeover from a wired to wireless sensor system, particularly one that is capable of autonomous operation, may require adjustments in corporate culture. How will maintenance workers react to the system? Will they harbor concerns over job security? Will managers and engineers need to think differently about the operations? Will technical training be required? Many new control systems are subverted by employees who misunderstand the new technology and lack confidence in its ability to improve over earlier operations. Those responsible for risk management are particularly

wary of such innovations. Forethought and planning on these issues could avert future problems.

20. **Societal attitudes:** The general public has limited understanding of complex technologies and their value. While the public has embraced wireless personal communications, will they show the same enthusiasm as the technology moves into industrial manufacturing? Will misperceptions or fringe elements generate resistance? Will the technology raise privacy issues? System developers and industrial end-users should not neglect emerging public attitudes as the technology evolves. Early public outreach can dissolve issues that might otherwise become major impediments to deployment.

Conclusion

21. Industrial wireless sensor systems hold tremendous potential to improve industrial productivity and product quality. As noted above, the challenges to achieving the full potential of these systems will require both technical and non-technical solutions. Technical solutions will require major funding and concerted R&D efforts that tap the expertise and resources of the diverse stakeholders in the technology. Sensor developers, wireless communications suppliers, computer processing specialists, and industrial end-users must work together to develop and demonstrate effective systems that perform successfully in plant operating environments and deliver on the promise. All stakeholders should be but many have expressed concern about potential interference. The newer 802.11a and 802.11g standards support speeds as high as 54 Mbps (million bits per second) encouraged to join in this worthwhile endeavor.