Available online at www.sciencedirect.com
ScienceDirect
Energy Reports 6 (2020) 430–446
www.elsevier.com/locate/egyr

Tmrees, EURACA, 25 to 27 June 2020, Athens, Greece

Green Industrial Internet of Things from a smart industry perspectives

Mohamed Tabaa[a,*], Fabrice Monteiro[b], Hassna Bensag[a], Abbas Dandache[b]

[a] LPRI, EMSI Casablanca, Morocco
[b] LGIPM, Lorraine University, France

Received 5 August 2020; received in revised form 9 September 2020; accepted 26 September 2020

Abstract

The goal of industrial revolutions is not only to improve and respond directly to the needs of industry in a productive side fact, but also to improve the standard of living of society and make life easier for customers. Therefore, economic growth should always go hand in hand with each industrial revolution. In this context, the increasing demand for electricity, the non-renewable nature of conventional sources and the rising price of fuel, are considered the constraints of the 21st century and need to be definitively managed in order to meet the constantly increasing demand for electricity from the population in the best possible conditions. Information and Communication Technologies (ICTs) are the foundation on which tomorrow's innovative solutions are created. However, smart embedded systems and the internet are two major players driving ICT technologies forward. These technologies have impacted several sectors, where we find a crossroads of several industrial sectors: medical, manufacturing, automation, energy and others. The application these technologies in a smart grid framework with the integration of renewable energy sources and used for an optimization and efficiency mission let Internet of Things (IoT) to take the sustainable and industrial character and named Green Industrial Internet of Things (GIIoT). This last, seems to be a promoting axis for the development of future applications. In this paper, we present an overview of the impact of the Internet of Things on the evolution of applications in relation to the different revolutions, an inventory of the different industrial revolutions, an overview of the GIIoT as well as some applications and perspectives.
© 2020 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the scientific committee of the Tmrees, EURACA, 2020.

Keywords: IoT; Green Industrial IoT; Technologies; Smart industry; Smart applications; Industry 4.0; Society 5.0; MIC2025

1. Introduction

The industrial revolution was set in motion to define a system that evolved from a computer-controlled automated facility to a system that processes mass data. This provides intelligent decisions in an automated approach to improve an industrial sector, as well as a society's way of living. The initiative adopted by the German government, concerning Industry 4.0, was aimed at integrating the new technology into the industrial sector [1]. From 1760 to 1880, the first industrial revolution was initiated by James Watt in England by developing a steam engine. From 1880

* Corresponding author.
E-mail address: tabaa.mohamed@emsi-edu.ma (M. Tabaa).

https://doi.org/10.1016/j.egyr.2020.09.022
2352-4847/© 2020 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the scientific committee of the Tmrees, EURACA, 2020.

Nomenclature

ICT	Information and Communication Technologies
GIIoT	Green Industrial Internet of Things
MIC2025	Made in Chine 2025
SDG	Sustainable Development Goals
IIC	Industrial Internet Consortium
M2M	Machine-to-machine
CPS	Cyber Physical System
HART	Highway Addressable Remote Transducer Protocol
ISA	International Society of Automation
ISM	Industrial Scientific and Medical
IETF	Internet Engineering Task Force
6LoWPAN	Low Power Wireless Personal Area Networks
LPWAN	Low Power Wireless Area Networks
BPSK	Binary Phase-Shift Keying
LoRaWAN	LoRa Wide Area Network
NB-IoT	Narrow Band Internet of Things
MQTT	Message Queuing Telemetry Transport
XMPP	Extensible Messaging and Presence Protocol
AMQP	Advanced Message Queuing Protocol
CoAP	Constrained Application Protocol
DDS	Data Distribution Service
OMG	Object Management Group
AI	Artificial Intelligence
BEV	Battery Electric Vehicles
HEV	Hybrid Electric Vehicles
PHEV	Plug-In-Hybrid Electric Vehicle
FCEV	Fuel Cell-Electric Vehicle

to 1950, the use of new energy sources such as gas, electricity and oil contributed to the second industrial revolution. From the 1950s to the progress of industry was due to electronics with the arrival of transistors and microprocessors, but also to telecommunications and computers. This revolution led to the development of the aerospace sector and many others. Since 2010, and after three successive industrial revolutions (mechanization, mass production and digitalization), the time has come for intelligent factories [2]. Around the world, other revolutions have emerged, inspired by the German model: the Japanese "Society 5.0" [3] model and the Chinese "MIC2025" model [4].

The connected objects, the Bidgata, cyber security, cobot, Blockchain and artificial intelligence are mainly the catalysts of the industry of the future. These technologies are today in the most important phase of their development. Therefore, the main challenge is to develop the appropriate technology that will respond immediately to market requirements, and to have flexibility in multiple environments [5–7]. Given the growing interest in the industrial revolution, this development is currently in its initial exploratory phases and academics have begun to develop pedagogical approaches in this direction. In parallel, several works have eventually started to advance the scientific model of Industry 5.0 (impact of robotics on human life) [8,9].

Recent theories suggest that economic growth depends on the diffusion and absorption of new technologies, based on skills, to create and apply them in a mutual way. It is on this basis that Japan has defined the term Society 5.0, which refers to a modern society that makes effective use of the connected object, Big Data and artificial intelligence, for the purpose of improving the world, where technologies and organizations as a whole will be major components of Society 5.0 [10,11]. It should be noted that the world is going through a new era, an era of globalization and the evolution of digital technologies. This evolution is bringing changes in vertical sectors as well as directly on society. The environment and the values of citizens are increasingly diverse and complex. The revolutions in the world, Industry 4.0, Made in China 2025 or Society 5.0, aim to develop activities targeting new digital technologies. Indeed, the wave of digital transformation is the key element of all these activities.

This digital transformation is becoming a pillar of the industrial strategy [12,13]. This transformation has completely changed the mode of function of the majority of industrial applications as well as companies. The latter now need employees capable of understanding and using and developing new work models. Therefore, the stakes of this transformation are characterized by a mastery of process digitization, a redefinition of business lines, good data analysis and agile integration within the company.

This paper comes to focus on the direct involvement of the Green Industrial IoT ecosystem in relation to the evolution of smart industry. This paper will be presented as follows: state of the art of smart industry in relation to industry 4.0 in the third part. The IoT ecosystem related technologies as well as IIoT and GIIoT will be presented in part 4. In the fifth part, we present the challenges and opportunities offered by Industrial GIIoT for a range of industrial sectors. Towards the end a conclusion and perspectives.

2. Smart industry: State of art

The industry of the future comes to accelerate the modernization of the industry's tool, as part of the deployment of new technology. This is not just a simple deployment of sensors, robots or innovative tools, but above all it is a boost for the digitization of industrial sectors. New digital technologies and digitization are the catalysts for such a revolution in the industrial model, changing the structuring and interaction for excellent business agility. This can only be ensured through a better use of technology and data, for an excellent integration in the industrial ecosystem. In this section, we present a state of the art of Industry 4.0 as well as global industrial models including: Society 5.0 and MIC2025. We may present the impact of new technology, in particular green industrial IoTs, on the evolution of these models.

2.1. Industry 4.0

Industry 4.0 is characterized by a new way of organizing the company to put an end to complex hierarchical structures. Therefore, ICT techniques must be merged with industrial technologies. In Industry 4.0, embedded systems, IoT and CPS technologies link virtual space to the physical world to give birth to a new connected generation of so-called "smart " factories. These factories are capable of more efficient allocation of production resources, with the main objectives of customizing products, minimizing time to market and improving business performance. This opens the way to a new mode of industrial transformation. The concept of Industry 4.0 was first introduced at the Hanover Industrial Technology Fair in 2011, the world's largest technology and industrial trade fair. In 2013, Germany officially adopted the implementation of the concept by the German government's identification of Industry 4.0 in its future projects within its action plan "High-Tech Strategy 2020". It has rapidly evolved as a German national strategy based on 4 aspects: Building the CPS network, addressing two main themes based on the plant and intelligent production, thus achieving 3 types of integration: Horizontal, vertical and point-to-point [14]. As a result, German industry has welcomed the initiative with open arms. Small, medium and large companies from all sectors have participated in the creation of this new era. However, the boost from the government has helped to internationalize the concept of Industry 4.0 (Fig. 1). In 2014, the State Council of China unveiled its national plan, Made-in-China 2025, inspired by Industry 4.0 and designed to improve global China's industry and integrating digital and industrial technologies. At the same time, several countries have adopted this concept, we cite as an example "the new industrial France" by France, "Industrial Internet and advanced manufacturing partnership in USA" by the United States [11].

Industry 4.0 will allow companies to engage in the development and marketing of innovative products and services that until now could only be contemplated by some industry giants. Some of the benefits of Industry 4.0 are listed below:

– Monitor and control machinery and equipment in real time.
– Introduce intelligent processes by using machines that can analyze their own data to predict when their maintenance should be performed as an example.
– Optimize the Supply Chain, through product traceability, logistics tracking and inventory control
– Eliminate paper by scanning instances of mill processes (actual, in use processes) to verify compliance with designed processes.

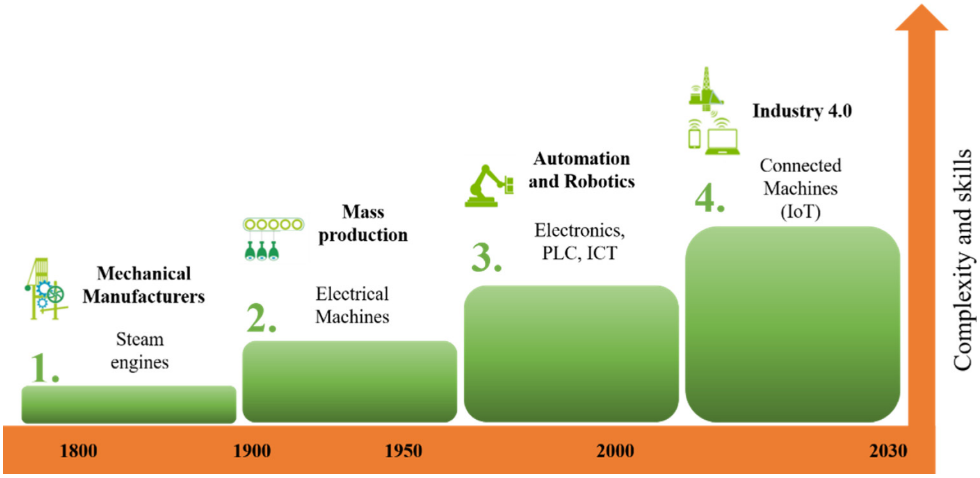

Fig. 1. Industry 4.0 concept.

2.2. Society 5.0

Society 5.0 was drafted in the 5th basic plan for science and technology by the science, technology and innovation council. This major forward-looking project is led by the Japanese government. We can easily define the stages of the society while basing ourselves on the history of humanity.

Society 1.0 is defined as a set of people who hunt and live in coexistence with nature. Society 2.0 formed people based on agriculture, growing organization and nation building. Society 3.0 is characterized by a vision that favors industrialization with the aim of mass production. As for society 4.0, it is a society based especially on information, realizing great value by connecting intangible assets such as information networks. Finally, the 5.0 society is a data society built on the basis of the 4.0 society focused on the human being. This has led to the creation of a large industrial capacity, in several sectors, while having a direct impact on citizens.

In this context, the 5.0 society aims at developing an economic and technological model around the human being, in which certain economic and societal challenges are met. Thus, citizens will enjoy an excellent quality of life, fully comfortable and modern. This society will perfectly meet the daily needs of people, regardless of region, age, gender, by providing the necessary goods and services. The key element in its establishment is the fusion of the real world with space in order to generate useful data. This creates solutions and opportunities for better problem solving. It is worth mentioning that Japan's growth strategy is based on the key elements of the SDG (Fig. 2). This intelligent strategy makes it possible to address the challenges that Japan is also facing from other countries, such as an ageing population, a falling birth rate, a shrinking population and ageing infrastructure. Japan is considered one of the first nations to address these challenges. By solving these challenges through Society 5.0, and sharing solutions with the world, Japan has been able to participate in solving similar challenges around the world, as well as in the realization of the SDG [4,15].

2.3. MIC2025

The Chinese government launched the MIC2025 strategy in 2015. It is an initiative that aims to modernize China's industrial capacity. Over a period of 10 years, this strategy is strongly focused on the intelligent development of the 10 strategic sectors. This strategy also contributes to improving China's position as a world power in high technology industries such as robotics, aviation and new energy vehicles such as electricity and biogas. This plan, based mainly on research and development, is seen as a key element of China's sustainable strategy for excellent growth and competitiveness in the future. It guarantees a transformation into a developed economy.

The plan aims to replace China's dependence on imported foreign technology with its own innovations. Therefore, the idea is to create Chinese companies capable of producing and innovating in several sectors and especially on a national and international scale. The focus is then on the local manufacturing process. China wants to increase

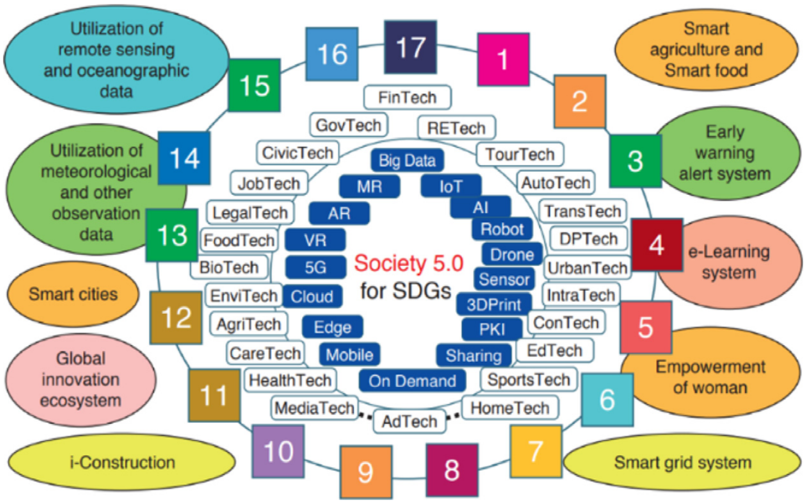

Fig. 2. Sustainable Development Goals.

its production, not in terms of essential components, but also in terms of the final product. This is ensured by investments oriented towards technological innovation and intelligent manufacturing in areas such as machine learning, where technology is difficult to replicate through reverse engineering. Intelligent manufacturing involves combining the internet with wireless sensors and robotics to improve efficiency, quality and productivity. Finally, it should be noted that China's strategy is inspired by the German "industry 4.0" initiative. It is broadly in line with the German and Japanese approaches to economic development and innovation (Fig. 3).

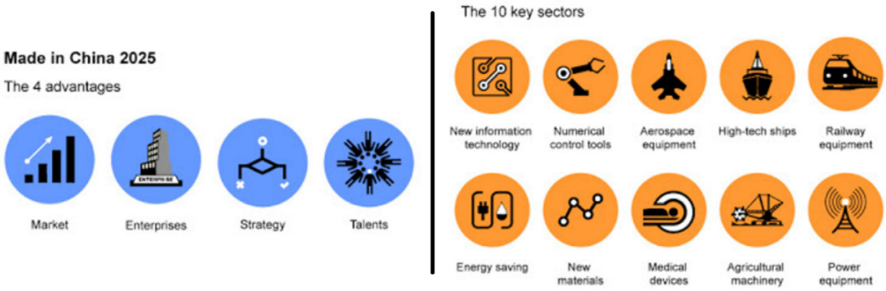

Fig. 3. Made in China 2025.

3. IoT and GIIoT

In the last few decades, technological developments in wireless communication systems have improved user needs in terms of accessibility, data quantity, intelligent decision making and energy consumption. These technologies are still evolving, thanks to the integration of new techniques to improve the connectivity of billions of objects. These connected objects, whether sensors or actuators, are by nature autonomous physical devices with a limited energy source. They are able to communicate with each other, creating a technological revolution. This revolution is bringing more ambitious innovations in a diverse range of applications: medicine, industry, energy, security and others.

For industrial applications, research is focused on creating connected, robotic and smart factories to improve current production systems. This interconnection of factories is achieved through the connected systems, in which employees, machines and products collaborate with each other to form the new revolution [16].

3.1. IoT

The concept of the IoT originated in the work done in 1999 by researchers at the Massachusetts Institute of Technology (MIT). The idea was put forward by Neil Gereshenfeld of the MIT Media Lab in his book "When Things Start to Think". The former director of the Auto-ID Center at the same institute, Kevin Ashton, is cited as the first person to use the term "Internet of Things" in the title of a presentation he gave to Procter & Gamble in 1999. The Internet of Things is then defined as "objects with identities and personalities operating in intelligent spaces using intelligent interfaces to connect and communicate in social, environmental and user contexts". Semantically, the IoT means "a uniquely addressable global network of interconnected objects based on standard communication protocols" [17]. The IoT focuses on the interconnection of various devices (small or large, smart or normal from an information processing perspective, mobile or fixed) together for a wide area network.

IoT is a new concept that is becoming increasingly popular in the field of wireless communications. The basic idea behind this paradigm is the ubiquitous presence of computing resources around us, which are able to interact and cooperate with each other, through unique identification schemes and agreed communication protocols, in order to perform certain common tasks together. The IoT is expected to have an even higher level of device heterogeneity than the current Internet. Devices such as ID tag readers, sensors, actuators, mobile phones, etc. should be "things" in the IoT ecosystem for better decision making through data storage and processing as well as distributed intelligence.

One of the thorniest issues in the IoT is the power consumption of devices, as we expect a large number of battery-powered devices to be connected to the IoT. Due to limitations such as small physical size, harsh environment and lack of human intervention, etc., it is important to make efficient use of available energy resources. Another issue is reliability. We do not want to require devices to be extremely reliable, because ensuring the reliability of individual devices can be very expensive. However, the reliability of a group of devices trying to perform a common task can be much higher than their individual reliability. To achieve this, IoT devices must be able to adapt to the failures of others and be able to self-configure [18,19].

The challenges of the IoT are related to the following themes:

– Communication and cooperation
– Addressability
– Identification
– Detection
– Actuation
– Integrated information processing
– Location
– User Interfaces

3.2. GIIoT

The smart grid is defined as a system of subsystems because of its complexity and heterogeneous infrastructure composed of various energy and communication technologies. However, the infrastructure of the smart grid is developed through the contribution of distributed power generation and energy control and optimization systems at any node of the grid. With the development of ICT applications, these nodes are very similar to the definition of the IoT ecosystem. The application of these elements in an energy management context allows the notion of the Internet of Green Devices to become a reality [20–25].

In this context, General Electric presents the Industrial Internet as a term meaning the integration of complex physical machines with networked sensors and software. The Industrial Internet brings together areas such as IoT, Big Data, machine learning and M2M (Machine to Machine) communication to collect and analyze machine data and use it to adjust operations [6,12,13] (Fig. 4.).

According to the IIC, the Industrial Internet connects intelligent devices and machines with people at work, enabling better decisions through advanced analysis that leads to transformational business outcomes. The Industrial Internet covers the non-consumer side of the IoT and applies "internet thinking" to industrial environments [26,27].

The Industrial Internet consists of three key elements that together represent the essence of the idea:

– Smart machines: this means connecting machines, fleets, facilities and networks around the world with advanced controls, sensors and software applications.

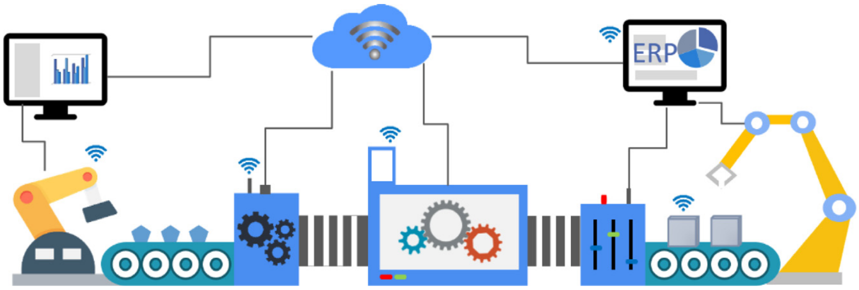

Fig. 4. Industrial Internet of Things Concept.

– Advanced analysis: means combining the power of physics-based analysis, domain expertise, automation and predictive algorithms to understand how machines and systems work.
– People at work: essentially means connecting people at all times to support smarter operations, design and maintenance, as well as high quality of service and safety.

The connection and combination of these three key elements allows companies and economies to benefit from many new opportunities and efficiency gains in several areas. The industrial internet will accelerate productivity growth in the same way that the industrial revolution and the internet revolution have done in the past.

4. Technologies, protocols and standardization

4.1. Short-range communication

4.1.1. IEEE 802.15.1

Bluetooth (IEEE 802.15.1) is a short-range wireless technology; invented by telecommunications provider Ericsson in 1994. It was originally designed as a wireless alternative to the RS-232 data cables known in the industrial sector. It promotes data management, low bandwidth and improved security. However, it has faced several challenges such as rapid battery discharge and frequent connection loss. In July 2010, the Bluetooth SIG announced the official adoption of version 4.0 of the Bluetooth Core standard with Bluetooth Low Power Technology. This version has eased some of the constraints of the classic Bluetooth version by offering an improved communication range, with latency times up to 15 times less than classic Bluetooth. However, both versions of Bluetooth do not offer support for mesh networking which has made the technology unable to provide an appropriate mechanism for multi-hop communication, not suitable for dense industrial networks [28].

4.1.2. IEEE 802.15.4/.4.E

The IEEE 802.15.4/4. E standard deals with wireless networks with low data and power. In this section, we will briefly discuss the best known and used protocols/standards, namely: Zigbee, Wireless Hart, ISA 100.11.a and 6LOWPAN. In addition, we will present a comparative table of the technical characteristics of each of these protocols (Table 1).

A. Zigbee

It is one of the most widely used standards with more than 70 million units installed worldwide. Zigbee is a trademark of Digi International, certified by the Zigbee Alliance in 2006 (IEEE 802.15.4 standard). It allows the creation of a network of objects. Zigbee is not designed to transmit a lot of data (250kbps max), but it does so with very little usage and in a reliable and secure way. In addition, ZigBee can be deployed in a mesh network, which allows it to have a high reliability and a greater coverage range. This is the reason why Zigbee is much more used in the industrial world.

B. Wireless Hart

Wireless Hart is the first standardized industrial (radio) network for industrial automation and process control applications, with more than 30 million HART devices installed worldwide. It is based on the HART communication protocol developed by the HART Communication Foundation. It adds wireless functionality to the HART

Table 1. Technical characteristics of short-range communication technologies.

	ISA100.11A	Wireless Hart	6LoWPAN	Zigbee
Frequency	2.4 Ghz	2.4 Ghz	868.915 Mhz / 2.4 Ghz	868.915 Mhz / 2.4 Ghz
Data throughput	250 Kbps	250 Kbps	250 Kbps	20/40/250 Kbps
Channels	–	10	1	16
Modulation	–	BPSK	BPSK	QPSK
Topology	Star – Mesh	Multiple	Multiple	Multiple
Access Shem	DSSS	DSSS	DSSS	DSSS & FHSS
Interoperability	No	No	No	No
Routing protocol	Redundant	Redundant	RPL	AODV
Autonomy	–	–	1–2 years	>10 years
Energy consumption	Low	Low	Medium	Low
Security	Yes	Yes	Yes	Yes
Authentication	–	–	–	AES CBS-MAC
Robustness	–	Yes	Yes	Yes (16-bit CRC)
Applications	Process automation	Industrial Process Control	IoT and industrial monitoring	Control and monitoring

protocol while maintaining compatibility with existing HART devices. The main features are reliability, robustness, security, energy efficiency and mesh networking. But it also lacks interoperability with other standards based on IEEE802.15.4 [29].

C. ISA100.11a

ISA100.11a targets monitoring, automation, and process control applications in industrial applications. ISA100.11a is developed by the ISA100 Standards Committee which is part of the ISA organization. ISA100.11a uses only the 2.4 GHz ISM band with frequency hopping to increase reliability and prevent interference from other wireless networks [30].

D. 6LoWPAN

6LoWPAN is a low-power wireless personal area network based on IPV6. It can read the connected objects if an IP address can be assigned to the actuators, controllers, devices and sensors. The approach of comparing different implementations of 6LoWPAN over WSN is based on wireless technology, which has become a primary means of communication for sensor networks [31].

4.2. Long-range communication

This category, as part of LPWANs is becoming more and more popular in the industrial and research communities due to: low power, long range and low cost. LPWAN technologies and standards can be subdivided into two categories: cellular LPWAN technologies most often mentioned and leaders are LTE-M and NB-IoT, and non-cellular technologies of which the most commonly used are: LoRa and SIGFOX. In this section, we will briefly present the most commonly used technologies and a comparative table (Table 2).

4.2.1. SIGFOX

Sigfox is a proprietary LPWAN technology, based on the narrowband modulation technique. This technology allows the use of BPSK modulation that is robust for long-range communications, and offers very low data rate transmission over very long-range communications in harsh environments. Each message has a width of 100 Hz, and a transfer rate of 100 or 600 bits per second, depending on the region. As a result, long distances can be achieved while being very robust against noise [32].

4.2.2. LoRaWAN

LoRaWAN is a standard for low-power networks sponsored by the LoRa Alliance. The LoRaWAN architecture is a “star of stars” structure of end devices connecting via gateways to connect to network servers. LoRaWAN is a low power WAN optimized for low power consumption is designed to support large networks with millions and thousands of devices. It features low cost, bi-directional communication, mobility and security for connected objects, machine-to-machine (M2M) communication [33].

Table 2. Technical characteristics of long-range communication technologies.

	Sigfox	LoRa	NB-IoT
Frequency	(868/915/433) Mhz	(868/915/433) Mhz	LTE
Bandwidth	192 Khz	250 and 125 Khz	200 Khz
Data throughput	100–600 bps	0.3–0.5 Kbps	200 Kbps
Max payload length	12 octets – 8 octets	243 octets	1600 octets
Range	10 Km (urban) 50 Km (rural)	5 Km (urban) 20 Km (rural)	1 Km (urban) 10 Km (rural)
Interference immunity	Very High	Very High	Low
Authentication and encryption	No	AES 128 b	LTE encryption
Localization	Yes (RSSI)	Yes	No
Topology	Star	Star on star	Cellular
Autonomy	>10 years	>10 years	>10 years
Security	Yes	Yes	Yes
QoS	No	–	Yes
Open source	Yes	Yes	No

4.2.3. NB-IoT

NB-IOT is based on narrow-band radio technology and standardized by the 3rd Generation Partnership Project (3GPP), and it is based on the LTE protocol. The NB-IoT communication protocol is based on the LTE protocol. In fact, NB-IoT reduces the functionality of the LTE protocol to a minimum and enhances it as required for IoT applications. NB-IoT will serve higher value IoT markets that are willing to pay for very low latency and high quality of service. NB-IoT is a new way to communicate with objects that require small amounts of data, over long periods of time, in hard-to-reach locations. It simply and efficiently connects devices to already established mobile networks and securely and reliably processes small amounts of relatively infrequent two-way data. It is also the most promising wireless cellular communication technology for 5G [34].

4.3. IoT communication protocols

IoT devices communicate via a communication protocol. Each protocol in the IoT system provides communication from one device to another, from a device to a gateway, from a gateway to the data center or from a gateway to the Cloud. Currently, all of these architectures use either cellular networks or IEEE 802.11 LAN protocols. This standard specifies the majority of media access control (MAC) and physical layer protocols (PHY) for the constitution of Wi-Fi computer communication in several 2.4 Ghz, 5 Ghz, 6 Ghz and 60 Ghz frequency bands. In this section, we present the most commonly used IoT protocols in several applications (Table 3). Table 4 presents a comparative study of all the protocols used for GIIoT applications and their perspectives.

Table 3. Technical characteristics of IoT communication protocols.

	MQTT	XMPP	AMQP	COAP	DDS
Architecture	Broker	Decentralized	Broker	Broker	BUS
Transport layer	TCP	TCP	TCP	UDP	TCP/UDP
Cooperation model	Pub-Sub Req/Resp	Pub-Sub Client–Server	Pub-Sub Client–Server	Client–Server	Pub-Sub
Form of data	Message	Data	Message	Data	Data
Open source	Yes	Yes	Yes	Yes	Yes
Header size	2 octets	–	8 octets	4 octets	–
Security	SSL/TLS	TLS/SSL	TLS/SSL	DTLS	TLS/SSL
QoS	3 level	–	3 level	Limited	Broad

4.3.1. MQTT

It is an open telemetry and monitoring protocol, whose main function is to publish information or subscribe to its reception, between several clients via a single server (called a broker). It was invented in 1999 by IBM

Table 4. Standardizations for GIIoT.

Standard	Region	Organizer	Perspective
Earth [35]	Europe	EU FP7 IP	Energy-efficient wireless communication
TREND [36]	Europe	EU FP7 IP	Energy-efficient networking
Green Net [37]	Europe	EU FP7 IP	Training of green communications
TSCGCC [38]	Global	IEEE	Energy-efficient computing standardization
Green Touch [39]	Global	Green Touch Consortium	Reduction of CO_2 footprint of ICT
Cool Silicon [40]	Europe	Silicon Saxony Management	Energy-efficient in the ICT
Celtic-Plus [41]	Europe	ICR industry partners	Smart connected World
GREEN-T [42]	Europe	CELTIC-PLUS	Energy-efficiency in heterogeneous wireless networks
Green IT [43]	Japan	METI&JEITA	Energy-efficiency of data centers, networks and displays
Go Energi [44]	Europe	Danish Energy Saving Trust	Energy-efficiency in households, commercial and industrial sector
Green Radio [45]	UK	MVCE	Green architectures
MQTT	Global	OASIS	Pub-Sub architecture
XMPP	Global	IETF	HTTP – Decentralized
AMQP	Global	OASIS	Message – PtP – Pub Sub
COAP	Global	IETF	REST architecture
DDS	Global	OMG	Distributed architecture
Green Grid [46]	Global	Global ICT	Energy-efficiency of data centers
6LoWPAN	Europe	IETF	IPv6 for low and devices
EPC global [47]	Europe	ETSI, CEN, ISO	RFID Technology
M2M [48]	Global	ITU-T/ETSI	M2M standardization
NFC	Global	ISO	Low-range communication protocols
Zigbee	Global	Zigbee Alliance	Zigbee standardization
Sigfox	Global	ETSI	M2M low bandwidth network
NB-IoT	Global	3GPP	LPWAN radio technology
LoRAWAN	Global	LoRa Alliance	Long-range communication protocols

researchers, and standardized in 2013 by OASIS. Among the characteristics of this protocol is its lightness, ease of implementation, flexibility and security, as well as its scalability, which allows it to handle thousands of concurrent connections via its messaging broker [49].

4.3.2. XMPP

It is an open protocol, based on the denatured client–server model without a broker. It is designed for near-real-time applications and thus effectively supports small, low-latency messages. The first Jabber/XMPP technologies were developed by Jeremie Miller in 1998, and standardized by the IETF. In the context of Green IIoT, XMPP may have some useful features such as scalability, flexibility and user-friendly device addressing [50].

4.3.3. AMQP

It is an open protocol, based on the "publish–subscribe" architecture. Developed by the JPMorgan ChaseIl bank, it has been designed with the following main characteristics as objectives: Security, Reliability, and Interoperability [51].

4.3.4. CoAP

It was created by the IETF group (Constrained RESTFul Environments Core) for IoT applications. CoAP is similar to HTTP in several ways, CoAP supports HTTP proxies, which means that clients can request resources from a CoAP server using regular HTTP requests. But it is not just a reduced or compressed version of the HTTP protocol. CoAP has new features specifically designed for limited environments that are not part of HTTP [52].

4.3.5. DDS

An API standard for data-centric connectivity was introduced in 2004 by the OMG. Its purpose is to address the data distribution challenges typical of defense and aerospace applications; based on a simple "publish–subscribe" communication paradigm, among its benefits is the support of system component integration, providing the low-latency data connectivity, extreme reliability and scalable architecture that mission-critical and business IoT applications require [53].

5. Challenges and opportunities

The evolution of automation and digitalization technologies makes the factory more intelligent. Therefore, the industry is modernizing by anticipating the needs of production. This industrial revolution is supported by new technology and new professions by which new industrial perspectives and services can open up. Therefore, the industry of the future has several advantages to make the whole value chain of a country evolve. In this respect, technological advances are converging in collaboration to support the success of the industry of the future. In this section, we will detail, on one hand, the key elements of the development of GIIoT, and on the other hand, some promising applications forming a connected industrial and societal ecosystem (Fig. 5.).

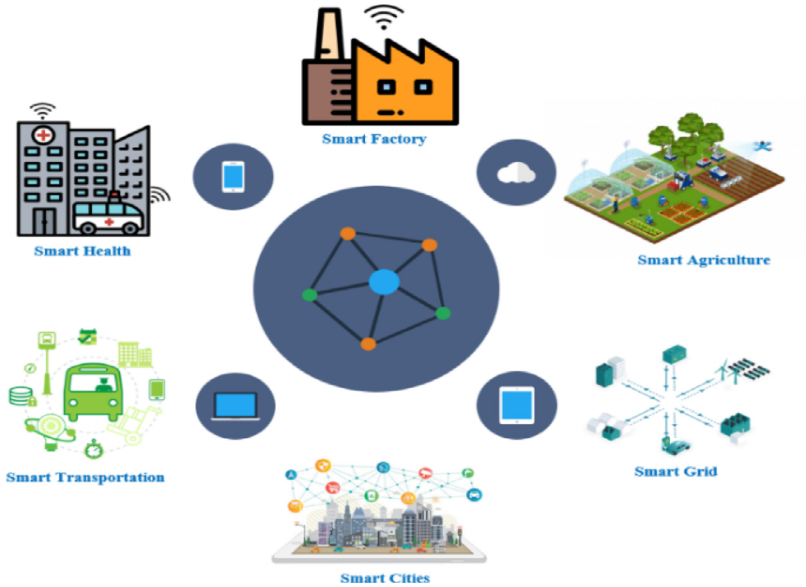

Fig. 5. GIIoT applications.

5.1. *Enabling technologies for Green IIoT*

5.1.1. *Artificial intelligence*

The concept of AI emerged as an answer to this problem in the early 1960s when experts discovered how to create algorithms based on rules and actions, because these algorithms lack the ability to learn. They examine some key parameters and make appropriate actions based on configurations pre-identified by humans. Between the 1970s and 1980s, experts improved the algorithms so that they could perform logical reasoning. In the early 1980s, scientists easily felt the limitations of the first generation of AI algorithms when faced with new situations that took into account the variability of real-world parameters, and instead of focusing on parameters and rules. They began to focus on statistical models and neural networks. One of the important projects that used the new AI paradigm is speech recognition, which uses many algorithms, including Hidden Markov and Gaussian mixing models [20,54].

Despite better performance than the previous wave of AI, these algorithms were not sufficient to reach the human level, adding the infrastructure and performance of computers that were not capable of computing such complex tasks. Currently, deep learning is breaking down these barriers by taking advantage of the high level of efficiency of today's computers and devices. Deep learning can be divided into three categories depending on how the architecture and techniques of deep learning are intended to be used.

Unsupervised learning is intended to be used when no target class is available, it is also called generative networks for its ability to classify learned characteristics into self-created classes, and it includes: Deep Belief Networks, Boltzmann machine, Deep encoder and others. Supervised learning, on the other hand, learns characteristics and classes in pre-established classes. They are also called discriminatory deep networks. And finally, the Deep Hybrid Networks which are nothing more than a combination of the above categories.

5.1.2. Cobot

The idea of the cobot or (collaborative robot) is the integration of robots into the manufacturing process in collaboration with employees. The cobot, its name comes from cooperation and robotics, working together with man in industry and it has no vocation to replace him. It is a category of autonomous robots dedicated to the management of objects in collaboration with a human operator, in the form of an automated process involved in cobotic relationships [55].

Generally, there are three categories of cobots: collaborative robots manipulated by a close collaborator (co-manipulation), robots manipulated remotely and systems assisting the human body in its effort in the form of electromechanical structures. In the same logic, these systems assist man in his work by providing safety, strength, precision, flexibility and comfort, without influencing his decision-making role.

5.1.3. Digital twin

In 2019, the American analyst firm Gartner ranked the Digital Twin as one of the strategic technology trends. The Digital Twin concept involves the development of multi-physical modeling of a complex system, taking into account the integration of real objects for real-time monitoring. Applications include production infrastructures (factory, railway network), machine tools, robotic systems as well as complex components [56].

In general, the digital twin encompasses different types of tools with development for different purposes. In the literature, there are three main types of digital twins namely:

– The virtual twin: this is a category of twin without coupling with reality namely: virtual factory or virtual machine. This type ensures the optimization upstream the development of a subassembly, and then the study of different scenarios of use.
– The coupled digital twin: this is a type of twin coupled with augmented reality to test the intervention of man on a machine or a part of complex nature. Therefore, it is a question of implementing a virtual sub-assembly and a virtual process.
– Coupling of digital twin and real twin: this type of digital twin is called "closed loop digital twins". It is a high-level digital twin, whose sensors at the real twin level ensure real-time transmission of information from the sensors to the digital twin capable of simulating the behavior and interacting back to the real twin for a change if necessary.

5.1.4. Green energy

The urbanization of the world has begun to attract the attention of researchers, particularly with regard to the issues related to it. By 2014, more than 54 per cent of the world's population lives in urban areas, and statistics estimate that this percentage will rise to 72 per cent by the 2050s. As a result, energy demand in all its forms is increasing proportionally. Therefore, countries with limited energy sources or importers of raw materials must be able to respond intelligently to these challenges. To this end, the emerging concept of smart cities is beginning to make sense [24,25].

The main concentration has been taken by the electricity sector, as the main consumer of energy sources in urban areas. This is prompting urban planners to reorient the city's intelligence towards smart energy cities. Electricity generation has undergone several changes over the decades, moving from decentralized to centralized energy and arriving at distributed energy with the integration of renewable generation. The application of renewable energy sources has been seen as an alternative option used by governments instead of modernizing traditional power plants. This is due to the availability of renewable energy sources and the advantages they represent, among others: profitability, inexhaustibility and reduction of greenhouse gas emissions.

5.1.5. Mobility

The emergence of Logistics 4.0 within the context of Industry 4.0, has enabled the optimization of the supply chain. This concept is based on the digitization of processes, building on the technological advances of Bigdata and the Internet of Things [57]. The benefits of Logistics 4.0 are an increase in the efficiency and speed of processes and a minimization of losses. In order to set up the promoter tracks for a better implementation of Logistics 4.0, there are 5 challenges to be taken up:

– Reducing production and delivery times.

– Intelligent logistics based on the automation of warehouse processes.
– Integrate an omni-channel strategy at the customer service level.
– Predicting customer needs through Bigdata.
– Manage product traceability remotely throughout the supply chain.

5.2. GIIoT applications

With the success of wireless technologies in consumer electronics in recent years, standard wireless technologies are being considered for deployment in industrial environments as well. Industrial applications involving mobile subsystems or simply the desire to save wiring make wireless technologies attractive. However, these applications are often subject to strict reliability and time requirements. In wired environments, synchronization and reliability are well ensured by fieldbus systems. When wireless links are included, the requirements for reliability and synchronization are much more difficult to meet due to the unfavorable properties of radio channels. In this section, we will present the most promising applications for the smart industry (Fig. 5.).

5.2.1. Smart factory

In the industrial sector, research work is focused on the creation of connected, robotic and intelligent factories to improve current production systems. This interconnection of factories is achieved through the connected systems. Employees, machines and products in these factories collaborate with each other to form the new revolution. At the heart of this revolution, GIIoT plays a key role in developing connectivity for this revolution [58,59]. GIIoT is based on the use of connected sensors or actuators to improve industrial processes and manufacturing. It integrates intelligence in data processing and analysis to ensure better M2M (Machine-to-Machine) communication. This has been in existence since the integration of electronics in the industrial sector during the third "industry 3.0" revolution. It is now necessary to work on robust communication architectures allowing objects in a noisy industrial environment to communicate easily in order to build reliable information for better decision making. In such an industrial environment, propagation differs from other conventional indoor means of communication through its large dimensions and the nature of the objects and obstacles [60,61].

5.2.2. Smart agriculture

The concept of Agriculture 4.0 or Agriculture of the Future is a new way of organizing all dimensions of the agricultural sector. It is an intelligent, high-tech, capital-intensive system that makes efficient use of land, water, air, energy and other natural resources using ICTs. This will ensure that everyone involved in agriculture and livestock (land, water, plants, and farm animals) receives exactly the data they need for better health and productivity [62,63].

This so-called intelligent agriculture uses, in particular, the green industrial IoT to collect the information. However, different sensors placed on equipment or in the field feed a massive storage platform, allowing the creation of a large database for professionals, farmers, advisors, researchers, etc.

This new way of farming can first of all provide decision-making tools: better understanding a situation and capitalizing on the behavior of crops or animals according to the seasons and the weather. It may also provide a better understanding of this sector, i.e. the state of maturity of a plot of land, the appearance of disease on plants, the state of health of an animal, etc. All this information saves the farmer time and simplifies decision-making based on objective data.

5.2.3. Smart grid

The level of electricity consumption in its intelligent context includes smart homes, industrial or public premises, and electric cars. In a smart grid a new notion of consumer–producer is beginning to take shape with the development of small-scale renewable domestic installations, especially for solar and wind sources. On the other hand, even consumers are involved in the control of the grid according to demand-side management. For this purpose, electrical loads are classified as static, controllable, thermal and storage loads for simpler modeling. At a higher level, all premises can be considered as loads, and their modeling and criticality degree depends on their role in the city; these load models can contain residential, official and industrial loads. Indeed, when official models are defined as critical loads belonging to the military or hospitals that require highly reliable micro-grids with less intermittent sources. Therefore, these loads involve certain considerations such as priority management in load sharing, high power quality and islanding control. The intermittent characteristics of renewable energy are tolerated by battery stores as a back-up model [64,65].

It should be noted that facilities located close to consumption sites reduce transmission line losses as a function of the distance between generation and consumption cycles. On the other hand, sensors that control air-conditioning and lighting, and smart meters that can be remotely controlled, help develop energy efficiency. However, recent research on electric vehicles has focused on the energy exchange of electric vehicles through the grid due to the development of the smart grid. The batteries of these vehicles are not only supposed to provide propulsion but are also considered as an energy storage device capable of feeding the grid in discharge mode.

5.2.4. Smart cities

A smart city is a city that uses new information and communication technologies to meet the challenge of improving a citizen's quality of life. This concept eventually participates in the development of the economic and tourist attractiveness of businesses and communities. These cities use connected objects to collect data in order to feedback information for the efficient management of resources. This large amount of data is collected from several sources forming several applications [66–68].

The processing and analysis of this data is used for the management and supervision of traffic, transportation, power plants, water supply networks, waste management, schools, hospitals and others. The major interest of this sensor network is the optimization of urban operations and services to make life easier for citizens.

5.2.5. Smart transportation

Electric vehicles are a new technology that lets the transportation sector use a diversity of primary energy power used. There are four types of electric vehicles, namely: BEV, HEV, PHEV, and FCEV.

BEV relies only on stored electricity, and their main components consist of a high-voltage battery, one or more electric motors and a controller to manage the power electronics. HEV is a combination of conventional combustion engine and battery. The battery is used to provide power for lower speeds; otherwise, the combustion engine will drive the car at higher speeds. PHEV has the same construction as HEV, except that the higher capacity batteries used to be charged with external connection. FCEV utilizes fuel cell technology to supply the motor by converting the hydrogen chemical energy to electric energy [69].

Plug-in Electric Vehicles (PEVs) are the most promising option to reduce emissions in the transportation sector. Otherwise, the integration of the charging option to these vehicles in a smart grid framework offers even greater potential for emission mitigation. The charging of the vehicles from grid is often referred to grid to vehicle (G2V), however the use of battery pack for energy storage with the 'smart grid' also has potential for vehicle to grid (V2G).

5.2.6. Smart health

Industrial Green IoT makes a significant contribution in the health sector. According to recent studies, the Internet of Things in the healthcare market is expected to grow from $41.22 billion in 2017 to $158.07 billion in 2022, with a CAGR of 30.8% [70–72]. Its main objective is to ensure patient safety, but also to improve the way doctors carry out their work to achieve predictive medicine. And has many applications: from remote monitoring; For example, for patients with chronic diseases who may find themselves in an emergency situation, there are dedicated services based on the emerging eHealth paradigm that provide patients with a special device containing the "panic button" (or a common mobile phone with a special application installed) that the patient must use in case of emergency.

6. Conclusion

Several countries around the world have begun to face major challenges regarding both the production and consumption of electrical energy. In addition, the significant presence of the universal constraint of global warming makes their current electricity networks unable to cope with the situation. Indeed, almost a total of 32840 Mt of CO2 is emitted worldwide. This quantity of CO2 is constantly increasing, especially with the increase in the use of fossil fuels. The urbanization of the world has begun to attract attention, particularly with regard to the related confrontations. In 2014, more than 54% of the world's population will live in urban areas, and statistics estimate that this percentage will rise to 72% by the 2050s.

New technologies such as artificial intelligence, connected objects, autonomous robots and Bigdata can provide the means and tools for intelligent decision-making to improve energy and industrial processes, strengthen a country's industry and improve the quality of life of its society. The integration of these new technologies in various services has accelerated the implementation of several innovative industrial models. This wave of revolution was initiated by the German government and consists of the integration of new technology into industrial sectors, known as Industry 4.0. Other models have emerged after this initiative: the Japanese model known as Society 5.0 and the Chinese model called Made in China 2025. Currently, all the revolutions have been able to offer solutions to improve industrial needs and processes on the one hand, and on the other hand, to improve the living conditions of citizens and facilitate access to several services.

The IoT seems to be the key element of the success of this current revolution. It is a tool for digital transformation of several sectors including energy and industry. In this paper, we have presented a review of the literature concerning the evolution of wireless communication technologies, with the aim of developing the GIIoT. We also presented the catalysts with which the IoT collaborates for better decision making. We also discussed the concrete applications of the implementation of GIIoT, as well as their impact on the development of the industry of the future.

CRediT authorship contribution statement

Mohamed Tabaa: Writing - original draft. **Fabrice Monteiro:** Supervision, Validation. **Hassna Bensag:** Writing - review & editing. **Abbas Dandache:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] LU Yang. Industry 4.0: A survey on technologies applications and open research issues. J Ind Inf Integr 2017;6:1–10.
[2] LASI Heiner, FETTKE Peter, KEMPER Hans-Georg, et al. Industry 4.0. Bus Inf Syst Eng 2014;6(4):239–42.
[3] FUKUDA Kayano. Science technology and innovation ecosystem transformation toward society 5.0. Int J Prod Econ 2020;220:107460.
[4] BALI SWAIN Ranjula et, YANG-WALLENTIN Fan. Achieving sustainable development goals: predicaments and strategies. Int J Sustain Dev World Ecol 2020;27(2):96–106.
[5] SHAIKH Faisal Karim, ZEADALLY Sherali, et EXPOSITO Ernesto. Enabling technologies for green internet of things. IEEE Syst J 2015;11(2):983–94.
[6] ZHU Chunsheng, LEUNG Victor CM, SHU Lei, et al. Green internet of things for smart world. IEEE Access 2015;3:2151–62.
[7] ZHANG Chaofeng, DONG Mianxiong, et OTA Kaoru. Enabling computational intelligence for green internet of things: Data-driven adaptation in LPWA networking. IEEE Comput Intell Mag 2020;15(1):32–43.
[8] Sisinni E, Saifullah A, Han S, Jennehag U, Gidlund M. Industrial internet of things: Challenges, opportunities, and directions. IEEE Trans Ind Inf 2018;14(11):4724–34.
[9] Younan M, Houssein EH, Elhoseny M, Ali AA. Challenges and recommended technologies for the industrial internet of things: A comprehensive review. Measurement 2020;151:107198.
[10] Salimova T, Guskova N, Krakovskaya I, Sirota E. From industry 4.0 to Society 5.0: Challenges for sustainable competitiveness of Russian industry. In: IOP conference series: materials science and engineering, vol. 497. (1):IOP Publishing; 2019, 012090, March.
[11] GLASER Bonnie S. Made in china 2025 and the future of american industry. Center for Strategic International Studies; 2019.
[12] Borawake-Satao R, Prasad R. Green internet of things schemes and techniques for adaptive energy saving in emergency services. In: Internet of things, smart computing and technology: A roadmap ahead. Cham: Springer; 2020, p. 173–88.
[13] Huang J, Meng Y, Gong X, Liu Y, Duan Q. A novel deployment scheme for green internet of things. IEEE Internet Things J 2014;1(2):196–205.
[14] SAADAOUI Safa, TABAA Mohamed, MONTEIRO Fabrice, et al. Discrete wavelet packet transform-based industrial digital wireless communication systems. Information 2019;10(3):104.
[15] Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J. Six transformations to achieve the sustainable development goals. Nat Sustain 2019;2(9):805–14.
[16] Korodi A, Crisan R, Nicolae A, Silea I. Industrial internet of things and fog computing to reduce energy consumption in drinking water facilities. Processes 2020;8(3):282.
[17] Avishay D, Pavlov V, Pavlova G, Petrov B, Dimitrov N. Industry 4.0–robots with distributed mobility and elements of artifical intelligence. Glob J Comput Sci Technol 2019.
[18] Zhu C, Rodrigues JJ, Leung VC, Shu L, Yang LT. Trust-based communication for the industrial internet of things. IEEE Commun Mag 2018;56(2):16–22.
[19] Padrah Z, Pop C, Jecan E, Pastrav A, Palade T, Ratiu O, Puschita E. An ISA100. 11a model implementation for accurate industrial WSN simulation in ns-3. In: 2020 International workshop on antenna technology. iWAT, IEEE; 2020, p. 1–4, February.
[20] NARCISO Diogo AC, et MARTINS FG. Application of machine learning tools for energy efficiency in industry: A review. Energy Rep 2020;6:1181–99.

[21] Moreno Escobar JJ, Morales Matamoros O, Lina Reyes I, Tejeida-Padilla R, Chanona Hernández L, Posadas Durán JPF. Energy-efficient industrial internet of things software-defined network by means of the peano fractal. Sensors 2020;20(10):2855.
[22] Mukta MY, Rahman MA, Asyhari AT, Bhuiyan MZA. IoT For energy efficient green highway lighting systems: Challenges and issues. J Netw Comput Appl 2020;158:102575.
[23] Saleem Y, Crespi N, Rehmani MH, Copeland R. Internet of things-aided smart grid: technologies, architectures, applications, prototypes, and future research directions. IEEE Access 2019;7:62962–3003.
[24] Chakir A, Tabaa M, Moutaouakkil F, Medromi H, Julien-Salame M, Dandache A, Alami K. Optimal energy management for a grid connected PV-battery system. Energy Rep 2020;6:218–31.
[25] Fentis A, Bahatti L, Tabaa M, Mestari M. Short-term nonlinear autoregressive photovoltaic power forecasting using statistical learning approaches and in-situ observations. Int J Energy Environ Eng 2019;10(2):189–206.
[26] RAYHANA Rakiba, XIAO Gaozhi, et LIU Zheng. Internet of things empowered smart greenhouse. IEEE J Radio Freq Identif 2020.
[27] DHARFIZI Awang Dzul Hashriq. The energy sector and the internet of things–sustainable consumption and enhanced security through industrial revolution 4.0. J Int Stud 2020;14:99–117.
[28] https://www.bluetooth.com/.
[29] Deji Chen, Nixon M. A. wirelessHART Mok. "Real-time mesh network for industrial automation". 2010.
[30] https://www.isa.org/isa100/.
[31] VERMA Abhishek, et RANGA Virender. Security of RPL based 6LoWPAN networks in the internet of things: A review. IEEE Sens J 2020;20(11):5666–90.
[32] https://www.sigfox.com/en.
[33] https://lora-alliance.org/.
[34] https://www.3gpp.org/news-events/1785-nb_iot_complete.
[35] EARTH. 2014, https://www.ictearth.eu/, [Accessed 20 Feb 2014], [Online], Available.
[36] TREND. 2014, [Accessed 20 Feb 2014], [Online], Available: http://www.fp7-trend.eu/.
[37] GreenNet. 2014, [Accessed 2 Jan. 2014], [Online]. Available: http://www.fp7-greenet.eu.
[38] Green Comm. & Comp, [Online]. Available: http://www.comsoc.org/about/committees/emerging#gcc.
[39] Greentouch. 2014, [Accessed 20 Feb 2014]. [Online]. Available: http://www.greentouch.org/.
[40] Cool silicon. 2014, [Accessed 1 Oct. 2014]. [Online]. Available: http://www.coolsilicon.de/.
[41] Celtic-plus. 2014, [Accessed 1 Dec. 2014], [Online]. Available: http://www.celticplus.eu.
[42] GREEN-T. 2014, [Accessed 28 Feb 2014], https://greent.av.it.pt.
[43] Green IT initiatives in Japan. 2014, [Accessed 28 Feb. 2014]. [Online]. Available https://www.meti.go.jp/english/policy/.
[44] Go' energi. 2012, [Accessed 12 Dec. 2012]. [Online]. Available: http://www.savingtrust.dk.
[45] Green radio. 2013, [Accessed 2 Feb. 2013]. [Online]. Available: http://www.mobilevce.com/green-radio.
[46] The green grid. 2012, [Accessed 28 Dec. 2012]. [Online]. Available: http://www.thegreengrid.org.
[47] EPCglobal. 2012, [Accessed 2 Feb. 2012], [Online]. Available: http://www.gs1.org/epcglobal.
[48] ETSI M2M standardization. 2014, [Accessed 4 Mar. 2014], [Online].Available: http://www.etsi.org/technologies-clusters/technologies/m2m.
[49] http://mqtt.org/.
[50] http://xmpp.org/.
[51] https://www.amqp.org/.
[52] https://coap.technology.
[53] https://www.dds-foundation.org/.
[54] Kaouter K, Mohamed T, Sofiene D, Abbas D, Fouad M. Full training convolutional neural network for ECG signals classification. In: AIP conference proceedings, vol. 2190. (1):AIP Publishing LLC; 2019, 020055, December.
[55] EL ZAATARI Shirine, MAREI Mohamed, LI Weidong, et al. Cobot programming for collaborative industrial tasks: An overview. Robot Auton Syst 2019;116:162–80.
[56] Tao F, Cheng J, Qi Q, Zhang M, Zhang H, Sui F. Digital twin-driven product design, manufacturing and service with big data. Int J Adv Manufact Technol 2018;94(9–12):3563–76.
[57] RUOHOMAA Heikki J, et SALMINEN Vesa K. Mobility as a service in smart cities-new concept for smart mobility in industry 4.0 framework. In: ISPIM conference proceedings. The International Society for Professional Innovation Management (ISPIM; 2019, p. 1–12.
[58] Tabaa M, Chouri B, Saadaoui S, Alami K. Industrial communication based on modbus and node-RED. Proc Comput Sci 2018;130:583–8.
[59] RHOLAM Oussama, TABAA Mohamed, et al. Smart device for multi-band industrial IoT communications. Proc Comput Sci 2019;155:660–5.
[60] Büchi G, Cugno M, Castagnoli R. Smart factory performance and industry 4.0. Technol Forecast Soc Change 2020;150:119790.
[61] OSTERRIEDER Philipp, BUDDE Lukas, et FRIEDLI Thomas. The smart factory as a key construct of industry 4.0: A systematic literature review. Int J Prod Econ 2020;221:107476.
[62] BU Fanyu et, WANG Xin. A smart agriculture IoT system based on deep reinforcement learning. Future Gener Comput Syst 2019;99:500–7.
[63] SALAM Abdul et, SHAH Syed. Internet of things in smart agriculture: Enabling technologies. In: 2019 IEEE 5th world forum on internet of things. WF-IoT, IEEE; 2019, p. 692–5.
[64] Dileep G. A survey on smart grid technologies and applications. Renew Energy 2020;146:2589–625.
[65] Al-Turjman F, Abujubbeh M. IoT-enabled smart grid via SM: An overview. Future Gener Comput Syst 2019;96:579–90.

[66] Ismagilova E, Hughes L, Dwivedi YK, Raman KR. Smart cities: Advances in research—An information systems perspective. Int J Inf Manage 2019;47:88–100.

[67] ZANTALIS Fotios, KOULOURAS Grigorios, KARABETSOS Sotiris, et al. A review of machine learning and IoT in smart transportation. Fut Internet 2019;11(4):94.

[68] YAN Jianghui, LIU Jinping, et TSENG Fang-Mei. An evaluation system based on the self-organizing system framework of smart cities: A case study of smart transportation systems in China. Technol Forecast Soc Change 2020;153:119371.

[69] RUOHOMAA Heikki J, et SALMINEN Vesa K. Mobility as a service in smart cities-new concept for smart mobility in Industry 4.0 framework. In: ISPIM Conference Proceedings. The International Society for Professional Innovation Management (ISPIM); 2019, p. 1–12.

[70] Karboub K, Tabaa M, Dellagi S, Dandache A, Moutaouakkil F. Intelligent patient monitoring for arrhythmia and congestive failure patients using internet of things and convolutional neural network. In: 2019 31st International conference on microelectronics. ICM, IEEE; 2019, p. 292–5, December.

[71] HOSSAIN M, Shamim et MUHAMMAD Ghulam. Cloud-assisted industrial internet of things (iiot)–enabled framework for health monitoring. Comput Netw 2016;101:192–202.

[72] A centralized cluster-based hierarchical approach for green communication in a smart healthcare system. IEEE Access 2020.

Further reading

[1] The ZigBee alliance. 2014, https://zigbeealliance.org/fr/, [Accessed 2 Mar. 2014], [Online].