Chapter 12
Internet of Things Applications and Use Cases in the Era of Industry 4.0

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Abstract The advent of the Industrial Internet of Things (IIoT) has pioneered a global revolution that is transforming the industrial world. This technological transformation toward a digitalized and connected world improving manufacturing process and production lines with more efficiency, higher capacity, increased worker safety and better return on investment compared to traditional industrial techniques. With the Fourth Industrial Revolution already underway, companies and organizations are swiftly moving toward smart factories, smart workforce, integrated machines and intelligent operations through the use of advanced technologies such as IIoT, cloud computing, cyber-physical systems, artificial intelligence and big data analytics. This chapter explores a variety of IIoT use cases in areas such as manufacturing, automotive, transportation, preventive maintenance production lines, etc. We examine a variety of real-life examples from the industrial sector where companies and organizations have successfully implemented IIoT-based solutions in their factory ecosystems with excellent results. With the global industrial sector advancing toward digitalization and automation, IIoT-based solutions will help to drive digital transformations and thereby create a better future.

Keywords IIoT · Industry 4.0 · Manufacturing · Connected industries · Smart factories · Big data · Blockchain

12.1 Introduction

The Industrial Internet of Things (IIoT) refers to an interconnected industrial ecosystem in which various machines and objects are embedded with electronic sensors, actuators or other digital devices so that they can be connected and integrated to collect and exchange data. IIoT, also known as Industry 4.0 or I4.0, offers advanced connectivity of physical objects, machines, systems and services, enabling object-

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to-object communication and data sharing. IIoT primarily uses IoT paradigms in an industrial environment to build smart factories, optimize production lines, enable customized manufacturing, using connected machines leading to an intelligent workforce.

IoT devices can generate information about an individual entity's behaviors, record it, analyze it and take necessary action. Gartner, a technology consulting firm, estimates that over 6.4 billion connected objects will be in use worldwide this year, in 2018 [1].

The concept of Industry 4.0 (or I4.0) was first introduced at the 'Industrial Internet Consortium (IIC)' which was conducted by AT&T, Cisco, General Electric, IBM and Intel in 2014 [2]. Industry 4.0 which refers to the 'Fourth Industrial Revolution,' is considered the next major technological leap in the industrial world and it is already underway. It is worth noting that the first such technology breakthrough happened in the eighteenth century with the introduction of machines, leading to mechanized production. The introduction and widespread implementations of the concepts of assembly lines and mass production are considered the Second Industrial Revolution and it happened in the early twentieth century. The Third Industrial Revolution was marked by the emergence of digital concepts such as data processing, data storage, computing and Internet in the twentieth century. The Fourth Industrial Revolution is primarily associated with the advent of big data analytics, IIoT, cloud computing, automation, customized productions, smart factories and cyber-physical systems.

Traditional industries rely on mass production and often prefer quantity over quality to generate revenue. In such systems, the products are manufactured in a pre-designed manner and often have limited flexibility and customizability to reduce manufacturing costs. However, with Industry 4.0, individual and customized products can be manufactured at the same cost as that of traditional mass-produced products. They are manufactured by smart factories that have highly optimized and automated production lines.

With this background, this chapter is organized as follows: Chapter 2 introduces the concepts of IIoT and Industry 4.0 while exploring the links between them. Chapter 3 explores the challenges and hurdles faced in the implementation of IIoT systems in industrial settings. Chapter 4 contemplates ways of overcoming the limitations faced by IIoT deployment in industries. Chapter 5 analyzes a number of use cases of IIoT in various industrial sectors such as logistics, warehousing, transportation and manufacturing.

12.2 IIoT and Industry 4.0

Although IIoT and Industry 4.0 are closely related topics, in fact almost synonymous, they are not interchangeable and have a lot of fundamental differences. IIoT is a special case of IoT specifically applied to the industrial sector. IIoT is primarily used to connect different machines, systems, networks and vehicles using sensors and gateways. This ensures that machines and vehicles can communicate with each

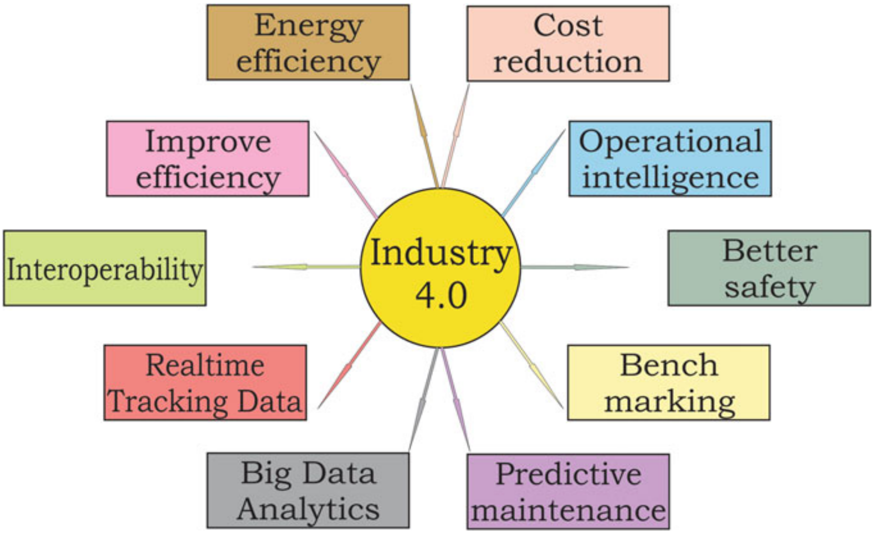

Fig. 12.1 Entities and factors that define Industry 4.0

other and exchange information between them. IIoT solutions can also be integrated with cloud platforms and big data analytics systems to derive deeper insights into the various processes and perform operations more effectively and efficiently [3].

Industry 4.0 refers to an Industrial Revolution that is driven by the efficiency and high level of optimization offered by technological advancements in fields such as IIoT, cloud computing, big data, AI and cyber-physical systems (CPS).

Figure 12.1 depicts various entities and factors that define Industry 4.0. It is predominantly associated with smart factories, intelligent operations, customized products and smart workforce. Compared to traditional factories, modern smart factories have better efficiency, real-time tracking and monitoring of processes, safer operations, better standardization and benchmarking and a high level of integration and interoperability. Moreover, Industry 4.0 can also be considered the coalescence of cyber-physical systems and IIoT [4].

12.3 Challenges and Limitations of IIoT

Although IIoT is a revolutionary concept that has the potential to transform the industrial sector, the adoption rate of IIoT technologies is very slow. Many studies and surveys have been conducted to determine the possible factors that could be contributing to the extreme slow and minimal implementation of IIoT-based solutions in Industry 4.0. In a study conducted by IBM in 2015 [5], high investment costs, lack of awareness, complexity, lack of interoperability and lack of flexibility in the existing IT infrastructure in industries are considered some of the main challenges in the implementation of IIoT.

IIoT solutions are generally expensive with high initial investment costs. This is mainly due to the difficulty in introducing IIoT systems to existing machines and networks. Besides, IIoT also requires the installation of a large number of sensors and supporting infrastructure that are diverse in nature and expensive [6]. The installation and implementation are made even more difficult by outdated machinery, lack of flexibility in the production process and a high degree of manual labor. The situation is further complicated by the fact that industries generally operate with stability as a priority and hence generally refrain from investing in complex technologies like IIoT [7].

Despite the numerous challenges inherent in the implementation of IIoT in conventional industries, it is an investment that is more efficient and effective in the long run. IIoT-based systems will out-perform traditional systems in terms of operating costs, energy efficiency, process optimization, automation and production rate [8]. In the following sub-sections, we elaborate more on the related challenges.

12.3.1 Energy Efficiency

Although IoT devices are generally small in size, they consume a considerable amount of electricity due to their high processing capabilities. Since full-scale IIoT network implementations may involve thousands of such devices, the efficient management of energy becomes a key challenge. Most IIoT devices run on battery power and are not connected to a direct power source. Moreover, the remote location of these IIoT devices can further complicate the process of maintenance and the process of recharging the batteries.

To overcome these challenges, IIoT technologies have to become more energy efficient and reliable. Ideally, this can be achieved through the use of lightweight algorithms, low-power sensors, efficient processors and optimized algorithms. Using low-power RF transmitters and receivers may also help to increase the battery life of IIoT devices.

12.3.2 Integration and Interoperability

IIoT systems are generally set up in haste without careful planning or proper network-level architecture. Moreover, IoT devices and sensor manufacturers do not follow any pre-defined manufacturing standards or design protocols. This causes problems in the integration of various IoT devices as different devices tend to be incompatible. This issue becomes more prominent when diverse and complex IoT networks are connected together. This may cause integrity and stability issues, vulnerabilities and incompatibility problems in the IIoT network that can severely hamper operations.

Another challenge faced in the implementation of IIoT solutions is the integration of physical systems and digital networks without considerable data loss or the introduction of vulnerabilities. IoT devices are usually developed as independent solutions and are then integrated with the manufacturing devices [9]. This could lead to a lack of effective connectivity and synchronization between the digital system and the operational system.

Interoperability is another major hurdle in the widespread implementation of IIoT technologies. Integrated IIoT solutions will have the necessity to share data between different systems without issues in synchronization [10]. The issue with interoperability of IIoT devices increases the time taken to implement IIoT solutions in industrial ecosystems substantially and also tends to raise the overall cost of implementation as well. These hurdles have to be addressed by introducing protocols and guidelines in the manufacturing process of IIoT devices to ensure standardization.

12.3.3 Cyber Security

With the growing number of interconnected IoT devices, networks are increasingly becoming exposed and vulnerable. As devices are interconnected with each other, a breach in any one device in the network can make the entire system exposed to external threats. This is especially the case with IIoT devices as they do not have strict security standards and protocols to govern them. They often tend to have minimal layers of cyber security and use lightweight encryption algorithms and hash tables that are vulnerable to brute-force attacks. These limitations arise primarily due to the low processing power and storage capacities of IoT devices. Since IIoT devices are not manufactured with strict security guidelines, system vulnerabilities and weaknesses are often overlooked.

IIoT devices also need resistance against physical attacks where a device can be opened and accessed physically to gain access to the network. Physical tampering is very difficult to detect and can lead to data loss over time. Therefore, IIoT devices have to be properly secured and should be difficult to access physically to ensure that they are not tampered. As an added layer of security, IIoT networks should use user-based access restrictions and authentication systems to ensure that only authorized personal can access the network [11].

Security concerns are a major challenge in the implementation of IIoT as breaches in security can cause massive damage in the form of confidential data loss, disruption of operations and financial damage. The lack of comprehensive cybersecurity solutions remains one of the main barriers in the implementation of IIoT technologies.

12.3.4 Connectivity Issues

IIoT devices in industries are often placed in remote locations amid active heavy machinery. This not only renders them inaccessible but creates a challenge in connecting the devices together as well. Moreover, devices placed in the vicinity of machinery may experience interference and disruptions in communication. The vulnerability of IoT devices to external interferences is well understood, and adequate shielding is needed. Disruption in the signal can have catastrophic consequences as it could lead to loss of critical information.

Another possible cause of connectivity issue may be due to the large number of devices connected to the IIoT network. Heavy traffic in the network can lead to a decline in the quality of the signal, latency issues and possible data transmission errors and data loss.

12.4 Overcoming the Challenges of IIoT

Although the Fourth Industrial Revolution, with IIoT as one of its key components, is already underway, companies and organizations still face a variety of challenges that prevent them from implementing full-scale IIoT-based solutions to real-life problems. These challenges often tend to hinder the technological advancement of industries across almost all sectors. However, overcoming these challenges offers excellent business opportunities to improve productivity and growth of the respective organization. Most challenges related to the implementation of IIoT can be resolved with monetary investments, awareness, scientific literacy and business initiatives.

Since the implementation of IIoT in existing industries is a very difficult and complicated task, it often tends to de-motivate investors and stakeholders from taking up initiatives. Therefore, it is essential to educate and inform them about the potential benefits of investing in IIoT. Although IIoT-based solutions have high initial investment costs and complexity in integration with existing systems, investors should be persuaded and convinced about the long-term benefits and excellent return on investment associated with them [12].

Standardization of IIoT plays an important role in overcoming the challenges of IIoT. Most IIoT ventures face difficulties in integrating IoT systems with existing systems and also with other IoT networks. This is primarily due to the lack of universally accepted standards and protocols in the design and manufacture of IIoT devices and sensors. Standardization removes most barriers in integration and improves interoperability. Standardization also helps stakeholders analyze the potential profits, hurdles and benefits of IIoT solutions as different networks, applications and systems can be compared easily.

Security is a major issue in IIoT devices. Due to the lack of stringent manufacturing protocols and guidelines, security aspects are often overlooked in IIoT devices. Powerful lightweight encryption and hashing techniques are needed to protect IIoT networks and devices from cyber-attacks and data thefts. Blockchain and public key asymmetric algorithms are possible solutions that organizations are currently exploring. Moreover, IIoT devices also need to be tamper proof to protect them from physical attacks and data leaching.

Security is an especially serious concern in the industrial paradigm where organizations tend to handle sensitive and critical data such as personal data, financial data, product designs and key organization level plans.

12.5 Industrial IoT Use Cases

The Industrial Internet of Things sees potential in a variety of production sectors such as logistics, transportation, manufacturing, energy generation, asset management, smart grids and maintenance. Although a lot of companies have already started implementing IIoT-based intelligent systems in their factories and production lines with immediate positive results, much of the potential for IIoT and advanced AI implementations in the industrial sector remains untapped. This is especially important in the industrial sector, as even small improvements and increase in efficiency can lead to a massive increase in profits and operational savings.

The growth of Industry 4.0 will rest on important key enablers, catalysts and supporting conditions. The key factors among these are continued dynamic innovation, an effective cyber security regime, supporting IT infrastructure and the right talent, skills and expertise. IIoT opens the doors to a variety of benefits for the industrial economy including individual machine optimization, which leads to better performance, lower costs and higher reliability. An optimized machine is one that is operating at peak performance and minimizes operating and maintenance costs. Intelligent networks enable optimization across interconnected machines. Some companies have been early adopters, realizing benefits and overcoming challenges related to capturing and manipulating of data streams. Historically, many of these efforts have centered on the digitally controlled systems of industrial assets with performance scope that is narrow and compartmentalized relative to what is now becoming possible. Given the size of the asset base involved, broader integration of systems and sub-systems at the product level through intelligent devices is expected as the cost of handling and processing data declines.

IIoT has already been successfully implemented in a wide range of industries. IIoT ecosystems are rapidly transforming the industrial paradigm into a smarter one. This has led to revolutionary improvements in the concepts of smart factories, automated warehouses, connected workforce, predictive maintenance, condition monitoring, asset management and quality management. These use cases and their enactment in various industrial sectors are explored in the following sections.

12.5.1 Smart Factories

Traditional factories lack interconnection between various systems and machines. This renders real-time management of operations difficult and tedious. Smart factories use IoT, cloud computing and big data analytics to integrate various sectors and departments in the factory into a centralized system [13]. IoT-enabled objects that are connected with each other will enable workers to remotely manage the factory units and take advantage of process automation and optimization. By connecting existing assets and equipment across global locations, manufacturers are able to generate live performance data without disrupting production. Connected smart factories provide dashboards to workers that aggregate performance data to provide a holistic view of equipment efficiency, operational statuses and key performance indicators. This enables manufacturers to assess the overall performance of various factories, in real time, by comparing the production performance and working efficiency of machines in the respective factories. With this information, a business can gain insights into the various factors that are contributing to performance variation among factories, and the performance of these factories can be optimized accordingly. Smart factories are the epitome of interconnected production lines with machines communicating with each other using IIoT technologies and a decentralized system that enables swift decision making in an autonomous manner.

Factories of the Future

Aircraft are complex machines that are made of millions of different parts that have to be assembled and built with utmost precision and perfection. While dealing with such complex challenges, integrating innovative production techniques is essential. Modern techniques such as graphic prototypes, 3D printing, laser projections, connected tools, robotic exoskeletons for assembly, advanced robots, digitization of the shop floor and integrated production are an integral part of the manufacturing process used in modern smart factories. As shown in Fig. 12.2, IoT and RFID tagging are used to track the millions of parts throughout their journey from various different factories and production lines [14]. Moreover, the location and performance of various tools across the factory are also tracked and processed through IoT gateways.

Assembling an aircraft involves thousands of complex procedures that need to be performed carefully. Since it is not possible to micro-manage all the tasks manually, these process steps have to be integrated and centralized. This can be achieved with the help of sensors-based IoT as the working condition, and the status of every tool across the factory can be tracked and monitored. With this data, the assembly process can be optimized by efficiently managing the tools and resources [15].

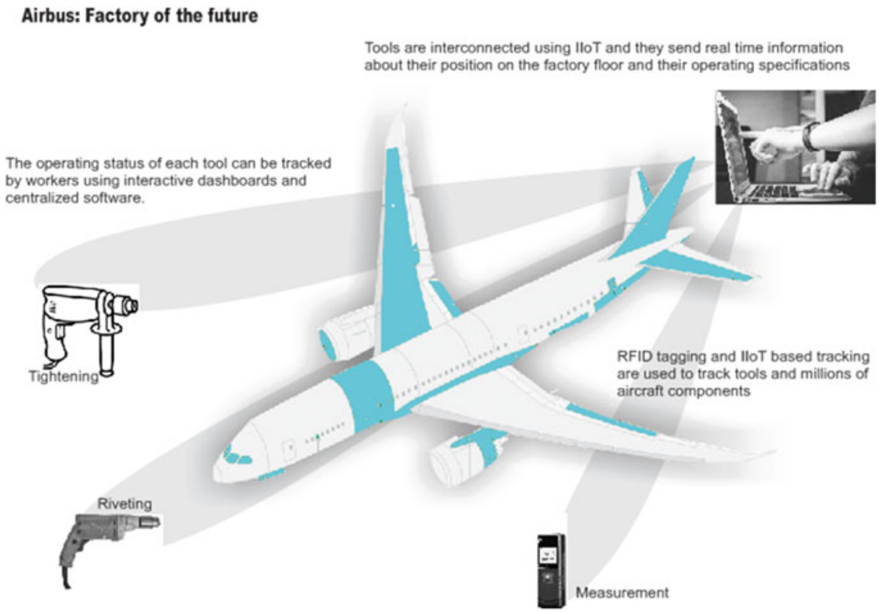

Fig. 12.2 Factories of the future

12.5.2 Condition Monitoring

Condition monitoring is the process of continuously or periodically monitoring the performance of a system to assess its operating condition and quality of output. It is often performed manually and is an extremely labor-intensive process. Besides, the current automated systems in use offer limited insights into the operations of machines due to physical and technical limitations and also have high investment costs. IoT-based sensors can be used to monitor processes and the operations of machines continuously, in real time as and when required. These sensors are connected to a centralized system that monitors the overall functioning of the machines. Any anomalous or undesired behavior can be immediately detected and necessary course of action can be taken. Traditionally, the working condition and key metrics of machines are displayed locally on the human–machine interface and workers have to work in the vicinity of the machines to continuously monitor them. With a centralized system, a single worker can simultaneously monitor the operation of multiple machines from a remote location. This reduces manual labor, saves cost and time, improves the efficiency of the overall process and improves the safety of the workers as they do not have to stand close to the machinery in potentially dangerous environments.

Cycle Time Monitoring of CNC Machines

Continuously monitoring the condition of computer numerical control (CNC) machines manually is extremely difficult and tedious. Since employees normally check the vibrations of machines at pre-defined intervals, there is a tendency for problems to go undetected. It is also hard to calculate the cycle time of various machines and pinpoint the exact factors that are causing machines to underperform and affect production [16]. Moreover, there are limitations to the extent to which a CNC machine's processes can be monitored and assessed manually.

To improve the monitoring processes, IoT-based sensors can be connected to the CNC machines to assess their working conditions and monitor key parameters such as vibration, noise, leakages and precision. Any deviations from normal expected behavior are immediately detected and resolved before any breakdown occurs. This reduces unexpected machine downtimes and increases the quality of the final finished outputs and products. It also improves work conditions and safety aspects of the workers as they can monitor the CNC systems from remote locations using handheld smart devices.

Condition Monitoring of Cooling Systems

Industrial cooling systems work by circulating cooling fluids through the system; the fluids carry the heat away to a heat sink. If the flow in the cooling systems is blocked, the fluid will not be able to transfer heat efficiently and it could potentially cause the temperature of the system to increase. Blockages in the flow of the fluid can also affect the fluid pump and could cause pump failure. Such unforeseen system downtimes can be catastrophic and can lead to massive delays and inconveniences.

To improve the monitoring processes, IIoT-based flow sensors and temperature sensors can be located at strategic points throughout the system to monitor it from remote locations. The flow sensors monitor the rates of flow of the coolants through the system. A considerable decrease in the rate of flow of the coolant can indicate a potential block in the system. The specific region with the constriction in flow can be identified and diagnosed by determining the location of the sensors that detected the issue. By continuously monitoring the status of the cooling system, problems can be proactively detected and necessary action can be taken before system failure [17].

12.5.3 Predictive Maintenance

Predictive maintenance is the process of anticipating potential failures in the system and scheduling appropriate maintenance before the breakdown occurs. Predictive maintenance can be considered a form of preventive maintenance as the system is, ideally, not allowed to fail and the issues are appropriately identified and addressed before the actual breakdown occurs. In predictive maintenance, various risk factors are assessed, monitored and analyzed to predict the occurrence of failures. It is generally classified into two types based on the method used to detect the signs of failure: statistical predictive maintenance and condition-based predictive maintenance [18].

Statistical predictive maintenance is based on the data that is compiled from various IoT-based sensors. The data is used to develop statistical models and perform predictive analytics to predict and forecast failures before they actually occur. Depending on the quality and quantity of the data, accurate predictions can be made and potential cases of failures can be identified with high levels of precision.

In condition-based predictive maintenance, equipment and processes are continuously monitored and assessed to identify any anomalies and deviations from desired behavior. The data generated by various sensors is transmitted through IoT gateways and is processed to identify possible scenarios of failures [19]. Once these failure cases are identified, appropriate maintenance activities can be scheduled to prevent undesired breakdowns.

By proactively performing predictive maintenance, the cost and resources associated with maintenance activities that are scheduled on a regular basis can be considerably reduced while the system reliability and operating efficiency are increased. The elimination of unwanted maintenance activities helps reduce cost and increase productivity as the system does not have to be frequently shut down to pave way for maintenance.

Predictive Maintenance for Milling Machines and Heat Exchangers

Spindles in milling machines are prone to breaking during the production process and repairing spindles can be very expensive. It can also lead to unintended breakdowns and ultimately affect the overall production efficiency. Therefore, predicting the exact time and location of the potential failure of spindles can save money and time. By positioning sensors in close proximity to the machines, vibrations, wobbles and oscillations can be detected especially while performing operations like milling and drilling. This system can be used to manage all the milling machines from a remote location, thereby preventing workers from being exposed to hazardous environments.

Deposits in the filters and ducts of heat exchangers can make them clog, thereby disrupting the flow. Moreover, it is extremely difficult to monitor the flow inside heat exchangers in real time. Due to this, accumulation of particles and development of blockages inside heat exchangers can go undetected. Complete blockages can potentially lead to catastrophic failure of the heat exchangers and can cause extended periods of downtime. IoT gateways and sensors can be leveraged to continuously monitor the flow rate and other vital signs in the heat exchangers. Any deviation from expected behavior can be immediately noted and relevant corrective action is taken [16].

Predictive Maintenance in Railways

Maintenance in railways is an important and difficult task which, when overlooked, can cause downtimes of critical rail lines. Such unexpected downtimes can cause delays and inconvenience for the passengers and considerable financial loss. Trains can be fitted with IoT sensors that detect wear and tear in various components throughout the system. Additionally, vibrations and noise level can also be monitored using such sensors as they can highlight potential sources of malfunction. The data from these sensors can be transmitted through cloud platforms and displayed in dashboards so that engineers and maintenance workers analyze the data in near real time and take necessary preventive actions. Unexpected breakdowns and downtimes are thereby prevented by performing predictive maintenance.

As depicted in Fig. 12.3, the entire rail network is connected with a series of IoT-based sensors, devices and components. The system also uses integrated signaling systems and route optimizing techniques to ensure efficient scheduling of trains. Image analytics is also used to perform visual inspection and highlight potential problems. Since the data from all the sensors are compiled to produce a consolidated output, the trains can be monitored from remote locations [20].

IoT-enabled Truck Fleets

Trucks often tend to travel long distances carrying heavy loads in difficult terrains. To obtain optimum performance and prevent unexpected breakdowns of these trucks, it is essential that the trucks are well maintained. Maintaining fleets of trucks is a massive task for operators in the trucking industry. Truck manufacturers have designed platforms to perform predictive and preventive maintenance by continuously monitoring the status and performance of their trucks. The trucks have a series of IoT-based sensors that are connected to the cloud processing and storage to perform real-time analytics.

The high volume of data generated from these sensors help derive deep insights and develop sophisticated data analysis models. This helps fleet operators manage

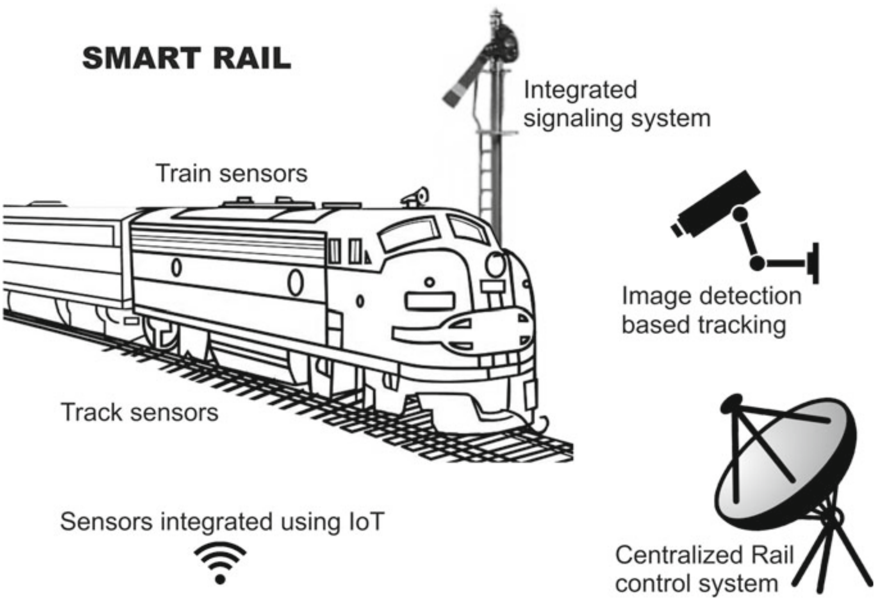

Fig. 12.3 Smart rail

and maintain their entire truck fleet in real time without halting the trucks and performing traditional scheduled maintenance activities [21]. This also leads to efficient micro-management of truck fleets with minimum effort, thereby saving time, energy, labor and resources. Since the performance of the trucks is continuously monitored from a remote location, problems or issues that occur while a truck is on-road are immediately identified and relevant authorities are notified.

12.5.4 Quality Management

It is essential to maintain the quality in a production line environment. Products often have to be manufactured with precise requirements and quality standards. The quality and integrity of such products have to be monitored continuously for adherence to quality standards and for optimum output. Conventional techniques generally involve inspecting a few random products for defects and the results are subsequently extrapolated onto the remaining products. Such a randomized sample may or may not reflect the quality of the population and defective products might find their way to the customers.

IoT gateways and connected sensors can be used to continuously monitor the processing units to ensure compliance with quality standards. This enables existing machines to communicate and perform sensor-based monitoring of the products and detect defects and quality breaches in real time.

Monitoring Lubricants and Filters in Hydraulic Valves

Hydraulic valves are tested for leakages and manufacturing defects using lubricating oils after production. This test is performed to identifying hidden cracks and faults that may potentially cause failure of the valves. The quality of the lubricants used to test hydraulic valves after production should meet specific preset standards. The oil quality is continuously monitored and maintained to meet the required standards by using IoT sensors. These sensors monitor a variety of parameters that affect the quality of the lubricating oil such as viscosity, oil temperature, presence of contamination and the composition of the oil. Using IoT, the quality standards can also be managed across multiple systems by integrating them into a central system.

Blockages in filters may constrict the flow of hydraulic fluid and could potentially cause catastrophic failure of the system. These blocks are generally difficult to deal with, as the system has to be shut down and the entire section of the hydraulic system has to be checked to identify the location and the cause of the block. By interconnecting the system with IoT-based sensors, the flow through the pipeline system can be monitored in real time. The flow sensors and gauges are continuously monitored to detect anomalies in the flow that could possibly hint towards clogged filters or blockages in the pipeline. The sensors help identify the location of the blockages and necessary action can be taken to clean or repair the filters that may be causing the issue.

Quality Management of the Pressing Process

Airbag control units are manufactured by mechatronic presses that assemble every component by a mechanical operation called mating. To gain a better understanding of these mating processes and how the process parameters and product quality relate, the process data is extracted from the proprietary press control system. With this data, the force and position of the pressing processes are observed and recorded. This data is used to define a template process which then serves as a reference for each press in the production. This allows a direct evaluation of every single pressing process, based on the raw data. Traditionally, this was only possible with a downstream quality assessment; whereas now, every pressing process is monitored and cross-checked with the template made from the raw historical data. This improves the quality of the products and significantly improves the efficiency of the pressing process.

12.5.5 Assets Tracking

Assets tracking is a method of tracking, monitoring and locating key physical assets. Industries like Maritime shipping, e-commerce, logistics and transportation rely on assets tracking systems to manage their assets. By tracking assets, organizations can detect inefficiencies through the pipelines, optimize logistical operations, maintain inventory and monitor the working condition of the assets.

The assets and individual entities are tracked using GPS, NFC and RFID tags and the data is transmitted using IoT gateways to a centralized asset management system. Moreover, industries with distributed assets can use IIoT to manage and track their assets [22].

Tracking assets is also important in warehousing to manage stock, monitor inflow and outflow of goods and to track the location of products. Assets management becomes essential especially when the number of assets is large and tracking them using traditional techniques is difficult.

Assets Management and Logistics

Grocery delivery companies have utilized IIoT technology to dispatch products from their warehouses. They use systems of robots that communicate with each other using IIoT for logistics and warehousing. When an order for a particular product is received, the system automatically assigns a robot to perform the task of fetching the required product and dispatching it for delivery. The robots carry the packages and move through the grid while communicating with each other using the IoT infrastructure. Each of the robot's location is tracked and monitored in real time in a centralized dash board. The robots travel along the grids to retrieve the specific item and ferry them to a drop-off point on the grid to be dispatched [23].

For restocking, the procedure works in reverse where the new stock is classified based on the type of product, and a robot is assigned to place the product in a specific shelf in the warehouse. This automated system is highly efficient and reliable compared to conventional human-operated warehouses. The system can handle large volumes of traffic and can work for extended periods of time.

Automated Warehouses

Traditional warehouses consist of racks and shelves that are stacked with various goods. When an order is placed, a warehouse worker receives the specific product's ID and location, and the worker has to manually go to the specific shelf, fetch and dispatch it. Such systems are generally labor-intensive, unsafe, time-consuming and inefficient.

Modern warehouses are automated using technological solutions such as robots, sensors, IoT, digital dashboards and integrated systems. Robots are used to move and store products inside the warehouse, eliminating manual human labor. The robots communicate with each other using IoT technology to optimize the logistical operation and to increase the efficiency of the process. These robots are faster, can carry heavier loads and can work for longer periods of time compared to human counterparts. This system has a high return of investment, increases reliability, improves work quality and leads to a more efficient and safer workplace [24]. Moreover, since robots pack the products into tighter spaces, more products can be stored in the same warehouse.

Connected Tools

Tracking the location and operation of tools in large factories is a very difficult task. The traditional approach used in the past cannot manage highly sophisticated systems and are not flexible. Manually tracking and documenting each tool's location in the workshop floor is a time- and resource-consuming activity and it is often prone to error and mismanagement.

Modern techniques use integrated systems that consist of tools and machinery that transmit data between each other through IIoT. The tools contain RFID tags and IoT sensors that are used to monitor their location and operating status in real time [25]. RFID is used to track parts when the wireless network is not available or feasible. Information such as the torque, RPM, drill-bit to be used, etc., is displayed on the tool itself, ensuring a smooth and an efficient process. Such innovations not only improve the manufacturing capabilities of smart factories but also reduce cost and improve production efficiency and time.

12.5.6 Fleet Management

According to a report by the American Trucking Association [26], the US trucking industry accounts for nearly $700 billion in economic activity. With trucking and transport being a massive industry, it is essential for companies to manage their fleets efficiently. Fleet operators should ideally try to manage their fleets in the most efficient manner possible to reduce operating costs and to increase profits. Route management, driver performance, vehicle performance and vehicle maintenance are all major factors in the fleet management. Fleet management systems are essential wherever large networks of connected vehicles are used such as the trucking industry, railways, warehouse robots, logistics, etc.

Modern IoT-based systems have a variety of advantages over traditional systems such as optimized logistics, driver performance monitoring for safety, better compliance with environmental laws, efficient route planning and vehicle status tracking for predictive maintenance. Efficient fleet management systems improve the work quality of drivers and reduce driver fatigue by optimizing workload distribution and allotting appropriate workforce for the tasks. Although investing in IoT systems for the entire fleet could be very expensive, the benefits of such an implementation substantially outweigh the downsides of such investments.

Railway Fleet Management System

Rail transport is reliable, cheap and environment-friendly especially in transporting large volumes of passengers and freight. And with the advent of integrated sensors, predictive analytics, big data and cloud technologies, railways have become more efficient and reliable. An IIoT-based fleet monitoring system introduced in Russia helped in significantly reducing delays and running costs. Sensors placed on the train locomotive and bogies monitor a variety of parameters including engine temperature, closed doors, noise, vibrations in specific coaches, etc. Besides, sensors placed on railway tracks and data from other systems are used to perform predictive maintenance and monitor the location of every individual train in the system [27].

IIoT is also used to micro-manage the railway system to monitor the performance of individual trains and routes. The schedules of trains are planned and changed based on demand in the specific routes. Moreover, the location and speed of the trains are tracked in real time using IoT. This ensures that the trains operate at optimum speeds and loads increasing the efficiency of the overall rail network. By managing the location, movement and operation of every train individually, the efficiency of the overall system is improved and enables the system to operate at maximum load capacity for extended time periods.

IIoT in Garbage Trucks

Collecting garbage in metropolitan cities is a logistical nightmare as every street and corner throughout the city has to be covered by a limited number of trucks within a specific time period on a daily basis. Such systems need highly optimized routes, sophisticated fleet management systems and careful planning for efficient operation. Modern garbage and waste management companies use IoT sensors on their garbage trucks to track the location of individual trucks in real time. Sensors are also used to measure the amount of garbage collected at various locations. This leads to highly optimized operations and efficient resource management as the routes of trucks can be carefully planned and organized based on demand. Moreover, traffic jams and road blocks can be detected and other trucks can be warned about the hurdles and can be re-routed accordingly. Since the routes are optimized based on the location of the trucks, it considerably improves the overall efficiency of the fleet management process.

Since the efficient fleet management system of modern garbage companies helps them reduce the cost of their operations, they are able to provide better service to their customers as well. Users can track and monitor the location of garbage trucks in their locality using an interactive mobile app as the data from the truck sensors is relayed in real time using IoT [28].

12.5.7 Worker Safety

The safety of workers is one of the most important concerns for any industry. According to the International Labor Organization, 2.3 million people worldwide die annually as a result of occupational illnesses and accidents at work. Besides, the report also suggests that over 860,000 non-lethal workplace-related incidences are recorded every day, leading to injuries. The concept of a connected workforce is used to demonstrate how IIoT can be used to improve worker safety and worker well-being, and enable safe work practices. Such a system can monitor a worker's biometrics, exposure levels to nearby hazards and broadcast the information to all nearby workers, thereby avoiding potential mishaps [29]. The reduction in the number of safety-related incidences considerably reduces the insurance costs, the severity of accidents and corporate liability.

A connected workforce is essential in extremely hazardous work environments such as underground mines, construction sites, excavation sites, factories, etc. In dangerous work conditions like these, workers effectively communicating with each other are crucial, and tracking the location and biometrics of workers could save lives.

Such IIoT-based implementations are a major leap in the safety aspects of some of the most dangerous jobs on the planet. It leads to increase in workforce management efficiency, improved resource management, faster operation times and overall worker safety.

Connected Workforce

The 'connected worker' is a system that consists of a variety of wearable IoT-based sensors that monitor information about workers and their environments such as toxic gas exposure, breathing, heart rate, posture and motion. A mobile hub system is used to collect and compile information from various sensors. This information can be analyzed in real time to monitor the vital signs of the workers and also to warn them about potentially hazardous situations.

The sensors collect data from a variety of sources including wrist watches, helmets, breathing apparatus, heart rate monitor, activity detection device and motion sensors. The analyzed data is shared on dashboards to the respective plant managers and incident commanders to inform them about potentially unsafe conditions and dangerous scenarios [30].

In the mining sector, this system can also incorporate a 'smart tagboard' functionality that can apply digital technology to know who is present underground at any time to ensure that none of the workers are left behind during emergencies. This is essential as the ability to track the location of individual workers in harsh work environments such as factories and underground mines can drastically reduce the number of safety-related incidences [31].

12.6 Conclusion

With the Fourth Industrial Revolution already underway, it is imperative for companies to adopt advanced intelligent systems and methodologies to run their factories. Smart integrated factories are the future of the manufacturing industry with the IIoT paving way for advanced factories that have automated production lines, integrated machines, highly efficient manufacturing cycles, cloud-based big data analytics, complex network of sensors, real-time data analysis, reduced downtimes and increased production capacities. As increasing attention is given to Industry 4.0, intelligent manufacturing is becoming more and more important in the advancement of modern industry and economy. Intelligent manufacturing is considered to be a key future perspective in both research as well as industry, as it provides added value to various products and systems by applying cutting-edge technologies to traditional products in manufacturing and services. Product service systems will continue to replace traditional product types.

While still early in the process, the integration of the industrial world with the Internet and associated technologies could be as transformative as previous historical waves of innovation and change. Advancements in AI and IIoT will pave for a connected industrial world where processes and operations will be integrated, interconnected and optimized for maximum performance and efficiency.

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