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Wireless Sensor Technologies for Industrial Applications

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Abstract

Capturing data for both operating machinery and its environment is of priority in most industries especially heavy industries. Some industries need to continuously and simultaneously monitor physical quantities such as temperature, pressure and speed of various parts of different equipment used in other to maintain and improve the quality of products and the efficiency of the process. The common and oldest system used to gather data is the wired sensor systems. This paper looks at wireless sensor technologies that can be used in heavy industries to capture much-needed data for analysis and logging. A few of the technologies were looked at. Challenges and advantages of each were highlighted. It was concluded that ZigBee communication technology has a better chance in the industrial environment.

Keywords: Wireless, Sensor, Network, Data Acquisition, Industrial environment.

1.0 INTRODUCTION

The idea of wireless communication; which is the transfer of information between two or more places that are not linked together by an electrical conductor (wire) existed before Guglielmo Marconi showed the British Telegraph Authorities his development; which was an operational wireless telegraph apparatus, February 1896 [1]. The root of wireless communication was when Hertz developed an instrument to prove Maxwell's electromagnetic (E.M) theories [2].

Since Marconi's development, wireless communication has been used as a backup or in places where wired communication systems could not be implemented. Wireless communication was then upgraded from just sending a code to sending compressed data wirelessly based on Claude Shannon's information theory in 1948 [3]. It has found its way into military, offices and home applications such as house doorbells. One of the fast-growing areas in wireless applications is Wireless Sensor Network (WNS).

A wireless sensor network (WSN) is a wireless network comprising spatially distributed autonomous devices that monitor physical or environmental conditions [4]. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes. The wireless protocol selected depends on the application requirements. Some of the available standards include 2.4 GHz radios based on either IEEE 802.15 (Bluetooth, ZigBee, etc.) or IEEE 802.11 (Wi-Fi) standards or proprietary radios, which are usually 900 MHz [5].

WSN is made up of three parts: the sensor, a wireless communication module and an application. Sensing is a technique used to gather information about a physical object or process. An object performing such a task is called a sensor [4]. In metrology, sensors are used to obtain physical quantities such as temperature and pressure. In modern metrology, different parts of a system or a plant are simultaneously and continuously monitored. This can be achieved by using WNS. The application displays the output of the remote sensors (nodes). This is often on a computer. There are several wireless communication technologies like Bluetooth, ZigBee, Wi-Fi and Wi-Max.

2.0 Wireless Communication in Industrial Environment with its Challenges

Industrial environments are uniquely different from office and home environments. High temperatures, excessive airborne particulates, multiple obstacles and long distances separating equipment and systems are special challenges that make it difficult to place and reach sensors, transmitters, and other data communication devices. These and other factors create a unique, complex, and costly challenge for establishing data communication channels that are reliable, long-lasting and cost-effective.

For example, a primary difficulty faced by many companies is the need to connect remote equipment sensors to central monitoring systems. Inside a steel mill, the environment is extremely intense: excessive heat, heavy machinery, large distances and high levels of Electromagnetic Interference (EMI) significantly shorten the lifespan of wires and network equipment. Wireless communication has had a rocky past and typically has not performed well enough to endure the harsh demands of industrial applications. There are several reasons for this [6].

2.1 Signal Echo

Typical open radio frequencies (900 MHz and 2.4 GHz) used in today's wireless data communication applications have a reasonable penetration rate through office cubicles, drywall, wood and other materials found in homes and offices but tend to bounce off larger objects, metals and concrete. This bounce can redirect the data signal and return it to the original transmitter, causing an "echo" or "multi-path". First-generation wireless systems could easily become confused with this type of interference and would cancel transmission altogether. The result was a state referred to as "radio null" and prevented data communication.

2.2 Noise

The electromagnetic emissions created by large motors, heavy equipment, high power generation and usage, and other typical industrial machinery could create extremely high levels of "noise" that interfered with early wireless equipment. In these "noisy" environments, transmitters and remote nodes were unable to "hear" each other, resulting in frequent data loss.

2.3 Channel Sharing and Interference

Radio frequency space became enormously crowded. FCC-approved frequency spectrums were shared by many devices, including those utilizing Wi-Fi IEEE 802.11 and IEEE 802.15.4. The result was data confusion as receivers and nodes gathered and sent information on the same channel as other devices in the area.

2.4 Industrial Protocols Not Supported

The vast majority of early wireless devices were designed for home and inter-office use. Therefore, very few engineers worked on industrial protocols such as Modbus. Additionally, casing, circuitry, and connections were designed for lightweight usage and were inadequate for rugged industrial settings.

2.5 Distance

The sheer distances between central control systems and remote sensors and equipment eliminated the feasibility of early wireless systems with ranges of several hundred feet or more.

3.0 Wireless communication Technologies

Data capturing and transmitting are categorized based on the applied wireless communication platform. There are many wireless communication technologies or platforms used today but only IEEE 802.XX standard wireless communication technologies are considered

3.1 Bluetooth

[7] designed and implemented a Bluetooth Energy Meter. Their design was based on a CSR Bluetooth BlueEZ module and an analogue device (ADE7756 energy meter). This paper aimed at designing an inexpensive wireless electricity meter. The designed meter was able to send the meter readings wirelessly using the Bluetooth module to any other Bluetooth device in its coverage area. Some examples of Bluetooth devices used for testing the design were phones and Personal Digital Assistants (PDAs).

[8] also demonstrated how wireless communication can be implemented in a medical application to ease health check-ups. They designed a Bluetooth-enabled electrocardiogram (ECG) monitoring system. In their system, a 2-lead ECG sensor transmits ECG data via Bluetooth to a remote computer which displays the ECG waveform of the users. They successfully achieved their aim of removing the physical constraints imposed by hard-wired l inks thereby allowing users the freedom to conduct their check-ups at any time anywhere. A greenhouse environment monitoring and controlling system based on Bluetooth technology was designed by [9] to eliminate the demerits associated with the traditional system which was difficult to maintain and tune. Gang's system had hardware for data acquisition. The hardware consisted of sensors, the Bluetooth module and a software application on a remote computer. The computer had a Bluetooth adapter which made the hardware part able to transmit data to the computer for the software to analyze and respond if the system needed to be tuned.

[10] presented a Bluetooth-based home automation system. Their objective was to design a system which would allow users to monitor and control different appliances in a home environment over Bluetooth. After successfully achieving their aim, they noticed that the system works best in a temperature-controlled environment.

The above paper shows how Bluetooth can be used as a means of transmitting data from a place to a remote place just as expected in this paper. Bluetooth is one of the most commonly used wireless technologies. Indoor appliances such as wireless computer mice, wireless computer headphones and wireless house doorbells are some of the devices that can be seen on the market using this technology.

Bluetooth wireless technology encompasses several key points that facilitate its widespread adoption [11].

1) It is an open specification that is publicly available and royalty-free;
2) Its short-range wireless capability allows peripheral devices to communicate over a single air interface, replacing cables that use connectors with a multitude of shapes, sizes and numbers of pins;
3) Bluetooth supports both voice and data, making it an ideal technology to enable many types of devices to communicate.
4) Bluetooth uses an unregulated frequency band available anywhere in the world.
5) Bluetooth modules are low-cost.

Based on the above merits, Bluetooth modules can be used to obtain effective data transmission, but the disadvantages of the technology rule it out. Critical observations of the areas of application of the reviewed papers show that Bluetooth technology is not mostly used in industrial applications.

Industrial machines like the CNC are often installed in harsh environments and if a Bluetooth module is mounted in such an environment the module will not work properly due to the extremely high temperature produced in industrial equipment.

Bluetooth network also easily jams up (resistance to and detection of service denial) when the module is found in a vibrating environment. Since vibration cannot be fully eliminated in most industrial equipment; it will not be expedient to use Bluetooth modules in industrial environments.

Based on the above disadvantages and other disadvantages which include high power consumption [13] this technology is rarely used in a n industrial environment.

3.2 Wi-Fi

[14] designed and implemented a Wi-Fi meter reading system using AT91RM9200 and Linux to develop a Wi-Fi wireless terminal which they claim has high reliability and high transmission rate. A management software which was designed on VC++6.0 platforms and uses a socket program to aid communication between the Wi-Fi terminal and the software was also developed. The aim of the paper here was to design a system that can continuously receive data from a meter and update computer software. In their experimental system, the data displayed on the management software was the same as that of an intelligent meter every two seconds.

[15] introduced a real-time wireless image transmission system via Wi-Fi. Their system had a single Concerto chip for image acquisition instead of the two separate processors; one for image acquisition and the other for the communication subsystem. A computer used as the collection point had three main paths to which data arrived wirelessly. The data was obtained from an image sensor which had a camera as the most important part. The data which contains the images is transmitted to the PC via Wi-Fi. The sensor had a Simple Link CC3000 Wi-Fi module embedded in it. Some of the problems encountered after the implementation of the system were security issues, low data rates, distance problems, hidden node problems and error rates.

A smart parking service based on a wireless sensor network was presented by [16]. The proposed system consisted of wireless sensor networks, an embedded web server, a central web server and a mobile phone application. In their system, low-cost wireless sensor network modules were deployed into each parking slot equipped with one sensor node. The state of the parking slot was detected by the sensor node and was reported periodically to an embedded web server via the deployed wireless sensor networks. This information was sent to the central web server using Wi-Fi networks in real-time, and also the vehicle driver can find vacant parking lots using standard mobile devices.

[14-16] demonstrated how Wi-Fi could be considered as the wireless technology. The above applications show that Wi-Fi can be used in a n industrial environment with vibration and other r elated harsh conditions. This technology will not be considered based on the problems [15]. Modules of the technology are expensive and require more power.

3.3 ZigBee

Due to the low cost, and low power consumption of ZigBee modules and the ability of its architecture to support a wider range of environments, ZigBee modules have been used as a means to transmit data in most applications more than any other technology in the last few years. It has sailed its way through sample in-door applications to complex industrial systems.

[17] demonstrated how effectively the ZigBee sensor network was used in a smart home energy management system to transmit data such as light intensity, temperature etc. to a service management software which can be monitored on a personal computer. ZigBee modules have also been used in several wireless meter reading systems. It has been used

for transmitting power and heat meter readings [18] effectively. All the readings that were transmitted could be monitored in real-time. ZigBee was also used in image transmission to overcome the problems that [15] faced; the simple link CC3000 WI-FI module was replaced with the CC2520 ZigBee module.

In other applications, ZigBee has been used to design a greenhouse monitoring and control system [19]. Effective and continuous monitoring of the system has been obtained, unlike when other wireless technology is used. ZigBee modules have also been used in outdoor systems. [20] designed a smart sensor to be used in an underground coal mine to transmit data regarding temperature, humidity and methane detection in the coal mine. The system also can trace the mineworker and provide an alarm service if the worker is in danger. The communication protocol used was ZigBee. ZigBee has been used in projects that involve the measurement of temperature; in a normal temperature environment and in an extremely hot environment such as a warehouse temperature proving ZigBee modules can operate in a wide range of different temperatures.

3.4 Other Technologies

WiMAX/IEEE 802.16 is claimed to be the most promising technology for Broadband Wireless Access both for fixed and mobile use. [21] presented how WiMAX technology can be used in environmental monitoring; In this paper information from that station was sent in real-time to an aggregation point using Mobile WiMAX and then forwarded to the scientific community in the monitoring Centre via a WiMAX backhaul, under wireless Fire Prevention system, they considered replacing the GSM/GRRS module in the then existing systems with WiMAX modules to overcome the challenges which they claim to be associated with GSM/GRRS communications such as high cost, poor image and video transmission in mountain regions . In Telemedicine, they considered installing Mobile WiMAX channels in ambulances and hospitals to provide fast information about an accident to a doctor on duty before the ambulance arrives at the hospital. WiMAX has been applied in similar environments in [22]. WiMAX was not considered in this paper because it is high power consumption; expensive and has fewer industrial applications to prove it can work effectively in such an environment.

Ultra-wide-band (UWB) technologies have drawn great interest in the wireless community. Various ultra-wide-band wireless sensor network applications include locating and imaging objects and environments perimeter intrusion detection video surveillance. These submissions above demonstrated the feasibility of UWB technology for wireless sensor network applications including UWB chip and radio module design. In this paper, UWB was also not considered because of high power consumption; 30mW, the high possibility of interference with other systems, the complexity of implementing it and the high cost of modules [23].

4.0 Criteria for Selecting a Communication Technology

Selecting a communication technology to suit a particular environment to be implemented in is very significant. Table 1 shows a chart comparing the various aspects of some wireless communication technologies which are very important to consider when choosing a wireless technology.

The frequency of a wireless technology is any frequency within the electromagnetic spectrum associated with radio wave propagation. Most wireless communication technologies use ultra-high frequency field propagation (300 MHz – 3 GHz) making ZigBee stand out because it uses a lower frequency.

Table 1: The Comparison of Wi-Fi, Bluetooth and ZigBee [6,24]

	Wi-Fi	Bluetooth	ZigBee
Frequency	2.4 GHz and/or 5 GHz	2.45 GHz	915 MHz (US) 868 MHz (EU) 2.4GHz (global)
Channel	14 @ 2.4 GHz 42 @ 5 GHz	79	10 @ 915 MHz 26 @ 2.4 GHz
Number of Nodes per Network (Maximum)	32	8	More then 25400
Distance between Nodes – Indoor.	70 m	Class1 = 100 m Class2 = 10 m Class3 = 5 m	20 m
Distance between Nodes – Outdoor.	160 m	100 m	100 m
Data Rate (Maximum)	54 Mbit/Sec	3 Mbit/Sec	250 Kbit/Sec
Transmission Scheme	DSSS	FHSS	DSSS
Topology	Star	Star	Mesh
Power Consumption Level	Very High	High	Very low

Commonly uses	Cable replacement, large data transfer, networking	Short distance cable replacement	Monitoring and controlling

Most industrial equipment such as motors produce electromagnetic field when operating. This tends to affect data transmitted at high frequencies making communication at lower frequencies more robust than high frequencies. The transmission scheme can either be 'Frequency Hopping Spread Spectrum' (FHSS) or 'Direct Sequence Spread Spectrum' (DSSS).

FHSS -Data is transmitted on a single channel at a time, but the channel is rapidly and constantly changing or "hopping". This scheme requires low bandwidth. DSSS -Data is transmitted simultaneously over every available channel, making it a bit more reliable in "noisy" environments, but it is also bandwidth intensive.

5.0 CONCLUSIONS

In conclusion, for any receiver and transmitter to communicate, there must be a channel for communication in the frequency allocated to the technology being used. Since Bluetooth and Wi-Fi are in the same frequency there is a tendency for both of them to choose the same channel. In case of interference, Bluetooth usually hops into another channel and tries sending the data again while Wi-Fi slows down and tries s ending again through the same channel. The transmission scheme can either be FHSS or DSSS.

The topology of a network is how information moves around the network. In a star topology, all slave devices communicate only to the master device. If two slave devices need to share information, this can only be done via the master device. This network is usually small to prevent overwarming of the master device. While devices in a mesh topology communicate to any device in the network via the fastest available route, the master device in a mesh topology only keeps, updates and shares the routing table with other devices in the network. The best topology to use is the mesh topology because it supports a high number of nodes and provides communication between nodes, even when the master is off.

From the comparisons made between Wi-Fi, Bluetooth and ZigBee, it can be concluded that ZigBee has a lot of advantages and will be suitable for the heavy industrial environments.

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