Chapter 2
Industrial Internet of Things (IIoT): Principles, Processes and Protocols

Somayya Madakam and Takahiro Uchiya

Abstract The Industrial Internet of Things (IIoT) is a paradigm shift, primarily in the domain of manufacturing industry. The concept is highly attractive for a majority of the industrial sectors due to better operational efficiency capabilities in the production process, smart objects identification mechanisms by embeddedness technologies, intelligent automation abilities and around the clock monitoring abilities. Importantly, it reduces workforce intervention in risky industrial environments. Some of the best practicing places and activities for the IIoT employment are factory shop floors, materials handling, assembly lines, production processes, finalising goods, and other inbound and outbound logistical tasks. The basis for the IIoT phenomenon growth is the Internet of Things (IoT) technologies, which have currently been ensuring efficient work execution in many spheres, industrial as well as commercial and social. This chapter provides a discussion on IIoT concepts and definitions, on business drivers behind the growth of this technology, and the evolution process of this phenomenon. This contribution also discusses the fundamental underlying principles, related technologies, deployment approaches in different areas and associated frameworks. The chapter also explore Japanese Industry-specific case studies, where the industries have already been employing the IIoT-related practices. These include Zenitaka Corporation, Tsuchiya-Gousei, Toyota and Hitachi. This book chapter provides a broader overview in crystal clear and sets the background for the rest of the chapters in this book.

Keywords Industrial internet of things · IIoT · Internet of things · IoT · Industry 4.0 · Smart factory · Operational efficiency · M2M · Japan

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2.1 Introduction

Technologies play an important role in our day-to-day life, as well as for business, government agencies and industries such as entertainment, tourism, aviation, transportation, healthcare and manufacturing, especially from 1960 onwards. Most of the Industrial Internet of Things (IIoT) technologies are helping in many ways in terms of identifications of objects, monitoring events, automation and monitoring of risky processes and environments, and in general, making available the services for people around the clock and securing people and things from anthropogenic and natural calamities. Under the realm of the IIoT technologies, the IIoT, also known as 'Industry 4.0' (or I4.0) is now seen in the context of industrial transformation across the globe. Smart manufacturing is the dramatically intensified and pervasive application of networked information-based technologies; so are the supply chain and logistics enterprises [1].

The current fourth industrial revolution (Industry 4.0) is gradually manifesting itself in all global industrial firms. It is based on the Internet of Things paradigm and service-oriented concepts relating to manufacturing and other industrial sectors, which has led to vertically and horizontally integrated production systems [2]. The underlying understanding is that smart machines with embedded IoT technologies are better than manually operated processes at correctly capturing, analysing, storing and communication of data from/to the other interconnected objects in real time and around the clock. This phenomenon is gradually taking hold in all industry sectors including oil and gas, energy production, coal mining, chemical plants, manufacturing units, pharmaceutical companies, logistics processes, shipping handling and aviation business, etc.

Manufacturers and industrialists in every sector have a significant opportunity at hand, to not only monitor but also automate many of the complex processes involved in their industries. While there have been systems that can track the progress of manufacturing and production, the Industrial IoT provides far more intricate control to the managers. Under the umbrella of IIoT, many technologies are getting embedded in the factory machines, materials and methods, including machine learning, artificial intelligence (AI), machine-to-machine (M2M) communication, distributed computing, cloud computing, edge computing and data analytics. Hence, the IIoT technology is an amalgamation of different technologies like machine learning, big data, sensor data, M2M communication and automation, which have existed in the industrial backdrop for many years.

A typical IIoT system consists of intelligent systems like software applications, microcontrollers, sensors and system security mechanisms. Government policies on Industry 4.0, Smart Factories, Make In India, Make In China 2025, Smart Cities and Japan's Industrial Value Chain Initiative Forum along with enlightened support for green initiatives, rising energy and crude oil prices, favourable FDI, regulatory bodies, etc. have propelled the IIoT evolution to its current favourable state.

With this background, this book chapter aims to discuss, in some detail, the IIoT principles, processes and protocols.

The next sections discuss in detail the concepts of Industrial Internet of Things and the evolution in automation. In addition, this book chapter explores certain IIoT-based test cases in Japan.

2.2 Industrial Internet of Things (IIoT)

The Industrial Internet of Things, or IIoT, is the use of IoT technologies to enhance manufacturing and industrial processes. The IIoT (also known as the Industrial Internet, Industry 4.0 and Smart Factory) incorporates machine learning, deep learning and big data technologies to harness the sensor data, machine-to-machine (M2M) communication and automation technologies that have existed in industrial settings for several years. This concept includes all the physical materials of the factories, with the aim to enhance the operational efficiency of processes.

In recent years, there have been great advances in the IIoT and related domains, such as industrial wireless networks (IWNs), big data, and cloud/fog computing, etc. These emerging technologies bring greater opportunities for promoting industrial upgrades and allowing the introduction of the fourth industrial revolution, namely, Industry 4.0 [3]. Industrial Internet helps to develop connected enterprises by merging the information and operational sectors of the industry. This improves visibility, boosts operational efficiency, increases productivity and reduces the complexity of process in the industry. Hence, the Industrial IoT helps with transformative manufacturing and production strategies that further help to improve quality, productivity and safety of the workforce. For instance, a machine can give advance notification to the owners or operators about an imminent breakdown or onset of an unacceptable environment (e.g., temperature rising beyond a critical limit). In other scenarios, smart glasses can allow field technicians to work hands-free while remote supervisors walk them through solutions. Intelligent factory floors can be connected to a cloud platform to obtain the status of raw material progress in real time. Such examples reflect how a manufacturing unit can be transformed with the aid of IIoT.

A typical IIoT system consists of intelligent system applications, micro controllers, wireless sensors, and smart security mechanisms, plus fully connected high speed data communication infrastructure including cloud computing and edge computing provision, etc. Moreover, data analytics are used to support business intelligence and corporate decision-making processes, not to forget the most critical human element aspect. The benefits that Industrial Internet of Things (IIoT) promises include enhanced safety, better reliability, smart metering, inventory management, equipment tracking and smart facilities.

A research study by Genpact [4] concludes that almost 81% of global organisations believe that successful adoption of Industrial Internet of Things is critical to future success—even more so for high-tech and large enterprises. It is well recognised that this latest wave of technological change will bring unprecedented opportunities, along with new risks, to business organisations and the society at large. It will combine the global reach of the Internet with a new ability to directly control the physical world, including the machines, factories and infrastructure that define the modern industrial landscape.

However, like the Internet was in the late 1990s, the Industrial Internet is currently in its early stages. Many important questions remain unanswered, including how it will impact existing value chains, business models, workforces, and what business actions and government leaders need to take now to ensure long-term success. While the IoT affects among other sections such as transportation, healthcare and smart homes, IIoT refers in particular to industrial processes and environments [4].

2.3 The Driving Factors

Today, the manufacturing and production environment for Industry 4.0 is mostly characterised by fast-changing processes, short development periods, abrupt technological evolutions and a growing necessity for individual demand and customised products. Consequently, significant changes are occurring in firms, not only for the physical plants but also for future technological manufacturing skills and competencies required for driving Industry 4.0 forward [5]. Industrial and IP-enabled low-power wireless networking technologies are emerging, resulting in the further advancement of IIoT [6]. In general, the growth of the IoT is making an emphatic impact on homes and industries.

While the IoT influences transportation, healthcare and smart homes, the IIoT refers in particular to industrial environments. IIoT is a new industrial ecosystem that combines intelligent and autonomous machines, advanced predictive analytics, and machine–human collaboration to improve productivity, efficiency and reliability. It is bringing about a world where smart, connected embedded systems and products operate as part of larger systems. The IIoT is already revolutionising manufacturing by enabling the acquisition and accessibility of far greater amounts of data, at far greater speeds, and far more efficiently than before. Some innovative companies have started to implement IIoT by leveraging intelligent and connected devices in their factories. The prime driving forces of IIoT across the globe can be considered and discussed as follows:

- The driving philosophy behind Industrial Internet of Things is that smart machines are better than humans at accurately and consistently capturing and communicating real-time data. This data enables companies to pick up on inefficiencies and problems much sooner, and thus saving time and money and supporting business intelligence efforts.
- Technology of smart sensors, robotics and automation, augmented/virtual reality, big data analytics, cloud integration, software applications, mobile, low-power hardware devices and scalability of IPv6-3.4x 10^38 IP address, etc. are also the major drivers for the industrial internet.

- The edge that IIoT gives to enterprises over their competitors helps them achieve better customer satisfaction and retention through value addition that IIoT inherently provides.
- Government policies on Industry 4.0, Smart Factories, Make In India, Smart Cities, Make In China 2025, and Japan's Industrial Value Chain Initiative Forum, supporting the green initiatives, rising energy and crude oil prices, and favourable FDI, etc. are all helping to fuel the IIoT evolution.

Thus, there are several factors that contribute to the growing global popularity for Industrial Internet of Things practices. Clearly, IIoT is not limited to one particular country or a particular industry type, as it is popularised across healthcare, pharmaceutical, transportation, R&D, aviation, mining and many more sectors.

2.4 Evolution of IIoT

The IIoT may be considered as the twenty-first century's industrial revolution, hence the term 'Industry 4.0'. Phenomenally, Industry 4.0 is rapidly changing firms' management, organisational systems and competencies, even if they are becoming more complex than in the past [5]. However, the IIoT phenomenon is growing fast. Indeed, the advent of IIoT-related technologies can be traced to the steam engines and moving to mass production, and electronics embeddedness in the manufacturing process, and then to the popularity of the Internet. It is indeed a long journey for today's Industrial IoT since the Industry 1.0 of 1776. The following lists present a brief summary of the development of the IIoT paradigm.

- **Industry 1.0 (1784**)—This was the first phase of industrialisation. However, the invention of steam engines kick-started the Industry 1.0 phase. The manufacturing was purely labour-oriented and tiresome at this stage.
- **Industry 2.0 (1870)**—The first assembly line production was introduced during this phase of evolution. This stage was a big relief for the workers as their labour was reduced to some extent. Henry Ford introduced the assembly line to automate processes in car manufacturing, and elsewhere as well, to improve the productivity using conveyor belt mechanism.
- **Industry 3.0 (1969)**—The third phase of the industrial revolution started in around 1969. It involved the advancement of electronic technology and industrial robotics. Miniaturisation of electronic circuit boards through programmable logic controllers and development of industrial robotics simplified, automated and increased the production. However, in Industry 3.0, the operations remained isolated and independent within the entire enterprise.
- **Industry 4.0 (2010)**—This evolution started around 2010, but gained popularity only from around 2016. The vision of connected enterprise through the interconnection of industrial assets through the Internet was fulfilled with the introduction of Industry 4.0. The interconnected smart devices communicate with each other, and cloud paradigm and data analytics created valuable business insights. IIoT

brought the advantages of asset optimisation, production integration, smart monitoring, remote diagnosis, intelligent decision-making and most importantly, the predictive and autonomous maintenance. Industry 4.0 thus presented a paradigm shift from automated manufacturing towards intelligent manufacturing. Unlike the previous industrial revolutions, the current fourth revolution aims to be more decentralised, automated and controlled via interdependence [9].

In November 2016, the International Society of Automation (ISA), Process Control and Safety Forum (PCS) in Houston Texas, and ISA's Communication division convened a panel to focus and discuss on the Industrial Internet of Things. In the panel, experienced industrial and control engineers shared their views, concerns and reservations with IIoT [7], in spite of the fact that the Industry 4.0 offers enormous and radically new market approach and segmentation [8]. Their deliberations and recommendations helped move the IIoT agenda further.

2.5 IoT Applications in the Industry

The Industrial IoT phenomenon is a magic wand for any national economy. The IIoT covers many industrial applications. It yields plenty of opportunities in automation, manufacturing, transportation, pharmaceutical, mining and chemical industry, just to name a few. Potgieter [10] states that the IIoT ecosystem comprises data generating equipment like sensors, actuators and gateways, which sit atop platforms that integrate and feed the required data to applications through dashboards or other reports, where decisions are made and controlled at the central server [10]. Another study by Dujovne et al. [6] reported that the industrial and IP-enabled low-power wireless networking technologies have converged, resulting in today's IIoT [11]. A number of industry-wide applications are now discussed in the following subsections.

2.5.1 Manufacturing

Manufacturing has the largest IIoT market. It is a major industry, from the perspective of IoT depending on software, hardware, network connectivity and services. Manufacturing is among the industrial sectors that is directly impacted by the disruption from the Industrial IoT. A smart production unit may consist of a large interconnected industrial system of materials, parts, machines, tools, inventory and logistics that can relay data and communicate with each other. IIoT connectivity drives the convergence of operational technology like robots, conveyor belts, smart metres and generators. In the manufacturing sector, intelligent sensors, distributed control and secure software are the crucial elements. Forward-thinking manufacturers connect their products to IIoT. They will position themselves as future leaders, while those that fail to act will risk being left behind. In manufacturing specifically, IIoT holds great potential for quality control, sustainable and green practices, supply chain traceability and overall supply chain efficiency. In an industrial setting, IIoT is key to processes such as predictive maintenance (PdM), enhanced field service, energy management and asset tracking. The IIoT can be regarded as an industrial machine connected to the enterprise cloud storage area for data storage as well as data retrieval and processing [12].

2.5.2 Transportation

The Industrial IoT includes a network of smart power, manufacturing, medical and transportation [13]. The transportation domain represents the second largest IIoT market from the perspective of expenditure on IoT applications. Today's transportation infrastructure is stressed to the breaking point. Many cities have begun smart transportation initiatives to optimise their public transportation routes, create safer roads, reduce infrastructure costs and alleviate traffic congestion. Especially, the airlines, rail companies and public transit agencies can aggregate enormous quantities of data to optimise operations. Smart cards, online reservations and in-vehicle Google mapping are some of the industry-specific applications to transportation. IIoT may be considered an amalgamation of 'Intelligent Enterprises' and 'Intelligent Machines' to manage the vehicular machines such as cars and trucks [14].

2.5.3 Energy and Utilities

Increasing cost and demand for energy have led many organisations to find smarter ways for monitoring, controlling and saving energy [15]. Hence, the oil and gas, smart grid and other related developments in the energy and utilities sector also forms a central part of the IIoT vision. According to the data from International Data Corporation (IDC), utilities represent the third most attractive industry, on the basis of expenditure in IoT, having reached a total of $69 billion in 2016. One area of investment that emerges as especially important is the smart grids for electricity and gas, which accounted for a huge $57.8 billion in 2016. Many industries are attempting to use better and smarter sensor-based management systems with the help of the Industrial IoT vision.

2.5.4 Healthcare

IoT provides new opportunities to improve healthcare systems. Having been powered by the IoT's ubiquitous identification, sensing and communication capacities, all objects in the healthcare systems including people, equipment, medicine, etc.

can be tracked and monitored constantly. Enabled by its global connectivity, all the healthcare-related information in logistics, diagnosis, therapy, recovery, medication, management, finance and even daily activities can be collected, managed and shared efficiently. For example, a patient's heart rate data can be collected by sensors at frequent intervals and then sent to the healthcare practitioners, e.g. doctors. By using personal computing devices like a laptop, mobile phone, tablet, and computer internet access, the IoT-based healthcare services can be mobilised and personalised to provide better care. The widespread mobile Internet service has expedited the development of IoT-powered in-home healthcare services. However, security and privacy concerns are two major challenges.

Health IIoT is a combination of communication technologies, interconnected apps, smart objects and people that would function together as one smart system to monitor, track and store patients' healthcare information for ongoing care [16]. Several healthcare-related IIoT applications are expected to widely utilise the evolving 5G communication technology. This 5G-inspired Industrial Internet of Things paradigm in healthcare enables users to interact with various types of sensors via secure Wireless Medical Sensor Networks [17].

2.6 IIoT Use Cases in Japanese Industry

Japan is well-known for her industries, firms and manufacturing units across Asia as well as the globe. Some of the big organisations that embraced the IIoT paradigm include: Toyota Motors, The LollipopRoad, Mitsubishi UFJ Financial, Luxatic, Sumitomo Mitsui Financial, The Business Times, Nippon Telegraph & Tel, Wiki-media Commons, Honda Motors, Sakura, Softbank, technobuffalo, Mizuho Financial, Japan Times and Nissan Motors.

Interestingly, Japan is a very small country in terms of geographical area with a low population; however, it is a fabulous manufacturing hub for automobile, banking, telecom, media, technological, service sector, agricultural and much else. Their culture and customs are unique from the rest of the world.

Recently, the Japan government has made concentrated attempts to promote research and development in the three key research areas: IoT, big data analytics and AI. Refer to the white paper 2018 [18] developed by the Japan Ministry of Internal Affairs and Communication. It suggests that, in order to realise productivity improvement and rich secure living in Japanese society amid the fierce competition in the era of IoT, BDA and AI, the technology Strategy Committee, Information Communication Technology Subcommittee of Information and Communications Council has already compiled the third interim report in July 2017. The report points to the Next Generation AI Commercialisation Strategy and the Next Generation AI with ICT Adaptability Strategy to ensure commercialisation for utilisation of super mass data that will further enhance the commercialisation. In order to study medium to long-term technology strategies for technological problems and promotion of technology development and commercialisation towards solution of future social challenges (including the ageing society and vitalisation of local communities), the review meeting to study ICT technology strategies has already been held since December 2017.

Riding the wave of IoT research, Japanese companies are doing very well in terms of Industrial IoT products, services and manufacturing practices across their industries as well as exporting their IIoT products and services to the rest of the globe. In the Japanese industry, utilisation of IoT is spreading along with IoT for individuals as well as businesses. IoT for industry brings many contributions such as improvement of company productivity, improvement in the quality of manufactured goods and reduction in labour costs. Specific fields of application include agriculture, construction, tourism, transportation, healthcare and many others.

Internet of Things has provided a promising opportunity to build powerful industrial systems and applications by leveraging the growing ubiquity of Radio Frequecny Identification (RFID), wireless, mobile and sensor devices. A wide range of industrial IoT applications have been developed and deployed in recent years as reported in [19]. As an activity group to promote IoT for industries in Japan, the Smart IoT Promotion Forum was established in 2015, and more than 2400 organisations such as Sony Corporation, Toyota Motor Corporation and Japan Microsoft Corporation joined them. In Europe, Japan and Korea, governments are playing an important role in IoT planning and deployment [20].

In this section, we discuss some of the Japanese companies who have successfully embraced the IIoT vision.

2.6.1 Smart Agricultural Crop Management—UPR Corporation

Crops produced in a vinyl greenhouse during winter are sensitive to cold temperatures and may undergo quality denaturation if the temperature fluctuates. To avoid such catastrophic losses, Japanese company, UPR Corp., developed an Internet of Things system [21] that facilitates temperature control and management. With this system, when unacceptable variation is detected in the temperature in an agricultural house (such as disconnection of the power supply to a remote system, thermostat actuation or shutdown of agricultural boiler), a mail message is transmitted to a supervisor's smartphone. Introduction of this system has reduced agricultural crop management costs and promoted realisation of an efficient temperature management.

2.6.2 Smart Agricultural Water Management—Vegetalia Inc.

Agriculture is considered to be 'climate-smart' when it contributes to increasing food security, adaptation and mitigation in a sustainable way [22].Hence, Vegetalia Inc. is now providing water management support for paddy rice via a system called ‘PaddyWatch’ [23]. It is a monitoring system capable of determining CO_2, soil temperature and other parameters at the farm fields. This system can confirm crop conditions and notify a supervisor by a smartphone or a tablet without mandating a visit to the farm field. Growing conditions of crops can also be confirmed at a remote location through analysis of parameter data (such as environmental data, cultivation and meteorological data) obtained using sensors of various kinds, and boosted by processing using artificial intelligence. By remote control, workers preferentially patrol an area where crops have not grown as expected—this ensures efficient operation and a reduction of production costs.

Checking of water levels in the paddy fields in real time contributes to great reduction in the patrolling hours. In addition, proper water management prevents a reduction in quality due to high-temperature heat generation, thereby exerting considerable influence on yield and crop quality. With systems such as this, smart agriculture is slowly gaining attention across the globe.

2.6.3 Industrial Production—Tsuchiya-Gousei Limited

The main business of Japanese company, Tsuchiya-Gousei Co. Ltd., is plastic moulding of parts for automobiles and clocks as well as stationery items such as ballpoint pens. A large variety of goods need to be produced efficiently. Therefore, production lines are often operated 24 h a day, every day. However, the availability of workers during the night-time and on holidays can become a serious issue for the management; the consequent trouble-shooting imposes a heavy burden on the management. Tsuchiya then introduced a relevant Internet of Things system [24]. With this system, the operational activities/schedules of all moulding machines (e.g. time for moulding, operating time, etc.) can be determined. Cameras connected to the network are distributed in the factory and office. The status of a moulding machine that becomes issue of concern can be examined via a smartphone or similar smart device. Using the system mentioned above, confirmation of emergency situations and operating systems can be confirmed promptly, even during night-time. The resultant increase in efficiency is impressive [24].

2.6.4 Industrial Production Management—Hitachi Limited

IIoT also focuses on safety–critical industrial applications [25]. In terms of production management, a digital twin type solution ‘IoT Compass’ [26] is provided at a production site, supplied by Hitachi. This solution was applied in advance at an automobile manufacturing factory in 2017.

The IoT Compass facilitates the resolution of difficulties, involving more than one process, providing cause analysis at locations where possible defects may occur, and improving the order production, taking into account the constrained conditions. This system is constructed based on the idea of a digital twin. This concept reproduces events in the physical world relating to the factory in a real-time manner, using digital equipment. Using this concept, a simulation space is constructed representing a factory where actual production is conducted and from where products are shipped. Data scattered in the factory are also linked. Such data are displayed with a treasure map function. This function allows digital data to be used with ease; additionally, it enables all production jobs to be optimised for enhanced effectiveness.

2.6.5 Industrial Printing—New Mind Co. Ltd.

Edible ink printers are manufactured and sold by New Mind Co. Ltd. Such devices can print fully coloured information on foods such as cookies and rice crackers, and thus, used on food production lines. To date, no means were available to ascertain how their foods are used after they were sold to customers. Given that edible printers are related to food manufacturing, considerations related to hygiene aspects are also required. Therefore, the remaining amount of ink and status of use need to be often checked. Accordingly, proper support should be provided to customers. To resolve any related issues, New Mind Co. developed a framework to handle edible ink printers using Internet of Things in collaboration with another company known as Infocorpus Inc. [27]. Now, the remaining amount of ink and its status can be monitored from a remote location. It is also feasible to provide appropriate verification of the cause of issue of a product at the customer's premises. Customer support is now fulfilled by the timely provision of advice and supplies such as ink based on use status of customers' edible ink printers.

2.6.6 Construction Electricity Saving—Zenitaka Corporation

The Zenitaka Corporation (in Japan) was founded in April 1931. The company provides general contracting services in Japan as well as internationally. As a part of power saving, e.g. at a work site in a tunnel, electrical equipment such as large machines, tunnel illumination, ventilation fans for dust removal and for prevention of reduction in oxygen concentration and of temperature rise are operated day and night. In this case, consumption of massive amounts of electrical power becomes an important issue. Another concern is ascertaining the precise position of every worker in the tunnel to enhance hazard prevention. To resolve these issues, an IoT-based system called 'Tunnel Eye' [28] was developed. Using this, the site status can be known and monitored using various instruments and RFID tags. In this way, the electrical equipment can be controlled automatically based on the information received.

This system was introduced on a trial basis in 2016 in the Shido Tunnel of the Takamatsu Expressway. Results demonstrate that power consumption was reduced by 20% compared to the conventional level, while still securing worker safety in the tunnel. Results confirmed the practical utility of resolving problems occurring at construction sites in mountain tunnels.

Regarding the safety aspects, even if an emergency state such as occurrence of fire or rock fall happens, the whereabouts of the workers can be easily traced from their work activity history.

2.6.7 Garbage Collection Related Solutions—KDDI Corporation

The KDDI Corporation is a Japanese telecommunications operator formed through the merger of DDI Corp. (Daini-Denden Inc.), KDD (Kokusai Denshin Denwa) Corp. and IDO Corp in October 2000.

KDDI Corp. (Designing the Future) developed an IoT system [29] for the resolution of garbage collection related issues on Kokusai street in Naha City and Okinawa. The garbage bins have an embedded mechanism such that garbage could be collected before overflowing. A distance sensor, a temperature sensor, RaspberryPi and an LTE-M communication module are provided to the IoT-based garbage bin. The amount of garbage accumulated is measured by the distance sensors, with correction done by using a temperature sensor and RaspberryPi. The obtained data are sent to the server to monitor when the garbage bin might overflow. When the garbage in the bin exceeds 80% of the available space, the person in charge of collection will receive a notification. At the garbage bin monitoring centre, the bin status can be checked by colour and by numerical figures from the data received.

A verification test of this system was performed in September 2017. The constructed ‘Overflow prevention garbage bin’ was placed on Kokusai street. Use of the technology was tested and verified on site under actual environmental conditions to assess the quality of communications between relevant sensors to ascertain its feasibility, validity and practical realisation. Results demonstrated that garbage bin information and position information of the collection team were known in the real. The resultant sightseeing solutions to garbage collection system, designed by KDDI Corp., were highly encouraging.

2.6.8 Inspection of Products—Yamato System Development Corporation

The logistics outsourcing division of Yamato System Development (in Japan) spent many labour hours and much time on the inspection of catalogs, brochures, manuals and package inserts of pharmaceutical products, without product identification information such as barcodes. It has been pursuing efficiency improvements for sometime. Previously, several experienced operators equipped with ‘eye for inspection’ checked products manually during final inspection before shipment, performing read-throughs twice, sometimes thrice. Eventually, a shipping instruction and a slip were attached with a string for shipment.

Yamato System has now introduced an IoT system [30] to improve the efficiency of these previously manually executed procedures. With the IoT-based new system, each item is identified by verifying an image of a product captured by a camera mounted on the working bench with image information of the item registered in advance. At the same time, object weight is measured by a weight scale mounted on the working bench, which verifies the weight information of goods registered in advance. Using the system, the company estimates that it is possible to reduce the number of workers by 20%; and monetary costs and time also by around 20% [30].

2.6.9 Logistics Management of Machinery—Toyota Motors Limited

Toyota Motors Ltd. had about 2700 machine tools and 2000 industrial machines. So, they introduced a ‘Factory IoT’ system [31] aimed at strengthening the businesses logistics solution through a unification of an IoT forklift database, having the integrated management of forklifts working at several hubs in the world and realisation of services involving predictive maintenance. Using this system, the time band of forklift operations, battery efficiency and other important information are determined and displayed. Using this information, customers can work out improvement plans to be carried out at various sites—plans such as effective utilisation of forklifts, reallocation of machinery and personnel at the sites. Result was an impressive improvement in logistics management activity.

2.6.10 Medical Care—Tokyo Women’s Medical University

At the Tokyo Women’s Medical University, a smart dispensary [32] collects medical information and presents and displays it as ‘Time-series medical treatment record’ to allow medical doctors, and engineers outside the operating room, to share information, thereby helping to contribute to the improvement in efficiency of treatment and safety. Information collected by this system can be analysed employing big data analytics. It is beneficial for maintenance and management aspects such as prevention of operational mistakes, early detection of equipment malfunction and cost management. Besides, remote operations based on data collected by other medical doctors can also be made possible by it.

2.7 Literature Analysis

Over the recent years, many informed discussions have taken place during business meetings, conferences, doctoral colloquiums and symposiums on Industry 4.0. An enormous volume of information is available in the form of research articles, book chapters, books, corporate whitepapers, audios, videos and blogs on the use of the IoT paradigm. However, the published academic literature is predominantly valued for its empirical evidence, rather than numerical, for this highly attractive phenomenon.

The use of Scopus and Google Scholar, in addition to Web of Science, helps to reveal a more accurate and comprehensive picture of the scholarly impact of contributions [33]. As per author's own investigation, by the end of 2018, there were 3045 results on smart factories, IIoT or Industry 4.0 from the Web of Science database. Out of these, journal papers are 1167, conference proceedings 1786, review papers 83, editorial material 46 and one book review. Moreover, every country is encouraging new academic manufacturing process literature, as is clear from country-wise analysis. Largest number of papers from various countries (Fig. 2.1) is as follows:

- People of Republic of China (307)
- United States of America (192)
- Germany (124)
- South Korea (102)
- Italy (81)
- England (77)
- Spain (68)
- India (48)
- Sweden (48)
- Taiwan (47)
- France (40)

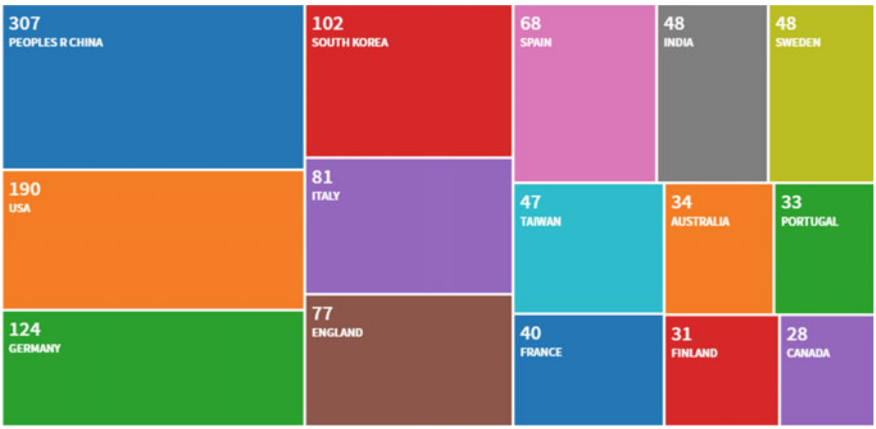

Fig. 2.1 IIoT countrywide publications—analysis chart

- Australia (34)
- Portugal (33)
- Finland (31)
- Canada (28).

This analysis has been represented in Figs. 2.1 and 2.2. Figure 2.1 depicts the contributions of authors on the IIoT phenomenon based on the aforementioned database. It clearly shows that the authors from China were engaged to research and rigorously publish. The chart given given as Fig. 2.2 showcases the 15 most active authors in this domain. This has been generated from the 'Web of Science' database analysis report.

Apart from the Web of Science academic and research database on IIoT, we have also drawn patent analysis using the 'Relecura' tool [34, 35]. From the analysis, we found that, since the inception of IIoT, there has been a tremendous growth in terms of patents. This is illustrated in Figs. 2.3 and 2.4.

Figure 2.3 represents the patent analysis with respect to various subject areas, e.g. security, power supply, automatic transmission, etc. Among the patents, the blue colour (in Fig. 2.4) refers to the total filed patents since 1988 while green colour indicates the total number of published patents over a while. The yellow coloured line represents the number of patents grants by the authorities. Sky blue coloured line represents expired patents. The graph analysis shows that from 2014 onwards, the Smart Factory concept captured the market due to its research & development and promotional activities.

Fig. 2.2 IIoT—authors-wise publications—Top 15

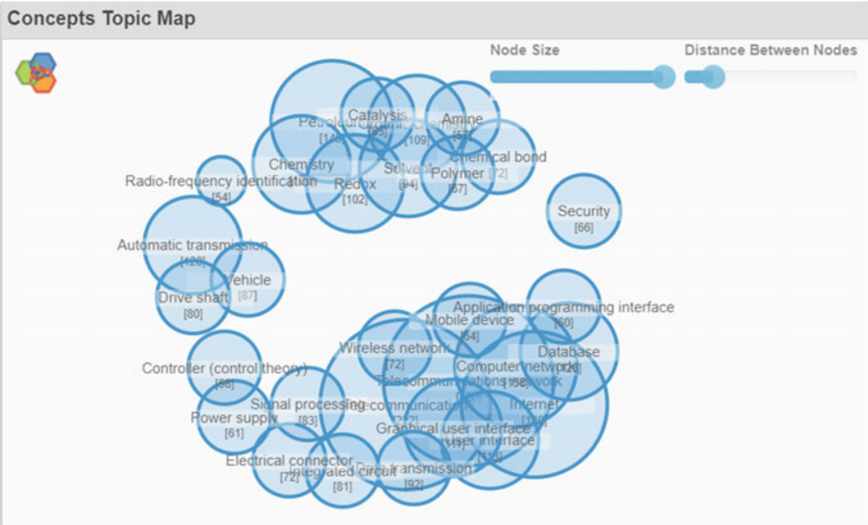

Fig. 2.3 Relecura patent analysis—subject-wise data analysis

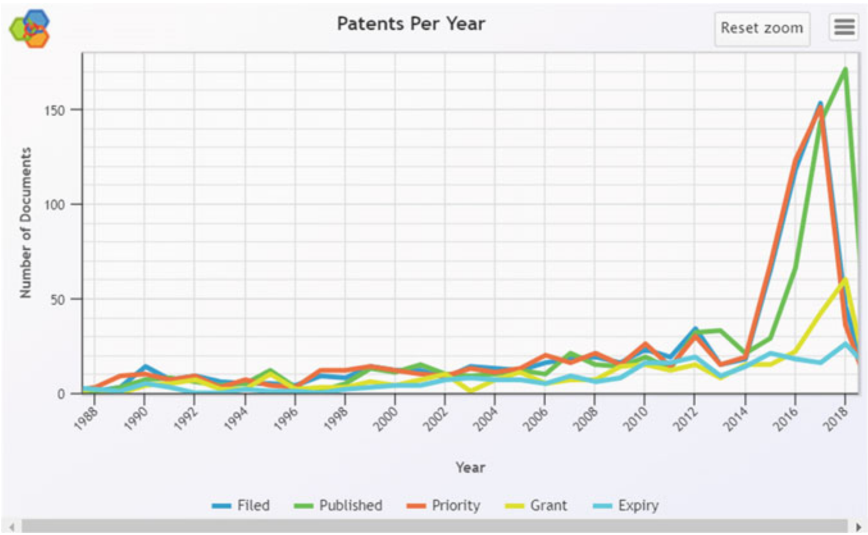

Fig. 2.4 Relecura patent analysis: year-wise data analysis

2.8 Methodology

This chapter aims to address the global audience including academicians, researchers, business people, industrial engineering students, mechanical engineering graduates, and manufacturing management professionals, who are looking for in-depth knowledge of the IIoT paradigm and its usage. The fundamentals were observed from different research manuscripts, blogs, corporate white papers, and subject videos. The major databases considered were Scopus, Google Scholar and Thomson Reuters [36]. The main keywords used to search were Industrial Internet of Things, Industry 4.0, smart factory, Industrial Internet, IIoT, and Digital factory.

The book chapter was authored in collaboration with an esteemed Indian-Japan academicians. This collaboration has led to the article exploring the fundamentals of Industrial IoT and illustrating a few novel test cases from Japan.

Almost 7–8 months were taken to compose this book chapter with detailed technical discussions on subject interoperability helping to shape it. The collected data is secondary and qualitative, and the manuscript has been composed and narrated thematically. Hence, the main themes discussed here are Industrial Internet of Things evolution, definitions, applications and test cases from across the globe, though mainly from the industry in Japan.

2.9 Conclusion

Technologies play an important role in our day-to-day activities as well as for business and industry. Similarly, the new dawn of Industry 4.0 or Industrial Internet of Things (IIoT) is aiming to embed technology into all the various industrial processes and machinery for automation and operational efficiency.

The IIoT paradigm is widely considered to be one of the primary trends affecting industrial businesses today and in the future. Industries are pushing to modernise systems and equipment to meet new regulations, to keep up with increasing market speed and volatility, and to deal with disruptive technologies like the IoT. Businesses that have embraced the IIoT have seen significant improvements towards safety, efficiency, and profitability.

It is expected that this trend will continue as IoT technologies are more widely adopted. Indeed, the IoT Technologies are serving as bases for this paradigm shift, for example, robotics, sensors, actuators, controllers, RFID, and other electronic computational devices to tag the material, methods, and people in the factories. Various algorithms are at work behind this phenomenon which were developed in C, C++, C#, Java, R, Python etc., using AI and machine leaning processes.

The IIoT brings new growth opportunities to many companies. However, there are technical challenges and important hurdles to overcome, as well, particularly in relation to device connectivity, security of networks, and international standards. Still, global standard institutes like IEEE, ITU, ISO and ANSI are working towards technological standards and especially device interoperability, including security of data at the time of production of such data. The emerging Industrial Internet will, no doubt, add new energy to the world of industrial products and services in the forthcoming years. However, to be a viable stakeholder as well as a partner in the digitally contestable future and to generate new avenues, companies will need to further evolve to become more technologically based.

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