Industrial Internet of Things (IIOT)

Over the last 10 years, the IoT has become a familiar topic in the mass media. This is because the IoT is more than just a new technology that impacts a restricted range of people or a specific market. It can be better understood as a set of technologies that impacts us all, and will change markets, even creating new ones. The IoT is changing our lives, feelings, and perceptions of the physical world daily, by modifying how we interact with it. The development of the IoT is a crucial moment in the history of humanity because it is changing our mindset, culture, and the way we live. Just like the internet age, we will have a pre-IoT phase and a post-IoT phase. The IoT era will be not an instantaneous transition, but a gradual and continuous shift during which the evolution never stops. The key idea behind the IoT concept is to deploy billions or even trillions of smart objects capable of sensing the surrounding environment, transmit and process acquired data, and then feedback to the environment.

After the advent of the steam engine in 1760, steam was used to power everything from agriculture to textile manufacturing. This caused the First Industrial Revolution and the age of mechanical production. At the end of the 19th century came the arrival of electricity, new modes of labor organization, and mass production, which started the Second Industrial Revolution. In the second half of the 20th century, the development of semiconductors and the introduction of electronic controllers produced the beginning of the automation era and The Third Industrial Revolution. In the Hannover exhibition of 2011, Henning Kagermann, Wolf-Dieter Lukas, and Wolfgang Wahlster coined the term Industry 4.0 for the project of renewing the German manufacturing system using the capabilities of the latest digital Technology.

Industry 4.0 is expected to be able to do the following:

- Connect or merge production with information and communication technology Merge customer data with machine data
- Harness the capability of machines communicating with machines
- Manage production autonomously in a flexible, efficient, and resource-saving manner

The IoT is used for further development of the manufacturing industry by including technologies such as big data analytics, the cloud, robotics, and most importantly, the integration and convergence between IT and OT (Operational Technology)

The term I-IoT refers to the industrial subset of the IoT as shown in Fig. 1. The IIoT, like the IoT, is not just a specific new technology, but instead refers to the whole chain of value of a product. Similarly, the IIoT impacts all sectors of the industrial world by significantly modifying the processes at each stage of the life cycle of a product, including how it is designed, made, delivered, sold, and maintained. The IIoT is expected to generate so much business value and have such a deep impact on human society that it is leading the Fourth Industrial Revolution.

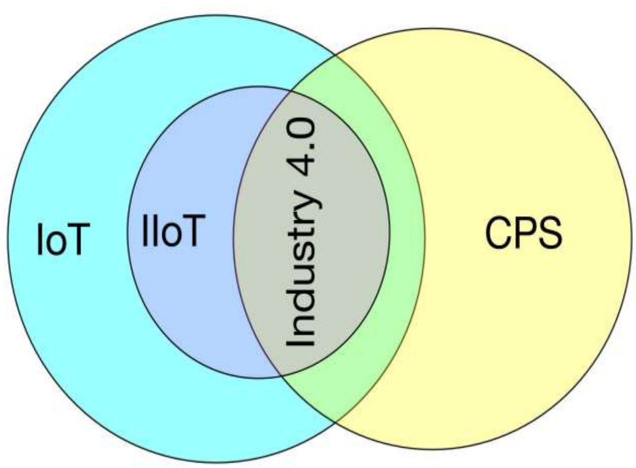


Fig. 1. IoT, CPS, IIoT, and Industry 4.0 in Venn diagram.

The Industrial Internet of Things (Industrial IoT) is made up of a multitude of devices connected by communication software. The resulting systems, and even the individual devices that comprise it, can monitor,

collect, exchange, analyze, and instantly act on information to change their behavior or their environment intelligently – all without human intervention. Industrial IoT (IIoT) covers the domains of machine-to-machine (M2M) and industrial communication technologies with automation applications. IIoT paves the way for better understanding of the manufacturing process, thereby enabling efficient and sustainable production.
It can also defined as "Industrial IoT (IIoT) is the network of intelligent and highly connected industrial components that are deployed to achieve high production rate with reduced operational costs through real-time monitoring, efficient management and controlling of industrial processes, assets and operational time"
The main objective of IIoT is to achieve high operational productivity, expanded efficiency, and superior management of industrial resources and forms through item customization, brilliantly checking applications for generation floor shops and machine well-being, and predictive and preventive support of industrial hardware.

Differences and Similarities between IoT and IIoT :

IoT, IIoT, and Industry 4.0 are closely related concepts but cannot be interchangeably. There are many similarities between the IoT and the I-IoT. The I-IoT, however, is strictly related to industry and so it has some specific features, as highlighted in the following list: Cyber security is a critical topic for any digital solution, but its implementation in the industrial world requires special attention. This is because the OT systems and devices in industry have a much longer life cycle and are often based on legacy chips, processors, and operating systems that are not designed to be connected over the internet. This means they live in an isolated LAN, protected by a firewall from the external world. It is critical to ensure that industrial digital devices stay running; any temporary disruption can imply a large economic loss.
IIoT solutions must co-exist in an environment with a significant amount of legacy operation technologies. They must also co-exist with different devices acting as data sources, including SCADA, PLCs, DCS, various protocols and datasets, and the back-office enterprise resource planning (ERP) systems as well. Industrial networks are specialized and deterministic networks, supporting tens of thousands of controllers, robots, and machinery. IIoT solutions deployed into these networks must, therefore, scale tens of thousands of sensors, devices, and controllers seamlessly. Physical objects in the industrial world are more complex and have a wider range of typologies when compared to the consumer world. In the industrial world, robustness, resilience, and availability are key factors. Usability and user experience, however, are not as relevant as they are in the consumer world. . What is usually addressed as IoT, could be better named as consumer IoT. Consumer IoT is human centered; the "things" are smart consumer electronic devices interconnected with each other in order to improve human awareness of the surrounding environment, saving time and money. In general, consumer IoT communications can be classified as machine-to-user and in the form of client–server interactions. A comparison between IOT and IIOT is given in Table-1.

TABLE I
COMPARISON BETWEEN CONSUMER IOT AND IIOT

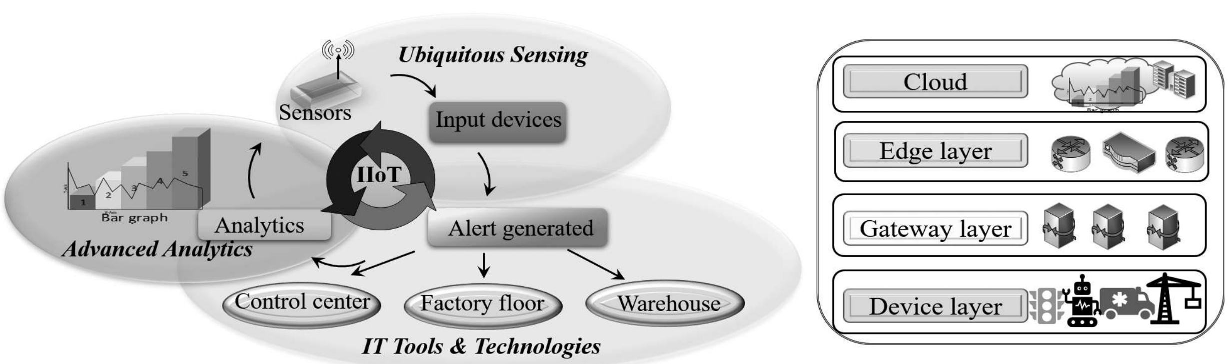
	Consumer IoT	Industrial IoT
Impact	Revolution	Evolution
Service Model	Human-centered	Machine-oriented
Current Status	New devices and standards	Existing devices and standards
Connectivity	Ad-Hoc (infrastructure is not tolerated; nodes can be mobile)	Structured (nodes are fixed; centralized network management)
Criticality	Not stringent (excluding medical applications)	Mission critical (timing, reliability, security, privacy)
Data Volume	Medium to High	High to Very High

Comparison between IIoT and traditional automation.

Features	IIoT	Traditional automation
Real-time communication	M2M communication is possible with minimum latency (dynamic). Better access and usage of the sensor nodes data.	Initially started with relay logic, with ladders and rungs. The development of Programmable Logic Controller (PLC) was a quantum leap in this direction, which replaced the relays and rungs.
Data model	Point-to-point data model	Broadcast-subscriber model
Data usage	The received data are translated into actionable information to improve operations, receive feedback, and execute accordingly.	To improve the operations, data are not directly translated.
Visualization	In order to optimize the entire production process, it can be visualized in a better transparent way.	Visualization of the entire production chain is semi-transparent.

IIoT Architecture:

The design of an IIoT architecture needs to highlight extensibility, scalability, modularity, and interoperability among heterogeneous devices using different technologies. IIoT architecture is described as a three-layered infrastructure consisting of – device, gateway, and platform/middleware layer as shown in Fig. 2. The device layer comprises heterogeneous type of smart sensor nodes which are deployed at various machines and devices. The sensor nodes sense and transmit data to the middleware layer through the gateway devices present at the gateway layer. After that, the gateway devices connect to the higher layers through infrastructures such as Wi-Fi and LAN, for further processing. The edge layer and cloud together form the middleware layer and satisfy the requirements of analysis, storage, and processes data. For example, GE Predix, Siemens Mind-Sphere, and Honeywell are some of the industrial cloud platform providers. On the other hand, C3IoT, Uptake, and Meshify are some of the software development firms. Further, DTS, Honeywell, Omega, Bosch, and Adafruit are certain sensor manufacturers. Some actuator technology manufacturers are Eckart, SKF, Fuyu, Knr, and Sirius.



Industrial Internet of Things Architecture

Opportunity of IIoT:

A key reason for adopting IIoT by manufacturers, utility companies, agriculture producers, and healthcare providers is to increase productivity and efficiency through smart and remote management.

Examples:

1. Thames Water, the largest provider of drinking and waste water services in the U.K., is using sensors, and real-time data acquisition and analytics to anticipate equipment failures and provide fast response to critical situations, such as leaks or adverse weather events. The utility firm has already installed more than 100 000 smart meters in London, and it aims to cover all customers with smart meters by 2030. With more than 4200 leaks detected on customer pipes so far, this program has already saved an estimated 930 000 L of water per day across London.
2. As another example, the deployment of 800 HART devices for real-time process management at Mitsubishi chemical plant in Kashima, Japan, has been increasing the production performance by saving US$20–30 000 per day that also averted a $3-million shutdown
3. Precision agriculture powered by IIoT can help farmers to better measure agricultural variables, such as soil nutrients, fertilizer used, seeds planted, soil water, and temperature of stored produce, allowing to monitor down to the square foot through a dense sensor deployment, thereby almost doubling the productivity
4. IIoT can also significantly impact the healthcare field. In hospitals, human or technological errors caused by false alarms, slow response, and inaccurate information are still a major reason of preventable death and patient suffering. By connecting distributed medical devices using IIoT technologies, hospitals can significantly overcome such limitations, thereby improving patient safety and experiences, and more efficiently using the resources
5. IIoT also provides opportunities to enhance efficiency, safety, and working conditions for workers. For example, using unmanned aerial vehicles allows inspecting oil pipelines, monitoring food safety using sensors, and minimizing workers' exposure to noise and hazardous gases or chemicals in industrial environments. Schlumberger, for example, is now monitoring subsea conditions using unmanned marine vehicles, which can travel across oceans collecting data for up to a year without fuel or crew, moving under power generated from wave energy.
6. Through remote monitoring and sensing powered by IIoT, mining industries can dramatically decrease safety-related incidents, while making mining in harsh locations more economical and productive. For example, Rio Tinto, a leading mining company, intends its automated operations in Australia to preview a more efficient future for all of its mines to reduce the need for human miners.

Challenges of IIoT:

Despite the great promise, there are many challenges in realizing the opportunities offered by IIoT

- Energy Efficiency: Many IIoT applications need to run for years on batteries. This calls for the design of low-power sensors, which do not need battery replacement over their lifetimes. This creates a demand for energy-efficient designs. To complement such designs, upper layer approaches can play important roles through energy-efficient operation
- Real-Time Performance: IIoT devices are typically deployed in noisy environments for supporting mission- and safety-critical applications, and have stringent timing and reliability requirements on timely collection of environmental data and proper delivery of control decisions. The QoS offered by IIoT is thus often measured by how well it satisfies the end-to-end (e2e) deadlines of the realtime sensing and control tasks executed in the system
- Coexistence and Interoperability: With the rapid growth of IIoT connectivity, there will be many coexisting devices deployed in close proximity in the limited spectrum. This brings forth the imminent challenge of coexistence in the crowded Industrial, Scientific and Medical (ISM) bands. Thus, interference between devices must be handled to keep them operational. Existing and near-future IIoT devices will most likely have limited memory and intelligence to combat interference or keep it to a minimum. While there exists much work on wireless coexistence considering WiFi,

IEEE802.15.4 networks, and Bluetooth (see surveys [88]– [91]), they will not work well for IIoT. Due to their dense and large-scale deployments, these devices can be subject to an unprecedented number of interferers. Technology-specific features of each IIoT technology may introduce additional challenges.

- Security and Privacy: Besides the requirements of energy efficiency and real-time performance, security is another critical concern in IIoT. In general, IIoT is a resource-constrained communication network which largely relies on low-bandwidth channels for communication among lightweight devices regarding CPU, memory, and energy consumption. For this reason, traditional protection mechanisms are not sufficient to secure the complex IIoT systems, such as secure protocols [103], lightweight cryptography and privacy assurance. The privacy in IIoT is the threefold guarantee for: 1) awareness of privacy risks imposed by things and services; 2) individual control over the collection and processing of information; and 3) awareness and control of subsequent use and dissemination to any outside entity. The major challenges for privacy lie in two aspects: data collection process and data anonymization process.

The IIoT system allows the industry to collect and analyze a great amount of data that can be used, monetized, and improve the overall performance of the systems for providing new types of services.

Reference:

1. Misra, Sudip, Chandana Roy, and Anandarup Mukherjee. Introduction to industrial internet of things and industry 4.0. CRC Press, 2021.
2. E. Sisinni, A. Saifullah, S. Han, U. Jennehag and M. Gidlund, "Industrial Internet of Things: Challenges, Opportunities, and Directions," in IEEE Transactions on Industrial Informatics, vol. 14, no. 11, pp. 4724-4734, Nov. 2018, doi: 10.1109/TII.2018.2852491.