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Communication Protocols for Smart Sensors in IoT Applications

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Abstract: The advancements in the field of electronics and wireless technology have put forward the idea of the Internet of Things which can be rightly called the third industrial revolution The Internet of Things technology is about connecting and communicating with anything anywhere at any time. The concept of the internet of things can be fully materialized with the help of its supporting technologies including the smart sensors, processors, and highly efficient communication protocols. The smart sensor nodes communicate with the base stations using different communication protocols. A brief review of the requirements of the IoT systems are studies and the communication protocols for the short-range and long-range IoT applications are discussed and compared in this study. Various short range and long range communication protocols which are used for the IoT applications are summarized along with the range covered and the number of nodes that can be connected. The major requirements and constrains of communication protocols employed in IoT applications are discussed. The study concludes that the choice of technology to be considered for the implementation of an IoT system is deeply connected with the types of applications which specify the range to be covered, the number of devices to be connected, the operational bandwidth available, the rate of transmission and the cost of the system. .

Keywords: Bluetooth, LoRa, GSM/GPRS, ISA 100, NB-IoT, Sigfox, Wi-Fi, WiMAX, WirelessHART, ZigBee, Z-Wave

1. Introduction

The third wave of the industrial revolution has started hitting the world in the name of IoT, which is a collection of several already existing technologies including wireless sensor networks, wireless communication technologies, data acquisition, and signal processing technologies, efficient power utilization technologies, and so on. IoT promises a connection between smart things around the world anytime. This ‘anywhere, anytime, anything technology’ is expected to boom to a connection of over 50 billion devices by the end of this year [1].

As IoT is a blend of several technologies, its implementation is also deeply tied up to the contributing technologies and their advancements. IoT system is based on billions and trillions of smart sensors and actuators, which are capable of data acquisition, processing, and communication. The interconnection between the smart nodes becomes the backbone of IoT. The wireless communication over the radio frequency has been seen to offer a solution to accomplish IoT technology [2].

The smallest unit of a sensor network is a sensor node that consists of a sensing unit, processing unit, communication unit, and a power supply system. The sensor nodes are remotely deployed and it's impossible to recharge or replace the battery of these nodes once they run out. The operations performed by the sensor node, as sensing, processing of the sensed data, and communicating this data, all these are powered by the limited battery power. The limited power supply in sensors becomes a problem in wireless connectivity between the sensor nodes. So power management has always been a major issue of concern in sensor networks. Maximization of the network lifetime by minimizing energy consumption has always been a research objective in this field along with the study of energy-efficient wireless communication protocols that can be employed for IoT connectivity.

A wireless communication system used for IoT applications needs to take into account, the amount of data that needs to be transferred, the power efficiency of the system, coverage area, the security and compatibility with other technologies, and the cost and the application [3]. The constraints to be applied to the communication technology are as summarized in Figure 1. The IEEE 802.15.4 standard which offers a dedicated wireless link for Low Power Wireless Personal Area Networks (LoWPANs) is a good choice in some IoT applications [4].

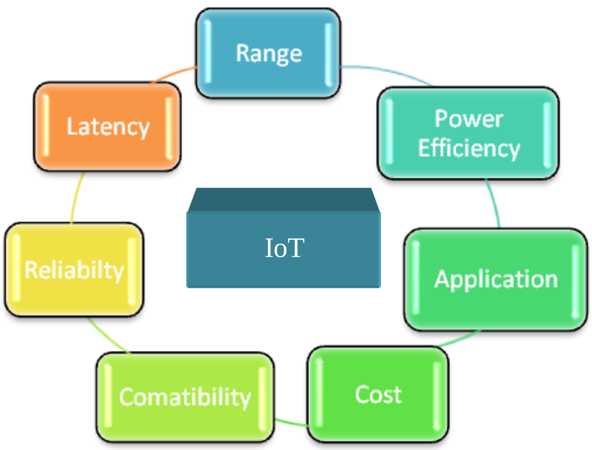

Figure 1: The Constraints on Communication Protocols for IoT Applications

In this work, section 2 explains the characteristics of the wireless communication protocols, section 3 studies in detail, the new constraints on intelligent sensor systems, and section 4 deals with the different LPWAN technologies employed for the massive deployment of IoT, and section 5 gives the conclusions that were derived from this comparative study.

2. Wireless Communication Protocols and Their Characteristics

A variety of communication protocols has been developed over time with different characteristics to suit different applications. Some popular protocols are Bluetooth, ZigBee, Wi-Fi, WiMAX, GSM/GPRS, etc [15]. The communication protocols which are employed for the transfer of information between smart sensor nodes, which are deployed for IoT applications, have the following major performance metrics.

- The available channel bandwidth
- The allowable delay or the transmission rate

- The range of communication
- The size of the sensor network deployed
- The energy consumption
- Cost

	Bandwidth	Transmission Rate	Range of Coverage	Number of Nodes	Energy Consumption	Cost
Bluetooth [5], [6]	1MHz	1-2Mbps	10m	8	Low	Low
ZigBee [7], [8]	0.3MHz	250Kbps	Up to 1000m	>65000	Low	Medium
Z-Wave [9], [14]	-	40Kbps	Up to 30m	232	Low	Medium
Wi-Fi [16, 17]	25MHz	54Mbps	10-100m	255	Medium	Low
WiMAX [18]	20MHz	70Mbps	Up to 50km	1600	Medium	Medium
GSM/GPRS [19]	200KHz	168Kbps	Up to 35km	1000	Medium	Low

Table 1: Comparison of Performance Metrics of various Wireless Protocols

Table 1 gives a comparison of the performance metrics of the popular IEEE standards. While Bluetooth protocol was majorly used for the replacement of traditional cables over short distances, ZigBee was utilized for overall monitoring and control. Wi-Fi, on the other hand, was used for internet access over a region of around 100m while WiMAX and GSM/GPRS monitored the internet and other network services including voice and data communication over long distances. The Z-wave protocol has regained popularity with the emerging IoT, especially in applications like smart homes and home automation [10, 11]. Z-Wave is controlled by Z-Wave Alliance which is a group of over 600 companies.

2.1 WirelessHart Protocol

The WirelessHART (Highway Addressable Remote Transducer Protocol), is widely used in automation and manufacturing industries. It offers a simple configuration, flexible installation and an easy access to data, while being reliable and robust. WirelessHART is similar to the popular Zigbee

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and ISA 100 communication protocols [12]. A well-designed WirelessHart system ensures longer lifetime and good stability. The major features of WirelessHART protocol are

➢ A centralized operational architecture.
➢ Energy efficiency greatly dependent on efficient network design.
➢ Robust and reliable data transmission ensured.
➢ The routing/topology, the network size and the link scheduling will decide the data latency during transmission.

Table 2: Major features of WirelessHART communication protocol [12]

2.2 ISA 100:

The International Society of Automation (ISA) formulated ISA 100.11a in September 2009, for secure and reliable wireless communication between non critical control and monitoring operations in industrial environments. It supports both star and mesh topologies for the connection of sensors and router devices in a network and it is very similar to the WirelessHART protocol in many aspects [13].

3. Constraints on Wireless Protocols used in Intelligent Sensor Systems

Smart sensor nodes are employed in the recent WSN applications. Nodes, the basic unit of a sensor network, is becoming more and more complicated these days. They are now incorporated with highly sensitive sensing units, advanced processors, and efficient communication interfaces, which are secure, reliable, and energy-efficient.

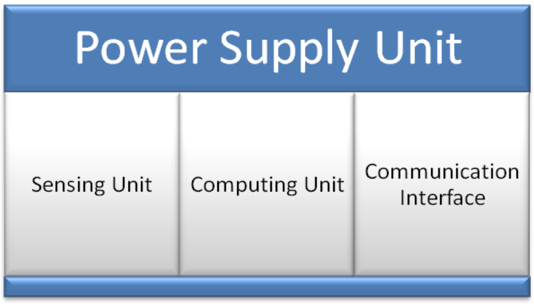

Figure 2: The basic architecture of a Wireless Sensor Node

The two-way communication interface configures the sensor node and also transfers data to the central information collection center. Compatibility with the sensor nodes and the communication interface plays a vital role in the realization of an efficient wireless network for IoT applications.

The parameter optimization of the sensor nodes deeply relies on the application for which they are employed. In applications where energy source can be occasionally replaced, the focus will be on the QoS of the system including the reliability, connectivity, and coverage of the network whereas in applications such as habitat monitoring, environment monitoring, and war-field deployments, energy conservation becomes the major design parameter as recharging or replacing the power source is not easy [20].

To summarize, the smart sensor networks employed in monitoring different situations require a continued connection along with efficient power utilization whereas sensor systems that are employed for tracking take care of being connected while the nodes are mobile. The event detection sensor networks concentrate on reliability and security while continuously monitoring and verifying the data transmitted by alert messages, confirmations, and acknowledgments.

4. LPWAN Technologies for IoT Applications

The developments in IoT technology have brought the Low-Power Wide Area Networks into the limelight. The large-scale IoT networks which cover wider areas depend on low power communication technologies like Sigfox, LoRa, and NB-IoT. IoT applications are generally characterized by low data rates, low energy consumptions, a long-range, massive number of devices, and cost-effectiveness [21]. Table 2 summarizes the major features of the three LPWAN technologies.

The communication protocols like ZigBee, Bluetooth, and Z-Wave support short-range IoT applications like smart homes and industrial automation. The cellular communication technology including the 2G, 3G, and 4G can furnish with larger coverage, but at the cost of higher power consumption. So large scale IoT applications desire to work with low power technologies, which support wider coverage area.

4.1 Sigfox

The Sigfox technology works on the unlicensed band and provides a bandwidth of 100Hz with a maximum data rate of 100bps. Sigfox started as a simplex technology and further developed into bi-directional communication technology. Sigfox can give coverage of over 10km in urban areas and about 40km in a rural region with high noise immunity and good power efficiency [22]. Sigfox has low deployment cost which makes it suitable for applications like manufacturing automation in industries. At the same time, Sigfox does not support encryption and authentication and cannot have adaptive data rates. Private networks cannot be designed using Sigfox technology [23].

4.2 LoRa and LoRaWAN

LoRa communication technology is another low power technology that works in the unlicensed band which is standardized by LoRa Alliance [24]. LoRa transmits signals in the SUB GHz ISM bands and utilizes spread spectrum modulation for the transmission. LoRa signals inherently contain a noise-like component which makes them robust to interference with other signals and signal degradations which occur due to multipath propagation [25]. The bandwidth for LoRa is 125 kHz and 250 kHz supporting a maximum data rate of up to 50kbps. LoRa data can be encrypted and can manage adaptive data rates. When LoRa is a non-cellular, long range and low power wireless technology, especially for industrial and home automation RF applications, LoRaWAN is a category of wireless wide area network topologies which requires covering longer range at less bandwidth and power consumption. It's the backbone technology in forming smart cities, smart farming, environmental monitoring and many others which has wider area of coverage. LoRaWAN can be summarized as a network protocol which enploys LoRa.

4.3 NB-IoT

The Narrow-Band IoT technology is a licensed system capable of co-existing with the traditional GSM and LTE [26]. NB-IoT can support Stand Alone operations, Guard band operations, and In-Band operations. NB-IoT protocol has been derived from LTE protocol and was specified in Release 13 of 3GPP.it has a bandwidth of 200 kHz at a maximum data rate of 200kbps [27]. NB-IoT is continuously revised in further 3GPP Releases [28]. It's a good choice for IoT applications through its deployment cost are considerably large.

Parameters/Comm. Technology	**Sigfox**	**LoRa**	**NB-IoT**
Range(Uraban/Rural)	10km/40km	5km/20km	1km/10km
Battery Lifetime	>10yrs	.>10yrs	>10yrs
Operation Frequency	Sub GHz	Sub GHz	Cellular Bands
Data Rate	100bps	50kbps	200kbps
Power Consumption	Low	Low	Medium
Deployment Cost	Low	Low	High
Bandwidth	100Hz	125/250KHz	200KHz
Interference Immunity	High	High	Low
Spectrum	Unlicensed	Unlicensed	Licensed

Table 3: Comparison of the major LPWAN Technologies

5. Conclusion

The paper has tried to give an overview of the communication protocols used for the small and large scale deployment of smart sensors for IoT applications. The small range communication protocols like Bluetooth, ZigBee, Z-wave, Wi-Fi, WiMAX, and GSM/GPRS are studied and compared first followed by the communication technologies employed by IoT applications with larger coverage including Sigfox, LoRa, and NB-IoT.

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