Chapter 5
Industrial IoT and Its Applications

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Abstract This chapter focuses on IIoT (Industrial Internet of Things) and its different applications such as the manufacturing industry, healthcare, and food industry. In all of these different application domains, the core technology and the core technological ideas remain the same; the only thing that changes is the type of sensors that would be used. Traditional manufacturing posed different challenges like unavailability of real-time data, unbalanced workload, and longer changeover time. Smart factory tries to overcome these challenges by integrating IoT and operational technology (OT). The chapter also presents how IIoT can help in transforming present-day healthcare and making healthcare much more affordable, much more efficient, and much more autonomous. IIoT solutions can be used to alleviate some of the problems that are encountered by people with respect to health. There are different sensors like ECG sensor, blood pressure sensor, glucose-monitoring sensor, and temperature sensor that can be procured by patients themselves for monitoring their health conditions at their homes. Further, these systems can be internetworked so that if any patient has a critical condition, different levels of alerts would be sent to the hospital to which this patient is registered. The chapter also discusses IIoT implementation in the food industry. The process involves sowing seeds, growing crops, applying fertilizers, applying pesticides, maturity of crops, harvesting crops, food grain processing, packaging of food grains, and transporting to a wholesale market and finally to the retail market. This is called the supply chain from field to plate. IIoT devices can be used in the agricultural field for monitoring the sowing of seeds, for growth of crops, for applying fertilizers, and for irrigation. These devices can also be used at each step. We describe each of these applications in detail in this chapter.

Keywords IoT · IIoT · Cloud computing · Big data analytics · Smart factory

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1 Introduction

Different IoT solutions [1] are being implemented in the industry for solving different industrial problems to make industrial processes and manufacturing processes much more efficient than the way it is at present. The main aim of IoT is to interconnect different smart objects so that they are uniquely identified and able to interoperate between themselves.

In these smart objects, intelligence is embedded. IIoT is an application of IoT in the industries to modify various existing industrial systems. IIoT links the automation system with enterprise, planning, and product life cycle.

IIoT borrows some of the features of IoT and some from the vision of Industry 4.0 and tries to have a separate vision and technology for itself. So Industry 4.0 gives a framework for automation and data exchange in manufacturing technologies. So, Industry 4.0 basically tries to improve the automation and data exchange in manufacturing and technologies; it tries to incorporate concepts from cyber physical systems, IoT cloud computing, and so on. IIoT and IoT are not the same [2] as IoT focuses on consumer-level services and consumer-level products whereas IIoT has the focus on the enterprise. IoT traditionally focuses on the convenience of the individuals, and IIoT focuses on the efficiency, safety, and security of operation. In terms of machine-to-machine (M-2-M) communication, its use is limited in IoT, whereas M-2-M communication is extensively used in IIoT; the whole industrial operation in a plant is automated. So, one machine talking to another machine is quite extensive in the industrial sector IIoT.

Some of the integral components for building IIoT are machine learning, big data technology, M-2-M communication, and automation. So machine learning involves learning from the existing data and then trying to make predictions so as to make things better in the future. The machine-to-machine communication is about two machines communicating with each other for getting a particular work or a task accomplished without any human intervention. So, a robotic arm opening the door of a refrigerator and then performing certain other tasks in the refrigerator are an example of machine to machine. So, maybe the robotic arm goes and opens the door of the refrigerator and checks whether there is sufficient milk in the milk pot of the refrigerator or not; if there is no sufficient milk, then the system as a whole will send an SMS to the milk person. So, we have machine-to-machine communication and automation without human intervention. So, these are the different aspects of IIoT. So, IIoT is supported by a huge amount of data collected from sensors, and it is based on wrap-and-reuse approach rather than rip-and-replace approach. We are not building a new system from scratch; we use the existing industrial systems; wrap them with sensors, actuators, and so on; and make things efficient. In IIoT, we try to reengineer the existing systems and the processes and we do not build anything brand new from scratch.

IIoT combines the second generation of Internet (where things are connected), fourth generation of industrial automation, and cloud computing. So, cloud has become a very popular technology since about more than half a decade and it is being used in the industrial sector as well. So, cloud offers computational environments, computational infrastructure, computational platforms, and computational software in addition to regular storage. Using cloud one can get access to everything in an industry without basically having to purchase these of their own.

In the IIoT network, we have physical objects, different systems and subsystems, platforms, and applications that are interconnected. IIoT networks can communicate with one another, external environment, and different people. The acquisition of IIoT has led to the availability and affordability of sensors, processors, and other technologies, which facilitate the capture of and access to real-time information.

IIoT has a plethora of applications like transportation [3–4], power plant security and safety [5], inventory management and quality control [6], facility management [7], milk processing and packaging industries, healthcare, manufacturing industries, and food industry. But in this chapter, we only focus on the three applications: healthcare, manufacturing industries, and food industry.

2 Requirements of IIoT

There are four broad requirements of IIoT. We need the hardware and software connectivity and a cloud platform with respect to processing, infrastructure, and data storage. Application development and big data analytics are very important. All these different sensors and actuators are fitted to these different machines and manufacturing equipment. They throw in a huge volume of data in real time that can reveal a lot of information. Data also have other characteristics, such as they come in huge velocities, and there are different types of such data, like speech, images, and video, all coming at the same time need to be handled, and so on. By mining such data using big data analytics, one can predict different things to make these industrial processes much more efficient.

Another IIoT requirement is with respect to access, i.e., one can access anything, at anytime, from anywhere in IIoT. So here end-to-end security is important.

User experience has to be taken into account as one of the fundamental requirements for building IIoT, i.e., what users exactly want, how their problems can be addressed and solved, how through the use of IIoT system users can do things better and how their experience as a whole can be improved.

Transition to smart machines: By adding sensors and actuators we are making the machine smart. Asset management is very important; through asset management, different sensors and actuators (which are the industrial assets) can be managed in a much more efficient way.

We now take a deep dive into the issues and challenges [8] in the adoption of IIoT:

- There are data integration challenges, so here we refer to a large number of machines. These different machines have their own heterogeneity in place.

Integration of these heterogeneous data coming in high volumes and velocities is a herculean task.

- Cyber security is very important because we are referring to a connected world, where there is connectivity between (i) machines themselves, (ii) machine and human beings, and (iii) machines and human beings. Due to this connectivity, it is quite likely that some vulnerabilities are introduced in the overall network, making it possible for different types of attacks and newer types of attacks to be launched.
- There is lack of standardization; large automation supplier firms do not encourage open standardization as it will reduce customers' reliance on them. So, small automation supplier firms basically lack the capability to incentivize this huge step. Lack of standardization leads to different issues related to device interoperability and semantic interoperability. So, different machines supporting different IoT devices need to talk to each other and they have been made by different vendors.
- Legacy installations are a very crucial aspect to be considered. Technology is evolving fast. Industries have a huge legacy machine base and these machines have been operating successfully since decades. With the incorporation of IIoT, we need to have support for these newer technologies and newer machines being procured. So fast-evolving technology should coexist with the legacy equipment without leaving any kind of vulnerability in the whole integrated system.
- The next issue with IIoT adoption is lack of skilled workers. The workers do not have IIoT-related skills, like data integration. The technologies associated with IIoT are new in nature, so workers should have fast and diverse knowledge about these technologies.

Now we discuss the different design considerations for building IIoT.

3 Design Considerations for IIoT

To use an IoT device for industrial applications, the following design objectives [9] have to be considered:

- Energy: Time for which the IoT device can operate with the limited power supply
- Latency: Time required to transmit the data
- Throughput: Maximum data transmitted across the network
- Scalability: Number of devices supported
- Topology: Communication among the devices, i.e., interoperability
- Safety and security: Degree of safety and security of the application

So, now we discuss some of the application areas of IIoT like healthcare industry, manufacturing industry, and food industry.

4 IIoT Applications: Healthcare

4.1 IIoT in Healthcare

Earlier, people used to die due to lack of healthcare. People used to forget about their health due to busy life, and this has also happened in the recent past. Additionally, the number of diseases has also increased in recent times. So, we have our IIoT solutions that could be used to alleviate some of the problems that are encountered by people with respect to health. So, IIoT solutions can help in making healthcare easier and affordable. There are different sensors [10] such as the ECG sensor, blood pressure sensor, glucose-monitoring sensor, and temperature sensor that are currently available in the market; these are affordable and can be procured by patients themselves for monitoring their health conditions at their homes or these could also be purchased by different healthcare facilities, hospitals, and so on. If any patient has a critical condition, different levels of alerts would be sent to the healthcare facilities or hospitals to which these patients are registered.

4.1.1 Concerns in Healthcare Regarding IIoT

There are different healthcare concerns with respect to their implementation of IIoT. Populations are aging all over the world, different diseases are increasing, and medical expenses are also increasing. These are some of the generic healthcare challenges, but from an IIoT perspective as well. Catering to these requirements is also a challenge; scalability of IIoT solutions will have to be taken into consideration not only in terms of numbers, but also in terms of diversity. So, all generic healthcare challenges also have implications on IIoT implementation in the healthcare industry.

4.1.2 IIoT Implementation for Old Population

Looking at the age groups, populations are growing older; between 2017 and 2050, the persons aged over 60 years are expected to increase more than double. By 2050, the number of elderly persons is expected to grow to 2.1 billion worldwide which is a huge number. We have a growing population and it will invite taking care of their health. Monitoring of elderly people’s health condition has to be done efficiently. So, telecare applications, smartphone, or telemedicine basically can help elderly people to live safely. So, we can have telemedicine solutions [11] being deployed in the homes of these elderly persons so that the doctors can remotely monitor the condition of these elderly people from their homes. This applies to not only elderly people but also other population.

4.1.3 IIoT Implementation for Increase in the Diseases

Not only the number of diseases but also the types of diseases are increasing day by day. So, we need to have a suitable and efficient large-scale monitoring system that will cater to the particular problem and address that problem. So, nowadays, we talk about having telecare applications, smartphone applications, and telemedicine applications for elderly people. We are also talking about these kinds of solutions for catering to the other segments of the population. So, continuous monitoring of patients' health can be done, and this can also help in reducing the number of cases of hospitalization. Sensors can collect blood pressure, respiration, pulse rate, heart rate data, and weight data continuously and as and when required; if any alarm has to be triggered, this can be done in a much more efficient manner, and this can be done if any abnormal solution is detected or any abnormality is going to arise in the future.

4.1.4 IIoT Reduces the Expenditure

IIoT-based solutions for healthcare can help in reducing the expenditure; different wearable healthcare devices can help in reducing the cost of health checkup; remote continuous monitoring of patients using smart sensors would be made possible. In hospitals and other healthcare units, smart beds can be deployed which can send notification to the doctor about the patient's activity.

4.1.5 Cloud-Enabled IIoT Healthcare Solution

There are different layers in the IIoT healthcare architecture. It starts from acquiring the data from the sensors; at the very bottom; sending the sensed data; processing the data; storing the data and getting different information knowledge etc. about what is going on, underneath from the data and trying to make more sense out of the data, through information processing, knowledge processing and so on.

Now we discuss the cloud-enabled IIoT healthcare architecture. On one end we are going to have all devices which are typically sensor enabled, i.e., the smart sensors and then some gateway. So, from these sensors, the data are going to be sent to the IoT-enabled cloud platform where different analytics will be performed. Not just analytics, but health data verification can be performed and the data can be stored and also processed in a computer or a computational resource in the cloud and so on. And there are lot of other different things that could also be done at the cloud and finally we are going to have this two-way communication and we are going to have healthcare applications which are going to be the beneficiaries from the cloud where analytics is performed. At the application end, different patient data about their health condition such as ECG, EMG, then may be pulse oximeter data, and many other different types of healthcare data could be made available after suitable processing and analytics. So, this is going to be the data flow architecture at very high level for healthcare IoT.

4.1.6 Benefits of IIoT in the Healthcare

Now we discuss the benefits of IIoT in healthcare. With IIoT, one can monitor the patient's health condition remotely. So, remote healthcare is possible. Remote real-time continuous monitoring of patients' health condition 24×7 is possible. Hospital staff can predict the arrival of a patient in their emergency units; it is also possible to have a hygiene monitoring system which can detect the cleanliness of the hospital and the healthcare facility. Medical staff can provide quality medical services with a small budget using IIoT. So, these are some of the benefits that IIoT implementation in healthcare can provide.

4.2 IIoT-Based Healthcare Devices

4.2.1 Wireless ECG Monitors

Wireless ECG monitors are there which can collect biosignals from ECG devices; the collected data could be sent to the cloud; and medical staff can analyze the health-related data in real time. In fact, we can have some programs which can autonomously analyze the data that are coming in and can send alerts. So, one example of a wireless IoT-enabled ECG sensor [12] is QardioCore. QardioCore is a wireless device for ECG monitoring.

4.2.2 Glucose Level Monitoring Device

IIoT is very useful in glucose level monitoring [13], particularly for diabetes patients as they need to check the glucose level quite often. Particularly, the ones who have higher degrees of diabetes are required to check the blood sugar quite often. So, if we have an automated IoT-enabled system to which the patients can be fitted, then automatically the data from these different patients can be made available to doctors who are treating the diabetes patients and so on; an example of continuous glucose monitoring device is the Dexcom. Dexcom devices can help in continuous glucose monitoring.

4.2.3 IIoT-Based Blood Pressure Monitor

Similarly, we have IIoT-based blood pressure monitors. Using IIoT devices the patient's blood pressure is measured in real time. Doctors can monitor the patient's blood pressure in real time; can get alerts if the blood pressure is beyond a particular threshold; and, depending on the blood pressure data, can prescribe medicines to the patients. One such example of blood pressure monitoring system is iHealth BP5.

4.2.4 IIoT-Based Body Temperature Sensor

In body temperature monitors, wearable sensors are there to continuously monitor the human body temperature. This sometimes is very much required for some patients who are suffering from diseases which make the patients vulnerable to a sudden increase or sudden decrease in the body temperature. So, there are different body temperature sensors in the market. One such body temperature sensor is by Kinsa. So, they have their smart thermometer which is an IoT-based body temperature monitoring device.

4.2.5 IIoT-Based Asthma Treatment

For oxygen saturation monitoring, particularly for asthma patients, this is very important; oxygen saturation can be monitored with the help of IoT devices such as pulse oximeter. So, pulse oximeter can help in measuring the oxygen saturation, so this pulse oximeter could be integrated with connectivity solutions such as Bluetooth, which can send continuously the data of the oxygen saturation level of the patient who is being monitored.

4.2.6 IoT-Based Contact Lenses

IoT-based contact lenses are also there in the market. There are different IoT-based contact lenses which also offer Wi-Fi connectivity with smartphones so that the condition of the patient, their eye condition, their sugar level, etc. could also be monitored.

4.2.7 Smart Inhalers

IoT-based asthma treatment solutions are already in the market. Smart inhalers are a very essential requirement of asthma patients, and hence they are being manufactured. ADAMM is an intelligent asthma monitoring device that has been developed. This particular device can keep track of the body temperature, coughing rate, heart rate, etc. which are preliminary symptoms of an asthma attack.

4.2.8 Smart Phone-Based Healthcare Solution

Different smartphone-based healthcare solutions are already available. Smartphone devices connected to electronic devices such as sensors can help in collecting the data of patients. Smartphone is used to monitor the health of users and detect diseases. Smartphone healthcare apps provide low-cost healthcare devices which are sort of diagnostic apps that help in detecting the health condition of patients; it can also help in medical communication between the patients and the hospitals and can also offer medical education in the form of tutorials to the patients.

4.2.9 Smart Phone App: Health Assistant

Health assistant is one such app which keeps track of the health condition of the patients. Google Fit is another solution which keeps track of different physical activities of the patient. ECG self-monitoring is another solution which serves as ECG device, based on the "ECG Self Check" software.

4.2.10 IIoT Healthcare Technology

Different solutions can be explored that are there in terms of healthcare and IoT implementations in healthcare. Cloud is enabled together with big data because most of this data generated from these healthcare sensors have the nature of big data. So, cloud enablement, big data analytics, etc. are very important in IoT implementation in healthcare.

4.3 IIoT Healthcare Requirement and Challenges

Security is of paramount importance in the healthcare sector. Privacy of individuals is very important because the data that is being carried forward from one device to another through a particular communication channel should not be hacked and unauthorized users should not be able to get access to the data. So, ensuring the confidentiality of the data, integrity of the data, authentication mechanisms and their implementation, and availability of the data are very important in terms of security requirements and their implementations in IIoT healthcare.

IIoT healthcare has different challenges. There are challenges with respect to limited computational capability, not being able to perform expensive operations. There are hassles with respect to having very less device memory, energy limitation, and also taking care of the mobility of these different devices because the patients themselves are mobile. So, consequently, these devices themselves are wearable devices, and the sensors themselves are also mobile. Taking care of the mobility of these different devices from a technical point of view is a challenge; both from a communication and algorithmic point of view there are different challenges. So, taking care of all of them is important for consideration.

5 IIoT in Manufacturing Industries

5.1 Smart Factory

Motivation for smart factory: Now we discuss the drawbacks of traditional manufacturing industries. The machines work in isolation; that is, these machines are not connected. And because of this reason, there is unbalanced workload in these different machines. There are other drawbacks like unavailability of real-time data, longer changeover time (converting a line or machine from running one product to another), and extending production time (lack of proper information and data of the production line). These drawbacks are removed in the smart factory with the implementation of IIoT.

Smart factory involves machinery and equipment which improve processes through self-optimization and automation. Benefits of smart factory are as follows: supply of real-time data, data analysis and quality control, reduced changeover time, reduced production time, and flexibility and easy management.

The manufacturing devices, equipment, workforce, supply chain, and work platform are internetworked and linked to accomplish smart production. The integration has to be done in order to reduce operational costs, improve the productivity of the worker, and reduce injuries at the workplace. The reason for using IIoT is to improve safety in the manufacturing plant. With the help of IIoT, resource optimization and waste reduction can also be achieved, which are also again very important aspects in industrial engineering.

Let us now look at how the smart factory is going to work. So, at the very bottom we have the sensor-enabled tools and workers. They throw in a lot of data which are going to pass through the gateway to the cloud where further data analysis, data visualization, etc. are going to be done and the results are going to be made available to the respective stakeholders based on their corresponding policies.

5.2 Features of Smart Factory

In a smart factory [14] we talk about connected devices which are going to send a lot of data in real time continuously. Optimized components and optimized data without any human intervention or with minimal human intervention are characteristics of a smart factory.

Smart factory is transparent in the sense that we get a lot of live data on the metrics that are implemented and those data can be used suitably at different levels of management for quicker decision, and hence, transparency is also promoted in a smart factory.

Proactive feature means that we know proactively we can predict the future outcomes and take preventive actions depending on the situation and what is going to happen in the future. So, based on the prediction of future outcomes one can take preventive actions proactively. So, all of these things are possible in a smart factory. Now we discuss smart factory applications.

5.3 Smart Factory Applications

5.3.1 Airbus: Factory of Future

Airbus is a German company which is a state-of-the-art implementation of IIoT. So, Airbus is a major pair player in the aviation sector. It is a European aircraft manufacturer and it applies a lot of IoT technologies in its production process. So, essentially what happens is that during manufacturing productions on the floor of the plants and also after the products are deployed in a real aircraft, a lot of data can be collected. Further lot of data can be collected from the flight recorders while the flights are in operation. So, collecting data on flights will help to improve the in-flight experience and the workers on the factory floor can use these IoT devices to know about how much the manufacturing has processed, what are the different gaps, etc. in the process. So, Airbus is the digital manufacturing initiative which is also known as the factory of the future.

So, in a factory of the future, we talk about different components, such as IoT sensors for supply-chain management. Now we discuss modular equipment; use of different robots, robotic arms, etc.; use of concepts of industrial augmented reality; use of computer vision; image processing and video processing in real time; and so on.

Now we delve into the implementation of factory of the future; Airbus now has mechanisms for digital tracking and monitoring. There are tools and machines, and sensors are integrated into them. Further wearable sensors like smart glasses can be used with maybe augmented reality support. So, Airbus is using all of these different things for its implementation.

3D real-time visualization of the production process is possible and all of these things are deployed on A330 and A350 models and their assembly lines which are there in the Toulouse manufacturing plant; they have also deployed this factory of the future for the A400M model and their assembly operations in the UK.

5.3.2 Amazon: Robotic Shelves

Amazon has robotic shelves, and as this name suggests, Amazon uses different types of robots that will carry these shelves and rearrange them. Amazon basically is an e-commerce company and these shelves and their rearrangement robotically are very important and that makes the processes much more autonomous and efficient. So, the good part of this thing is that because it is an autonomous robotic system, using this system, the robots can efficiently locate and search different items from different shelves. Thus, in 2014, the operating cost was cut down by 20% using these robotic shelves by Amazon.

5.3.3 Caterpillar: Augmented Reality App

Caterpillar has the augmented reality (AR) app which is integrated with IoT; Caterpillar is a heavy equipment maker, and it has come up with the augmented reality app that generates end-to-end view of the factory floor. So, the machine operators can detect the need for tool replacement whenever it is required after viewing the end-to-end view through that particular AR app. This app sends instructions for doing things like tool replacement, air filter change, and fuel monitoring.

Caterpillar has the IoT-driven ship maintenance that is done by their marine division. They use the shipboard sensors to perform predictive maintenance analytics. The sensors that are deployed can monitor generators, engines, GPS, air-conditioning systems, and fuel meters. The analysis of the sensed data provides useful insights with respect to the power usage of refrigerated containers, cost of hull cleaning, and optimized cleaning schedule and their data; these are all provided through the analysis of the data that are obtained through these different sensors that are deployed in the onboard devices of the ships.

So, preventive maintenance analytics talks about the use of all these machine learning techniques. Tools and techniques like Python and Weka could be used to come up with these different predictive analytics and so on. It is used to have easier fault correction, reduced downtime, and increased profitability, using predictive maintenance analytics, and this is what Caterpillar is doing.

6 IoT and the Food Industry

Before discussing implementation and application of IIoT in the food industry, we take a deep dive into the chain of activities to be followed in the food industry.

6.1 Field to Plate

We first discuss what happens in the food industry. It starts with the agricultural field where the crops are grown. Farmers sow seeds, grow crops, apply fertilizers, apply pesticides, etc. and then after the crops get matured, these get harvested.

Following harvesting, these food grains need to be processed and packaged. These packages are transported typically to a wholesale market. Then it goes to the retailer, and finally, the consumers buy, cook, and consume the agricultural produce. This is typically the chain from the agricultural field to the plate. So, this is typically the chain of activities that are followed; this is the supply chain because ultimately for each of the activities, the supply will have to be ensured through this entire cycle.

So, in this kind of scenario, for each activity, sensors can be used; IIoT devices can be used in the agricultural field for monitoring the growth of crops and the sowing of seeds and for applying fertilizers precisely adequately. So, sensors, actuators, and different agricultural robots can be used over here. So, not only over here, even in harvesting, food grain processing, packaging, transportation, and logistics these could be used. The sensors and actuators help the systems or the machines that are helping in the activities to be much more efficient and autonomous. Now we discuss how IIoT is implemented in the food industry [12].

6.2 Implementation of IIoT in the Food Industry

IIoT is implemented in the food industry using three layers: sensing layer, communication layer, and application layer. These layers need to be internetworked. In the sensing layer, we have network sensors for food quality monitoring along the supply chain. The food grains go through the warehouses and the network sensors also monitor the temperature in those warehouses and also other environmental conditions.

The communication layer deals with stakeholder access supply-chain data, communication between different stakeholders, and communication between different components of the supply chain.

The application layer has applications for farmers, retailers, government, analysts, consumers, and insurance companies.

We need sensors for doing many tasks like sensors for monitoring humidity, temperature, and composition of food products. The sensors throw a lot of data in real time which have to be analyzed in in order to make the most out of those data that have been retrieved. So, we need easier process control, increased food safety, etc. and it is also very important to have adequate end-to-end traceability. So, if we have the field to plate and the corresponding supply chain adequately implemented using suitable IoT solutions, then it would be possible for example to trace a rice packet back to the paddy field.

6.3 Impact of IoT on the Food Industry

We now discuss the impact of IIoT in the food industry. We have an efficient production line as IoT monitors the equipment performance and detects the anomaly in the production line. This efficient production line enables the generation of real-time solutions by predictive maintenance.

Using the temperature tracking sensors we can implement adequate, suitable, and efficient food safety measures. Also, we have Automatic Hazard Analysis and Critical Control Points (AHACCP) checklist, which ensures food safety.

IIoT ensures transparency of the supply chain as the real-time data about the products are available, and it is easier to find the inefficiencies and meet the food safety regulations. We have minimized wastage of food resources, and we can analyze in real time, for example, the information of food products and reduce food wastage. So, all of these things are possible if we have IIoT implementation in the food industry.

6.3.1 Utilizing the IoT in the Farms

On the farm we can have sensors to monitor weather, crop maturity, presence of insects, and conditions of the field with respect to the soil conditions, for example, how much soil moisture is there in the field, how much is the water level, how much is the fertilizer content of the field, and soil nutrient condition of the field. So, all of these things are possible with the help of IoT implementation in the food industry.

6.3.2 Utilizing the IoT in the Livestock Barns

In the livestock barns, sensors can help in monitoring the health parameters of different animals such as cows, buffaloes, and different other livestock, including sheep and goats. So, all of the life monitoring in real time is done using IoT-enabled devices. Automated feeding cycles can be set up with the help of IoT implementation, and diet control of these different livestock is possible with the help of IoT implementation. Automated temperature control in the brooding barns and hatchery is also possible with the help of suitable IoT implementation.

6.3.3 Utilizing the IoT for Equipment in the Food Industry

On the equipment level, IoT enables GPS tracking whenever these animals are moving around their exact location, and their position could be tracked. This is just an example; similarly, GPS could be used for tracking the mobility of different components in the food industry. Drone-assisted field monitoring applications in agriculture are quite common and are being implemented using IoT.

6.3.4 IoT for Maintenance in the Food Industry

In the food industry, IoT implementation can be done for maintenance. Sensors are embedded in different machines, such as farm machinery and tractors, to monitor their condition and performance and to detect whether any machine is going to go down in the future. The early detection of warning signs, smart maintenance of these machines, and extending the lifetime of these equipment are possible with respect to maintenance in the food industry through IoT implementation.

6.3.5 IoT to Improve Margins in the Food Industry

IoT implementation in the food industry can improve the margins through predictive analytics, spotting early warning signs, making well-informed decisions, and maximizing profits.

6.3.6 IoT for the Consumer

For the consumer, there are different initiatives; smart label is an initiative by the Grocery Manufacturers Association (GMA), which uses a QR code to provide product-related information to consumers. These consumers consequently can get information about the ingredient details of a particular food item, allergen exposure of that particular food item, nutrition, value, and other information.

6.3.7 IoT for the Product in the Food Industry

Consumers can scan the QR code to get details about the product; the product information includes nutrition, ingredients, allergens, third-party certification, social compliance programs, usage instructions, advisories, and also safe handling instructions.

6.3.8 IoT for the Food Processing Factory

In the factory, IoT implementation can help different machineries in the food processing industry and also aid different workers who are working in the food processing industry to remain connected autonomously. This connectivity can help in gaining insights to improve the quality of the food product, the quality of the food processes, and so on, and consequently, they can also help in the reduction of the time to market (TTM).

6.3.9 IoT for Empowering the Workers in the Food Industry

IoT implementation in the food industry can also help in empowering the workers through augmented reality, safety glasses, and other wearable sensors, thereby increasing the overall productivity and efficiency of their processes, workers, and the machinery they are using.

6.4 IoT Solutions for the Food Industry

We now discuss different IoT solutions [15] for the food industry.

6.4.1 City Crop

City crop is an intelligent indoor garden that provides intelligent indoor gardens to grow fruits, herbs, vegetables, greens, and edible flowers; they have implementation of automated climate control, automated livestock monitoring, and automated smart notifications that can be sent to the concerned stakeholders and also to the plant doctors.

6.4.2 Diagenetix

Diagenetix has the product bioranger which can help in detecting the presence of microbial diseases in the food. Bioranger is a small handheld device that connects with Android and instantly detects pathogens in the food.

6.4.3 Eskesso

Eskesso is a company that has the cooking sorcery which is basically for smart cooking. So, they have Wi-Fi-connected smart cooking device that can help in easy monitoring of the cooking status via the smartphone app. Smart cooking helps by placing the food packet and Eskesso device in a pot of water; selecting the recipe and starting via smartphone app one can get the food cooked in a smarter way through minimal involvement.

6.4.4 Culinary Science Industries: Flavor Matrix

Culinary science industry *Flavor Matrix* infuses foods and beverages with unique flavors; they collect data on the food ingredients, collect user data, and use different implementations of machine learning and data analysis to enhance the flavor of dishes and provide user-specific food and beverage pairing.

6.4.5 IntelliCup

IntelliCup is the smart cup solution which is a smart beverage vending machine which reduces the waiting time and increases the profit at beverage shops. These are like IoT-enabled cups which have NFC-integrated chips at the base of the cup, and they connect the cups to the mobile banking platform and IntelliHead which is a modular dispensing unit. This NFC chip helps in connecting each user to a cup. So, the cups are usable and made with biodegradable material. There are separate apps for the merchants and the customers, the customers create IntelliCup accounts using the app, they transfer the funds to the e-wallet, and the cups are linked to the e-wallet by scanning a QR code via the app and docking the cup on the dispensing unit using the IntelliHead. So, customers enjoy the beverage that is finally produced through this smart cup.

7 Conclusion

In this chapter, we focused on IIoT and its applications in the food industry, manufacturing industries, and healthcare. Most of the industries are transforming globally. They have been mandated to transform to be Industry 4.0 compliant. And they are transforming towards the adoption of IIoT technologies. So, we discussed the different aspects of both Industry 4.0 and IIoT. We also focused on the requirements of IIoT and design consideration for IIoT. It makes the industrial processes much more efficient and autonomous. In all of the different applications of IIoT, the core technological ideas remain the same and cannot be changed. So, the only thing that changes is the type of sensors that would be used. The specific requirements that a particular industry has are mostly dealt with in the application level, and at the device level more or less the concepts remain similar.

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