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An Overview and Comparison of Wireless Technologies and Standards for Industrial Wireless Sensor Networks

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Abstract:
The tremendous research and development has provided a number of wireless technologies and standards used for communication in Industrial Wireless Sensor Networks. The primary reason for writing this article is to study all available Wireless technologies and standards and to identify their area of usage, study different parameters like power consumption, functionality, communication range, transmission speed, data type etc. Another important and main reason of this article is to select best suitable technology for our next research. Various parameters of established technologies like Wireless HART, Zigbee, ISA 100.11a and Dash7 have been compared using a comparison table.

Keywords: Wireless HART, Zigbee, Dash7

I. Introduction

Wireless Sensor Networks have been gaining popularity in both research and in industries over the time. WSNs have advantaged a wide range of applications covering health, agriculture, military, surveillance and monitoring security, production industries, mining industries and many more[3] [5]. Features that make Wireless Networks prominent over wired network are Flexibility, Scalability, cost effectiveness, easy deployment, connectivity and security and easy maintenance[5].

WSN has also replaced wired networks completely from harsh, uncertain and high stress environments like underground mines, where it is inconvenient to dispose wires and long cables which is an expensive and time-consuming process[5].

Generally, the industries are operating through wired communication. They are performing well but they lack in flexibility and demanding regular maintenance. Therefore, they are making functionality complicated, costly and difficult to upgrade the system. With the recent developments in the field of Micro Electro Mechanical Systems (MEMS) it became possible to fabricate low-cost embedded systems that are being installed with the industrial equipment, to sense the physical parameters. These sensed parameters are wirelessly transferred to the central place where these are analysed and necessary measures are initiated[6]. In addition to collecting normal sensory measures, WSNs helps to gather the instantaneous data from the locations those are hazardous or unapproachable through wired networks. Additionally, it

maintains quality, productivity and informs plant personnel to replace or repair the components to maintain the health and efficiency of plant. In nut shell the use of WSNs in industrial scenario is to reduce the investment and operational costs in comparison to the wired networks without losing its quality of service (QoS). Therefore, WSNs may provide self-organizing, self-healing rapid deployment, flexible and intelligent-processing capabilities to industrial automation and control. That may highly reliable rapid responding to real time applications, remotely accessible at affordable cost[9].

Based on the criticality and operational requirements of Industrial systems, Industrial Society of Automation ISA, has classified the Industrial Wireless Sensor Networks into 6 classes and three categories[11]. These classes range from just monitoring to safety to emergency control of the system as mentioned in the table I.

Category	Class	Priority	Description	Tolerance
Safety	Class 0	Very high	Emergency control- always a critical function	Few Milliseconds
Control	Class 1	High	Closed-loop regulatory control - Often a critical function	Tens of Milliseconds
	Class 2	Medium	Closed-loop supervisory control-Generally a noncritical Function	Tens of Milliseconds
	Class 3	Medium	Open-loop control- The operator takes action and controls the actuator (human in the loop)	Seconds to minutes
Monitoring	Class 4	Medium	Alerting, short-term operational effect, event-based maintenance	Seconds to minutes
	Class 5	Low	Data Logging, downloading, uploading no immediate operational consequence like history collection, sequence of events, preventive maintenance etc.	Minutes to hours

Table I Classification of Classes of Industrial Wireless Sensor Networks

In industrial applications the timely data deliveries become more important as the class number decreases. The industrial users are concern to use WSNs for the industrial monitoring as in classes 4, 5, and for the non-critical portion of industrial applications as classes 2, 3[11]. Monitoring applications includes equipment monitoring as well as asset monitoring.

II. Industrial Standards

A number of wireless standards have been developed to interface sensor nodes to different wireless networks. They considered the low power consumption, reliability and maintainability as key parameter for their designing. The various groups like Wireless Network Alliance, ZigBee Alliance,

International society of Automation, HART communication foundation and a new group named as Dash7 Alliance are working for IWSNs. They established standards for IWSNs. The established standards are ZigBee, Wireless HART, UWB, IETF 6LoWPAN, ISA100a, Bluetooth and Dash7 Protocol.

A. Zigbee

ZigBee is 802.15.4 based communication protocol built for the wireless low-rate personal area networks (LR-PAN) developed by IEEE 802.15 TG4. The low power consumption limits its lines of sight communicate range that ranges up to a distance of 100 meters and can operate on a single cell battery for many years[7]. The long-distance communication is achieved by following communication over multiple intermediate nodes. The ZigBee Technology is targeted to home automation, industrial monitoring and control, battle field military applications, surveillance. The ZigBee devices can work in three modes as: ZigBee Coordinator, ZigBee Router and ZigBee end device. The ZigBee Coordinator initiates a network configuration request. This stores information, supports for bridging the different networks for communication. The ZigBee standards are publicly working in a 29 unlicensed international frequency band used by industrial, scientific and medical (ISM) radio. Zigbee Alliance which is a non -profit organization has offered three versions of Zigbee i.e. Zigbee PRO, Zigbee RF4CE and Zigbee IP. Being capable of adapting different topologies like star, mesh and tree it becomes more suitable for use in industries

B. WirelessHART

The Highway Addressable Remote Transducer protocol (HART), is a simple universal standard for industrial automation. This follows the communication over the analog wires. This protocol was used in an early implementation of fieldbus. Its best feature is it can operate with 4 to 20 mille ampere of current for industrial process monitoring and control. The WirelessHART is an extended version of HART protocol[8]. That provides the wireless communication facility to control various industrial applications. WirelessHART provides reliable, energy efficient and secure communication facility over 2.4 MHz ISM band to follow the 802.15.4 based frequency hopping technique for the communication. The secure communication is provided by the encryption, verification and authentication. That makes it suitable to industries for wireless automation and control with over 30 million HART devices installed worldwide. The modified version incorporated with channel hopping technique makes it more reliable technology.

C. Ultra Wide Band (UWB)

Ultra Wideband, known as UWB is low power, short range wireless communication technology used for transmitting a large amount of digital data over a wide spectrum. Its application includes sensor data collection, personal area communication, multimedia communication and tracking application. In UWB the information is transmitted in same manner as transmitted in the spread-spectrum. The train of very short impulses is transmitted in the periodic manner. The UWB base applications gained attention those are applicable to IWSNs. But due to high peak energy pulses it is not an appropriate approach for long distance communication. This has a good localization capability for sharing the 30 allotted frequency band by hiding information behind noise floo[17]r. This can send information at low power with high transmission rates. Further, it has capability to provide secure communication within adverse environment condition. The major challenges like hardware development, multipath interference and propagation characteristics should be considered for the designing of UWB.

D. 6LoWPAN

The IPv6 over Low Power Wireless Personal Area Network (6LoWPAN) is the standard intended to the users using small, low-power, low processing capable devices. They participate in the wireless mode to access internet of things. Following the headed compression technique standardized in RFC6282, the packet being forwarded and accepted in the IEEE 802.15.4 based wireless networks[17. According to industrial prospective 6LoWPAN has capability to access the internet protocol (IP) based devices using IP network locally and remotely.

E. ISA 100.11a

Name	Standard	Class	Year	Data Rate	Range	Frequency	Power Consumption	Packet size
Zigbee	IEEE802.16	WPAN	2003	20-250kbps	70m-300m	868/915/2400	Low(100-1000 days)	127 bytes
Wireless HART	HART	WPAN	2007	250kbps	50-250m	2400	Low	128 bytes
ISA100.11a	ISA 100	WPAN	2009	250kbps	50-250m	2400	Low	-
UWB	IEEE802.11	WLAN	1991	110mbps	10-30m	2400	Low	-
6LoWPAN	IETF	WPAN	2005	20-250 kbps	Small	868/915/2400	Low	2 bytes
Bluetooth	IEEE 802.15.1	WPAN	1994	720kbps	10m	2450	Very low	27 bytes
DASH7	ISO/IEC 18000-7	-	2009	27.8kbps	250m	433/868/915	Low	256 bytes

This is a wireless communication standard, developed by International Society of Automation (ISA) , targeted to the industries for automation and process control. The ISA 100 is a working group of ISA constituted in 2005. The responsibilities were to establish standard and policy to define procedure, technical report, and to submit the recommendation for implementing WSNs in industrial environment. This was targeted to field implementation level. In 2009 the standard was commissioned for the industrial process monitoring and control[8].

F. Bluetooth

The Bluetooth is short range wireless communication technology, developed to connect the consumer devices wirelessly in ad-hoc fashion. In order to make it more interesting Bluetooth special interest group put it ISM band at 2.4 to 31 2.485 GHz for personal area networks. The IEEE standardized Bluetooth as 802.15.1. The Bluetooth communication is following packet based protocol and communicates in master slave mode. The low power consumption and 1mbps data rate make it interesting for IWSNs application[12].

G. Dash 7 Alliance Protocol (D7AP)

The Dash 7 Alliance Protocol or D7AP is an open wireless sensor and actuator network standard, maintained by the DASH7 Alliance. D7AP originates from ISO/IEC 18000-7 which was mainly used for military purposes. In 2011, it gets collaborated with WSN and the original standard was extended to support WSN/IoT functionalities to achieve faster throughput, low latency and better security. Initially, ISO/IEC 18000-7 defined an air interface only for the 433 MHz band but later extended to all sub-GHz ISM and SRD bands (433, 868 and 915 MHz). In April 2015, the version 1.0 of D7AP was publicly released[15]. D7AP released Version 1.1 in 2017 which was a major update to Version 1.0 in area of security and interoperability. D7AP is suitable for applications which require low power usage and low data transmission rate[17]. It provides a good compromise between transmission range and power consumption. Being Bidirectional it is suitable for industrial applications with effective transmission range of 100m to 500m[16]. In LOS situation it supports range of 1km or more. This protocol is designed on **B.L.A.S.T** networking technology that means it supports **B**ursty data transfer with a **L**ight packet size not more than 256 bytes. This protocol does not require synchronization and handshaking between devices hence it is **A**synchronous. It is a **S**tealth and **T**ransitive Protocol that means it does not require periodic beaconing and being upload centric it does not require fixed infrastructure or any base station. A brief overview and comparison of all the famous Protocols and Standards of Wireless Sensor Networks used in industries have been shown in Table II.

III. Related Work

Pedran Radmand in 2010 [1] presented a comparison of Industrial WSN standard in which he compared Zigbee, Wireless HART and ISA.100 standards and Standards and Protocols concluded Wireless HART and ISA.100 as the most suitable for industrial application rather than Zigbee.

Aamir Shaikh in 2012 provided a complete overview of Wireless Sensor technologies along with its application of use [22]. He concluded by considering Zigbee as the most unique and useful technology for industries. But he also demands for some improvements to make the Zigbee protocol more efficient.

Priyanka Rawat in 2013 [21] presented various technologies and standards. Out of available technologies she considered IEEE802.15.4 to be most flexible technologies. Also for applications with high data rates she considered Bluetooth Low Energy (BLE), the most suitable technology. She concluded the paper with the fact that choosing the technology should be completely application dependent.

Svetoslav Atanasov in 2013 has thoroughly examined and compared maximum number of available technologies and standards used in WSNs[20]. He has presented a comparison between various technologies and standards based on few important parameters. He also concluded the fact that one needs to pick the technology suitable to the needs, conditions, environment and application of the user.

A.K Verma in 2015[10] compared the standards Zigbee and Wireless HART, where he appreciated the use of Wireless HART in industrial Safeguard environment and highlighted the challenge of lack of security. He has compared the two technologies covering the main features, architecture along with the area of application in a tabular form.

Ing. Jakub Silva in 2015, has overviewed the existing technologies used in creating a WSN, differences, constraints, standards and corresponding recommendations have also been made. He concluded with the fact that the protocols needs to be battery-aware instead of energy-aware[2].

Artem Proskochylo in 2015 presented an overview and analysed the common technologies used in creating Wireless Sensor Networks. They have compared Zigbee, Wi-Fi and Bluetooth technologies considering few parameters. They have also reviewed the main advantages and disadvantages of applying these technologies[19].

In 2016, Q Eang and J Jiang discussed the most popular WSN Standard like Zigbee, ISA.100.11a, WIA-PA. They have examined, compared and highlighted the uniqueness of each of them[18].

Jebril A. Battsh[8] evaluated the performance of three most popular technologies in Wireless Sensor Networks i.e. Zigbee, WirelessHART, and ISA100. He considered parameters like throughput, end to end delay, and energy consumption for comparison and concluded with the results that showed ISA 100 and Wireless HART performed better in large networks as compared to Zigbee. He also stated that ISA 100 is more flexible than Wireless HART as it uses properties like slotted and slow hopping and having configurable timeslots.

IV. Conclusion

This paper presents an overview of existing protocols and standards used in Industrial Wireless Sensor Networks. All these networks have unique characteristics and limitations, intended user may choose among them according to the desired network requirements. We have also discussed a new and recently known protocol for Industrial application i.e. Dash7. It has been used for developing industrial networks and performing well with low operating frequency and long range of operation. Hence it can be considered for applications where a compromise between range and operating frequency can be tolerated. Each protocol has its own advantages and disadvantages so user must look in to it while choosing a protocol.

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