Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2020, 7(8):19-24**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Industrial Wireless Sensor Networks

Matthew N. O. Sadiku[1], Uwakwe C. Chukwu[2], Abayomi Ajayi-Majebi[3], Sarhan M. Musa[1]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Department of Engineering Technology, South Carolina State University, Orangeburg, SC, USA
[3]Department of Manufacturing Engineering, Central State University, P.O. Box 1004, Wilberforce, OH, USA
Email: sadiku@ieee.org; uchukwu@scsu.edu; ajayi-majebi@centralstate.edu; smmusa @pvamu.edu

Abstract Recent advances in wireless communication and embedded systems have caused the rapid deployment of wireless sensor networks (WSNs) in all sectors and has started to find its place in industrial environment. For industrial applications, wireless technologies have benefits of flexibility, cost, convenience of laying out, maintenance, and expansion. Industrial wireless sensor network (IWSN) is an emerging version of WSN for industrial applications. IWSN is a technology with promising future and a wide range of applications. Unlike traditional WSN, IWSN focuses on critical and time sensitive industrial applications. This paper discusses the applications, benefits, and challenges of WSN technology in industrial environment.

Keywords wireless sensor networks, industrial wireless sensor networks

Introduction

Recent advances in semiconductor, wireless communication, and embedded computing technologies, artificial intelligence, and big data analytics are driving the deployment of wireless sensor networks to meet the demanding harsh industrial environments. These emerging technologies have enabled companies to analyze the large volumes of data obtained from multiple types of sensors.

Wireless sensor network (WSN) technology has contributed significantly in all sectors of our daily life from homes to industries. It has demonstrated a great potential for several applications including industrial, commercial, and consumer applications. In particular, deployment of industrial wireless sensor networks (IWSN) has attracted more attention in recent years and they are being used in various applications. IWSNs are committed to bring the industry automation into the era of Industry 4.0 for the sake of improving the factory efficiency, reliability, and productivity.

Overview OF WSN

A wireless sensor network (WSN) usually consists of a large number (hundreds or thousands) of sensor nodes deployed over a geographical region. A wireless sensor device consists of a sensor that measures a physical phenomenon. The wireless sensor nodes are compact, light-weighted, and battery-powered devices that can be used in virtually any environment. The sensor nodes monitor physical or environmental conditions such as temperature/heat, humidity, sound, vibration, pressure, light, object motion, pollutants, presence of certain objects, noise level or characteristics of an object such as weight, size, speed, direction, and its latest position. The sensor node is made up of four components: a power unit, a transceiver unit, a sensing unit, and a processing unit. The node may also have some application-dependent components. The sensor market has been segmented into temperature sensor networks, pressure sensor networks, level sensor networks, flow sensor networks, humidity sensor networks, motion and position sensor networks, gas sensor networks, light sensor networks, chemical sensor networks, and others [1].

WSNs belong to the general family of sensor networks that employ distributed sensors to collect information on entities of interest. In general, there may be both sensing and non-sensing nodes in a WSN; i.e. all sensors are nodes but not all nodes are sensors. A sensor has four operating modes: transmission, reception, idle listening, and sleep. Collision occurs when two or more nodes transmit at the same time. A sensor node is designed to use an operating system (OS). TinyOS (developed at UC Berkeley) is perhaps the first operating system specifically designed for WSNs. Most WSNs are application specific and are designed to meet the challenges for that specific application. Applications of WSNs typically involve some kind of monitoring, tracking, or controlling. A number of WSNs have been deployed for agricultural and environmental monitoring [2]. Network topologies in a WSN may range from star to a full mesh topology. The way the sensors are connected determines whether the sensors can be safely, securely and cost-effectively deployed in the typical harsh industrial environments. A typical wireless sensor network is shown in Figure 1 [3].

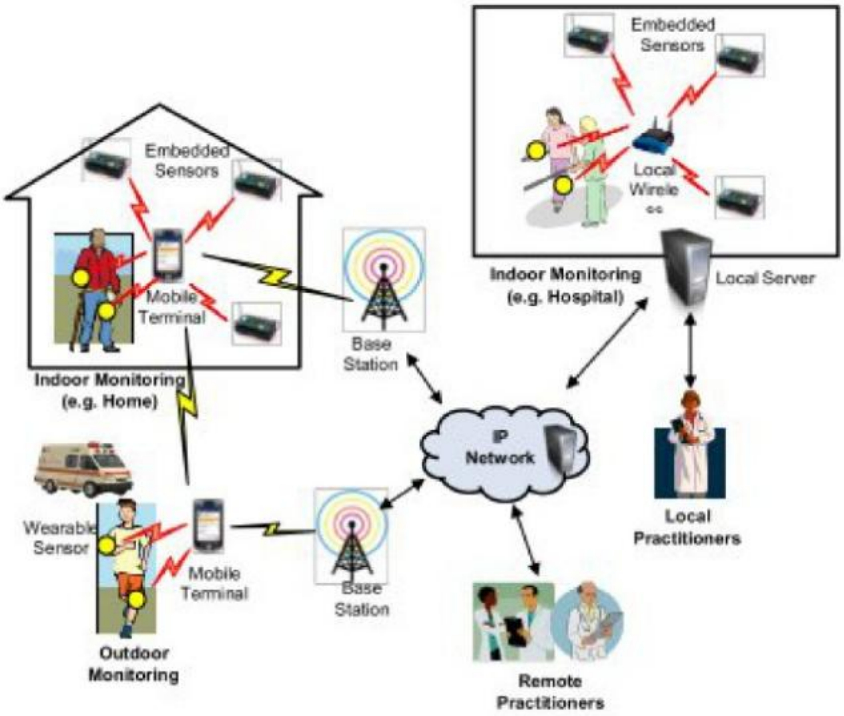

Figure 1: A typical wireless sensor network [3]

Wireless sensor networks were initially motivated by the military for battlefield surveillance, but they are now used for various other applications in agriculture, homes, offices, military, environmental monitoring, industrial monitoring, natural disaster prediction, health care, vehicle tracking and detection, security systems, and many others [4]. WSNs are creating new solutions and applications and are essentially changing how industry operates. The state-of-the-art WSNs have lower deployment and maintenance costs and last longer.

Industrial WSN

Wireless sensor networks are finding their way into numerous applications in our homes, work places, governments, universities, and industry. Industrial standards benefit WSN implementation and redundancy, high-reliability and low complexity, which are common demands of industrial networks. Industrial wireless sensor networks (IWSNs) is a network infrastructure that enables connectivity between sensor nodes and gateways without cables. They incorporate WSNs with intelligent industrial systems. They use wireless communication which allows us to do things we could not do before. In contrast with traditional WSNs, the network structure of an IWSN is generally centralized. A typical topology of an IWSN is shown in Figure 2 [5].

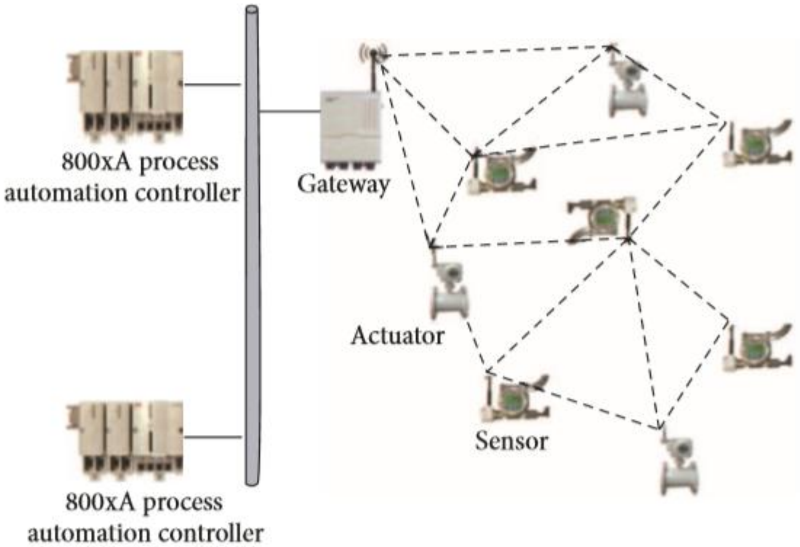

Figure 2: A typical topology of an IWSN [5]

IWSNs play a crucial role of connecting machines, parts, products, and humans and creating a diverse set of new industrial applications because of their simple deployment, low cost, less complexity, and mobility support. IWSNs technologies promise to play a significant role in developing more reliable, efficient, stable, flexible, and application-centric industrial systems.

IWSNs may be regarded as an extension of the Internet of things paradigm that integrates smart sensors in industrial processes. They will help companies gain competitive advantages in industrial manufacturing by increasing productivity, reducing the costs, and developing new products and services.

A set of standards have been developed for IWSN. These include WirelessHART, ISA100.11a, WIA-PA, and IEEE 802.15.4e. All these standards are based on the IEEE 802.15.4 physical layer, but define different mechanisms for the upper layers .The IEEE 802.15.4 standard is designed for WSN requiring low cost, low power, low data rate (up to some few hundred of kbps), and scalability [6]. Selecting an IWSN requires a closer look at communication protocols, device availability, and present and future user needs.

IWSN Requirements

Industrial wireless sensor networks are expected to meet the following seven requirements [7]:

1. *Minimal cost and compactness:* For large-scale deployment of IWSNs, low-cost, and compact sensor nodes are important.
2. *Self-configuration:* Mobile nodes as well as failed nodes makes the topology dynamic. By using self-configurable IWSNs, failed sensor nodes can be replaced by new sensor.
3. *Scalable architectures:* Scalability refers to the ability of a network to scale well. IWSNs architecture should be scalable, flexible, and robust enough to support applications with different requirements with
4. *Resistance to noise and co-existence:* Transmission over the wireless channel is prone to noise and interference which may cause packet errors which may harm production, equipment, and personnel. IWSN should efficiently withstand and work properly in the presence of interference.
5. *Low-delay:* IWSN communication is expected to have real-time guarantees and predictable behavior. IWSN requires timeliness in exchanging messages among nodes. In other words, tt is important to receive the data in a timely manner. Low-delay/latency is required for spectrum handoff schemes due to delay sensitivity QoS requirements of industrial systems.
6. *Reliability*: The reliability of wireless sensor network is always an issue in an industrial environment. It is a critical aspect of time synchronization for industrial wireless applications. It is defined by the

packet error rate suffered by an application. The network designers may need to consider the trade-off between reliability and energy consumption.

7. *Energy efficiency*: The nodes of IWSNs are usually powered by battery, and this often determines the lifetime of the whole network. However, large amounts of transmission data will increase the energy consumption. So energy efficiency needs to be factored into the design of node hardware.

Compliance with these demanding requirements is important since failure to comply can result in serious damage and human injuries.

Applications

Key industry players such Texas Instruments, Ericsson, and Analog Devices are developing industrial wireless sensors for multiple applications and launching new products. Applications include environmental sensing, condition monitoring, and process automation, machine monitoring, process monitoring, asset tracking, safety, surveillance, agriculture, food industry, construction, electric power, as oil and gas, automotive, manufacturing, healthcare, and smarter water network infrastructures [1]. These IWSN applications can be classified into three groups, as shown in Figure 3 and explained as follows [8]:

Figure 3: Taxonomy of IWSN applications [8]

- *Environmental sensing:* This group generally represents the widest field of WSN application nowadays. IWSN applications for environmental sensing cover the problems of air, water pollution, etc. Environment monitoring refers to outdoor applications, requiring a large number of sensors which should be water-proof, prone to shocks, etc. In hazardous environments, there are numerous needs for fire, flood or landslide sensing.
- *Condition Monitoring:* The monitoring application dominates the market due to its elimination of wiring constraints and easy maintenance. Wireless sensor network are rapidly becoming a feasible solution for monitoring and control applications. WirelessHART is widely used for process measurement and monitoring applications. It is extensively used in industries such as oil and gas, utilities, and manufacturing due to its cost-effectiveness and reduced complexity. IWSNs have sensing, processing, and communicating capabilities, which make them ideal for monitoring different offshore operations in the oil and gas industry. They may serve more peaceful functions of monitoring undersea wildlife and volcanic activity [1]. They are also well suited for the health monitoring.
- *Process Automation*: This is expected to boost the adoption of IWSN in the manufacturing industry. Smart sensors can automatically supervise processes without manual intervention creating process improvements through improved monitoring and correction from anywhere. The utilities segment constitutes a major share of the IWSN market. It is partly due to the rapidly increasing deployment of smart grid infrastructure worldwide. Smart grid employs automatic metering.

Benefits and Challenges

The wireless capability of IWSN offers many benefits. It allows adding remote sensors without the cost of laying cables and makes it faster to install WSN compared to wired solutions. IWSNs outperforms any wired network in modularity, ease of use, and cost-effectiveness.

IWSNs bring other benefits over traditional wired industrial monitoring and control systems, including wireless communication, low cost, self-healing, self-organization, rapid deployment, flexibility, and intelligent processing, profitability, efficiency, productivity, reliability, and safety mainly through three aspects: (1) boost revenues by increasing production, (2) develop new hybrid business models, and (3) exploit intelligent technologies to fuel innovation [9].

The complexity of WSN design is a significant barriers to the widespread adoption of WSNs and IWSNs. Major challenges are reliability and robustness in harsh environments and real-time response. Network security is also of main concern in industrial WSNs. Security considerations and threats include node impersonation, man-in-the-middle attacks, denial-of-service attacks, and network injection. Other challenges to industrial applications of WSNs include latency, fault tolerance, synchronization, real-time constraints, limited bandwidth, and battery life. Another challenge is that the designer has to deal with the electromagnetic interference (EMI) in the propagation environment. IWSN has to deal with heterogeneity of data collected and heterogeneity of objective network to integrate with.

Conclusion

The industrial wireless sensor network (IWSN) may be regarded as the next frontier in the industrial Internet of things (IIoT). It must meet a high bar for smart, safe, secure, and reliable operation over several years. The applications of IWSN are expected to open large opportunities for collecting data, enabling remote control, and automation to improve the safety and productivity of facilities [10]. With the rapid deployment of IWSNs, industrial enterprises are moving towards fourth industrial revolutions to achieve factory automation. More information about IWSNs in can be found in the books in [11-13].

References

[1]. "Industrial Wireless Sensor Network Market, Industry Report, 2019-2025," August 2019, https://www.grandviewresearch.com/industry-analysis/industrial-wireless-sensor-networks-iwsn-market

[2]. M. N. O. Sadiku, S. M. Musa, and O. S. Musa, "Wireless sensor networks in chemical industry," *Invention Journal of Research Technology in Engineering and Management*, vol. 1, no. 12, version 3, Nov.. 2017, pp. 30-32.

[3]. G. S. Quirino, A. R. L. Ribeiro, and E. D. Moreno, "Asymmetric encryption in wireless sensor networks," https://www.intechopen.com/books/wireless-sensor-networks-technology-and-protocols/asymmetric-encryption-in-wireless-sensor-networks

[4]. "Applications of wireless sensor networks," in K. Sohraby, D. Minoli, and T. Znati, *Wireless Sensor Networks: Technology, Protocols, and Applications*. John Wiley & Sons, 2007.

[5]. K. Yu et al., "Realflow: Reliable real-time flooding-based routing protocol for industrial wireless sensor networks," *International Journal of Distributed Sensor Networks*, 2014.

[6]. D. V. Queiroza et al., "Survey and systematic mapping of industrial wireless sensor networks," *Journal of Network and Computer Applications*, vol. 97, 2017, pp. 96-125.

[7]. S. S. Oyewobia and G. P. Hanckea, "A survey of cognitive radio handoff schemes, challenges and issues for industrial wireless sensor networks (CR-IWSN)," *Journal of Network and Computer Applications*, vol. 97, November 2017, pp. 140-156.

[8]. M. Erdelj, I. Lille, and E. Natalizio, "Applications of industrial wireless sensor networks," https://www.researchgate.net/publication/282194760_Applications_of_Industrial_Wireless_Sensor_Networks

[9]. O. Sun et al., "Industrial wireless sensor networks 2016," *International Journal of Distributed Sensor Networks*, vol. 13, no. 6, 2017.
[10]. M. Cheffen, "Industrial wireless sensor networks: Channel modeling and performance evaluation," *EURASIP Journal on Wireless Communications and Networking*, vol. 29, 2012.
[11]. D. Caro, *Wireless Networks for Industrial Automation.* ISA, 4th ed., 2014.
[12]. V. Cagri Gungor and Gerhard P. Hancke (eds.), *Industrial Wireless Sensor Networks: Applications, Protocols, and Standards*. Boca Raton, FL: CRC Press, 2013.
[13]. R. Budampati and S Kolavennu (eds.), *Industrial Wireless Sensor Networks: Monitoring, Control and Automation.* Woodhead Publishing, 2015.

About Authors

Matthew N.O. Sadiku is a professor in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics and computer networks. He is a fellow of IEEE.

Uwakwe C. Chukwu is an associate professor in the Department of Industrial & Electrical Engineering Technology of South Carolina State University. He has published several books and papers. His research interests are power systems, smart grid, V2G, energy scavenging, renewable energies, and microgrids.

Abayomi Ajayi-Majebi is a professor in the Department of Manufacturing Engineering at Central State University in Wilberforce, Ohio. In 2015 he was honored by the White House as a Champion of Change for his significant contributions to the engineering education of minority students. He is a senior member of both the Society of Manufacturing Engineers and the American Society for Quality.

Sarhan M. Musa is a professor in the Department Electrical and Computer Engineering at Prairie View A&M University, Texas. He has been the director of Prairie View Networking Academy, Texas, since 2004. He is an LTD Sprint and Boeing Welliver Fellow. His areas of research interest include computational electromagnetics and computer networks.