17 INDUSTRIAL IoT

17.1 Introduction

The Industrial Internet of Things (IIoT) is the use of Internet of Things (IoT) technologies in manufacturing. Also known as the Industrial Internet, IIoT incorporates machine learning and big data technology, harnessing the sensor data, machine-to-machine (M2M) communication and automation technologies that have existed in industrial settings for years. The driving philosophy behind the IIoT is that smart machines are better than humans at accurately, consistently capturing and communicating data. This data can enable companies to pick up on inefficiencies and problems sooner, saving time and money and supporting business intelligence efforts. In manufacturing specifically, IIoT holds great potential for quality control, sustainable and green practices, supply chain traceability and overall supply chain efficiency.

A major concern surrounding the Industrial IoT is interoperability between devices and machines that use different protocols and have different architectures. The nonprofit Industrial Internet Consortium, founded in 2014, focuses on creating standards that promote open interoperability and the development of common architectures.

Industrial Internet of Things (IIoT) can be considered as the intersection of Internet of Things (IoT) and Industry 4.0 as shown in Figure 17.1. Industry 4.0 is a name for the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing. Industry 4.0 is commonly referred to as the fourth industrial revolution.

Industry 4.0 creates what has been called a "smart factory". Within the modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real time, and via cloud computing, both internal and cross-organizational services are offered and used by participants of the value chain.

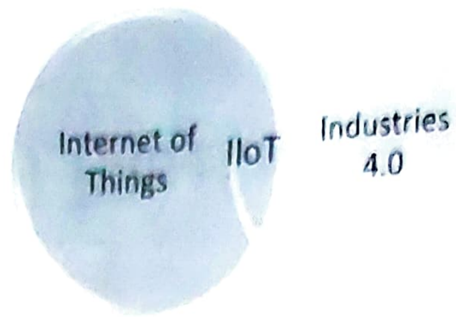

Fig.17.1: Industrial Internet of Things

Industrial Internet of Things (IIoT) is also known as Enterprise IoT while Internet of Things is known as Consumer IoT. Enterprise IoT is not equal to Consumer IoT. But there are some common aspects for both. Figure 17.2 shows the relationship between IIoT and IoT. IIoT is supported by huge amount of data collected from sensors. It is based on "wrap and re-use" approach than "rip and replace" approach.

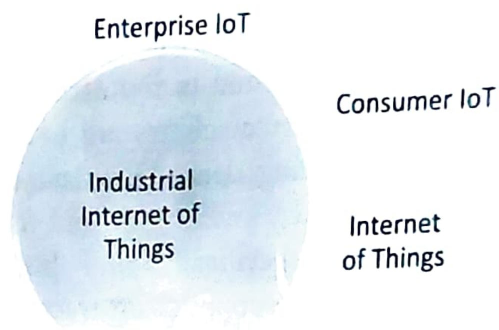

Fig.17.2: Relationship between IIoT and IoT

The first industrial revolution came with the mechanized production. With mass production came the second industrial revolution. Internet evolution and automation paved the way for third industrial revolution while fourth industrial revolution came with Industrial Internet of Things (IIoT). IIoT is a network of physical objects, systems, platforms and applications. These networks can communicate with each other, external environment and other people. The acquisition of IIoT has led to the availability and affordability of sensors, processors and other technologies which facilitates capture and access to real-time information.

17.2 IIoT Requirements

The IIoT can be characterized as a vast number of connected industrial systems that are communicating and coordinating their data analytics and actions to improve industrial performance and benefit society as a whole. Industrial systems that interface the digital world to the physical world through sensors and actuators that solve complex control problems are commonly known as cyber-physical systems. These systems are being combined with Big Data solutions to gain deeper insight through data and analytics.

Imagine industrial systems that can adjust to their own environments or even their own health. Instead of running to failure, machines schedule their own maintenance or, better yet, adjust their control algorithms dynamically to compensate for a worn part and then communicate that data to other machines and the people who rely on those machines. By making machines smarter through local processing and communication, the IIoT could solve problems in ways that were previously inconceivable. As innovation grows so does the complexity, which makes the IIoT a very large challenge that no company alone can meet.

At its root, the IIoT is a vast number of connected industrial systems that communicate and coordinate their data analytics and actions to improve performance and efficiency and reduce or eliminate downtime. A classic example is industrial equipment on a factory floor that can detect minute changes in its operations, determine the probability of a component failure and then schedule maintenance of that component before its failure can cause unplanned downtime that could cost millions of dollars.

The possibilities in the industrial space are nearly limitless: smarter and more efficient factories, greener energy generation, self-regulating buildings that optimize energy consumption, cities that can adjust traffic patterns to respond to congestion and more.

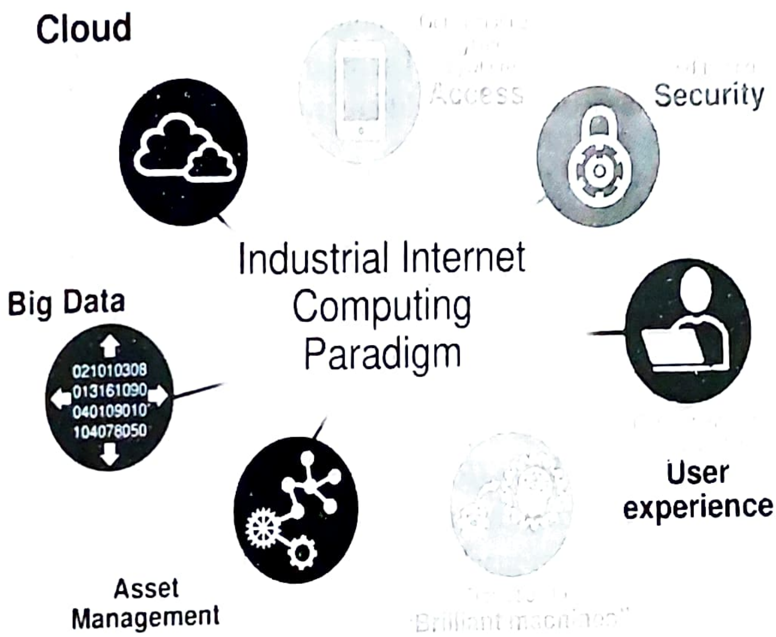

Fig.17.3: IIoT Requirements

The IIoT requirements are cloud computing, access (anywhere, anytime), security, Big data analytics, UX (user experience), assets management and smart machines as shown in Figure 17.3.

Service management in IIoT refers to the implementation and management of the quality of services which meets end user's demand. Service is a collection of data and associated behaviors to accomplish a particular function or feature of a device or portions of a device. Services can be of two types namely primary service and secondary service. Primary services are the basic services which are responsible for the primary node functions. The auxiliary functions which provide services to the primary service are termed as secondary service.

17.3 Design Considerations

To use an IoT device for industrial applications, the following design objectives are to be considered.

Energy: It is defined as the time for which the IoT device can operate with limited power supply. There is power constraint for IoT devices and the more the IoT device could work with little power supply, the more energy efficient is the IoT device.

Latency: It is defined as the time required for transmitting the data to the Cloud or other processing centers. While designing IoT devices and network, latency should be kept in mind and latency should be reduced as low as possible.

Throughput: It is defined as the maximum data transmitted across the network in unit time. Design consideration should keep in mind the increase of throughput.

Scalability: The IoT devices connected to the network may increase day by day. The network should be scalable to accommodate these devices.

Topology: This means communication among the devices. Interoperability is a major concern while designing IIoT networks. There are several types of devices operating with different standards, devices made by different vendors etc. which is a challenge for interoperability of devices.

Safety and security: The data collected and transmitted over the network should be safe and secure. Various encryption algorithms for privacy and security of data need to be implemented. Availability of data, confidentiality of data and data integrity are other factors that need to be considered while designing IIoT.

17.4 Applications of IIoT

The growth of the Internet of Things (IoT) is drastically changing how consumers interact with their cars, homes and appliances, but the aptly named second digital revolution has major implications for industry too. From machine-learning, machine-to-machine communication to artificial intelligence, the Industrial Internet of Things (IIoT) takes IoT technologies and directly applies them to industrial concerns and in the process improves efficiency and productivity.

While consumer-focused IoT solutions have dominated headlines in recent years and the relatively long life cycles of industrial equipment has limited growth in this sector so far, major firms and manufacturers are beginning to embrace IIoT on a big scale, attracted by the opportunity to drive down costs and increase competitiveness. We will see the application of IIoT in various fields like manufacturing, healthcare services, transportation, logistics, mining, firefighting etc.

17.4.1 Manufacturing Industry

Manufacturers and industrialists in every sector have a significant opportunity at hand where they can not only monitor but also automate many of complex process involved in manufacturing. While there have been systems which can track progress in the plant but the Industrial IoT (IIoT) technology provides far more intricate details to the managers. IIoT finds application in manufacturing in the following areas.

1. **Digital/connected factory**: IoT enabled machinery can transmit operational information to the partners like original equipment manufacturers and to field engineers. This will enable operation managers and factory heads to remotely manage the factory units and take advantage of process automation and optimization. Along with this, a digitally connected unit will establish a better line of commands and help identify key result areas (KRAs) for managers.
2. **Facility management**: The use of IoT sensors in manufacturing equipment enables condition-based maintenance alerts. There are many critical machine tools that are designed to function within certain temperature and vibration ranges. IoT Sensors can actively monitor machines and send an alert when the equipment deviates from its prescribed parameters. By ensuring the prescribed working environment for machinery, manufacturers can conserve energy, reduce costs, eliminate machine downtime and increase operational efficiency.
3. **Production flow monitoring**: IoT in manufacturing can enable the monitoring of production lines starting from the refining process down to the packaging of final products. This complete monitoring of the process in (near) real-time provides scope to recommend adjustments in operations for better management of operational cost. Moreover, the close monitoring highlights lags in production thus eliminating wastes and unnecessary work in progress inventory.
4. **Inventory management**: IoT applications permit the monitoring of events across a supply chain. Using these systems, the inventory is tracked and traced globally on a line-item level and the users are notified of any significant deviations from the plans. This provides cross-channel visibility into inventories and managers are provided with realistic estimates of the available material, work in progress and estimated the arrival time of new materials. Ultimately this optimizes supply and reduces shared costs in the value chain.
5. **Plant Safety and Security**: IoT combined big data analysis can improve the overall workers' safety and security in the plant. The Key Performance Indicators (KPIs) of health and safety, like the number of injuries and illness rates, near-misses, short-term and long-term absences, vehicle incidents and property damage or loss during daily operations can be monitored. Thus, effective monitoring ensures better safety. Lagging indicators, if any, can be addressed thus ensuring proper redressed health, safety and environment (HSE) issues.

6. **Quality control**: IoT sensors collect aggregate product data and other third-party syndicated data from various stages of a product cycle. This data relates to the composition of raw materials used, temperature and working environment, wastes, the impact of transportation etc. on the final products. Moreover, if used in the final product, the IoT device can provide data about the customer sentiments on using the product. All of these inputs can later be analyzed to identify and correct quality issues.
7. **Packaging optimization**: By using IoT sensors in products and/or packaging, manufacturers can gain insights into the usage patterns and handling of product from multiple customers. Smart tracking mechanisms can also trace product deterioration during transit and impact of weather, road and other environment variables on the product. This will offer insights that can be used to re-engineer products and packaging for better performance in both customer experience and cost of packaging.
8. **Logistics and Supply Chain Optimization**: The Industrial IoT (IIoT) can provide access to real-time supply chain information by tracking materials, equipment, and products as they move through the supply chain. Effective reporting enables manufacturers to collect and feed delivery information into ERP, PLM and other systems. By connecting plants to suppliers, all the parties concerned with the supply chain can trace interdependencies, material flow and manufacturing cycle times. This data will help manufacturers predict issues, reduces inventory and potentially reduces capital requirements.

17.4.2 Healthcare Service Industry

Medical diagnostic consumes a large part of hospital bills. Technology can move the routines of medical checks from a hospital (hospital-centric) to the patient's home (home-centric). The right diagnosis will also lessen the need of hospitalization. Industrial Internet of Things (IIoT), has an extensive applicability in numerous areas, including healthcare. The full application of this paradigm in healthcare area is a mutual hope because it allows medical centers to function more competently and patients to obtain better treatment. With the use of this technology-based healthcare method, there is an unparalleled prospect to improve the quality and efficiency of treatments and accordingly improve the health of the patients. Some of the applications of IIoT in healthcare service industry are given below.

1. **Simultaneous reporting and monitoring**: Real-time monitoring via connected devices can save lives in event of a medical emergency like heart failure, diabetes, asthma attacks, etc. With real-time monitoring of the condition in place by means of a smart medical device connected to a smart phone app, connected devices can collect medical and other required health data and use the data connection of the smar tphone to transfer collected information to a physician. Center of Connected Health Policy conducted a study that indicates that there was a 50% reduction in 30-day readmission rate because of remote patient monitoring on heart failure patients. The IoT device collects and transfers health data: blood pressure, oxygen and blood sugar

levels, weight and ECGs. These data are stored in the cloud and can be shared with an authorized person, who could be a physician, your insurance company, a participating health firm or an external consultant, to allow them to look at the collected data regardless of their place, time or device.

2. **End-to-end connectivity and affordability:** IIoT can automate patient care workflow with the help healthcare mobility solution and other new technologies, and next-gen healthcare facilities. IIoT enables interoperability, machine-to-machine communication, information exchange and data movement that make healthcare service delivery effective. Consequently, technology-driven setup brings down the cost, by cutting down unnecessary visits, utilizing better quality resources and improving the allocation and planning.
3. **Data assortment and analysis**: Vast amount of data that a healthcare device sends in a very short time owing to their real-time application is hard to store and manage if the access to cloud is unavailable. Even for healthcare providers to acquire data originating from multiple devices and sources and analyze it manually is a challenge. IoT devices can collect, report and analyses the data in real-time and cut the need to store the raw data. Moreover, healthcare operations allow organizations to get vital healthcare analytics and data-driven insights which speed up decision-making and is less prone to errors.
4. **Tracking and alerts**: On-time alert is critical in event of life-threatening circumstances. IoT allows devices to gather vital data and transfer that data to doctors for real-time tracking, while dropping notifications to people about critical parts via mobile apps and other linked devices. Reports and alerts give a firm opinion about a patient's condition, irrespective of place and time. It also helps make well-versed decisions and provide on-time treatment. Thus, IoT enables real-time alerting, tracking and monitoring, which permits hands-on treatments, better accuracy, apt intervention by doctors and improve complete patient care delivery results.
5. **Remote medical assistance**: In event of an emergency, patients can contact a doctor who is many kilometers away with a smart mobile app. With mobility solutions in healthcare, the medics can instantly check the patients and identify the ailments on-the-go. Also, numerous healthcare delivery chains that are forecasting to build machines that can distribute drugs on the basis of patient's prescription and ailment-related data available via linked devices. IoT will improve the patient's care in hospital. This in turn, will cut on people's expense on healthcare.

17.4.3 Transportation and Logistics

The Industrial Internet of Things (IIoT) has the potential to revolutionize the transport industry. It provides access to new data streams and has made self-driving vehicles a reality. IIoT holds the potential to reduce pollution, optimize the mobility of people and goods and save lives. Here are some of the key applications of IIoT in transport.

Lightweight RFID-based trackers that can reveal a team member's location at any time can be embedded in any suit to communicate continuously with the linked network. By monitoring each team member's location at all times in conjunction with linked thermal cameras, commanders can begin to map out the response location and offer precise guidance for the team's movement. As equipment is easy to lose in a smoky environment, different tools can be similarly tagged and tracked to prevent loss or to enable retrieval either during or after a fire.

17.4.6 Smart Dust

The concept of tiny sensors the size of a grain of sand, with the ability to detect everything from chemicals to vibrations, was first thought up in the early-1990s, but little progress was made in the following years turning this intriguing idea into a reality. However, interest in this nascent technology has grown recently, with research firm Gartner predicting smart dust will trend in the next five to ten years.

Applications of these connected smart dust particles in the IIoT are virtually endless, from oil exploration companies spreading smart dust to monitor rock movements to small sensors all over factory equipment continually looking out for changes and problems.

At the moment, smart dust sensors are still out of reach, primarily due to the difficulty in miniaturization and the prohibitive cost of producing huge quantities. However, they are slowly but surely becoming cheaper to manufacture, so it may not be long before billions upon billions of miniscule smart dust particles populate the world.

17.4.7 Drones

Unmanned aerial vehicles, or drones, have quickly become one of the most talked about products in the tech space, thanks to their many useful applications. In the near future these machines could play a significant part in the IIoT by acting as either a sensor or by providing a connection between sensors and data collection points.

Drones may not yet be seen as a fully fledged connected IIoT device, but they can carry all range of sensors and are autonomous machines capable of gathering massive amounts of valuable data. Construction companies can use drones to undertake daily land surveys and feed this data into software to ensure construction is on schedule and send an alert if anything looks out of place or improperly built. But drones are no mere data collectors, with the devices potentially being able to quickly act on the data they collect and communicate with other drones in the IIoT to work together to overcome problems.

17.4.8 Futuristic Farming

Far from the factory floor, in countless farms around the world, is where the IIoT could make the biggest difference. Utilizing the latest technologies is nothing new for the agriculture industry, but implementing smart, connected IIoT projects enables farmers to make use of the massive amounts of data generated on their farms.

The large size of many farms makes manual surveys ineffective and difficult, leading farmers to turn to IIoT solutions. Oyster farmer Ward Aquafarms, with the help of telecoms firm Verizon, deployed an IIoT program to maximize productivity and ensure the quality of food in the supply chain, using satellite imaging and IIoT track-and-trace technology to monitor farming operations all the way from harvest to delivery.

In areas like precision agriculture, real-time data about soil, weather, air quality and hydration levels can help farmers make better decisions about the planting and harvesting of crops.

17.4.9 Aerospace

Aerospace companies have mainly introduced IIoT solutions on the factory floor for tracking tools and parts, with some beginning to expand the number of on-board IoT devices. An airplane that knows when it's going to encounter maintenance problems before they actually happen would save a significant amount of man-hours and money for airlines. Taleris, a joint venture by General Electric and Accenture, is at the forefront of developing IoT solutions for airlines, aimed at minimizing delays and disruptions by analyzing data collected from sensors on airplanes.

Uptake of these IoT technologies in the aerospace sector has been slow, as cost-savings are not easy to estimate, but as the benefits of these systems become apparent, interest from airlines will grow. The widespread usage of analytics programs that have the ability to monitor aircraft proactively not only improves turnaround times for airlines but also helps meet customer needs more effectively.

17.4.10 Energy Networks

Energy companies can expect to see their operations fundamentally altered when IoT is fully embraced in their sector. Spikes in energy consumption around major TV broadcasts and weather events have long troubled utility firms. But with effective energy demand management through the IIoT, the need for investment in both energy networks and power plants is reduced.

Smart meters are one example of the industry's move towards IoT technologies, although at the moment they only record usage amounts and timings. Utility firms could potentially provide price information to these meters, which could in turn interact with other IoT devices to use energy at the most efficient time.

New oil and gas pipelines are fitted with sensors that detect leaks and alert repair teams, so issues are fixed before they can cause problems and the number of blackouts and brownouts are kept to a minimum. Any improvements the IoT can achieve in energy supply management will become increasingly valuable as utility companies look for the most effective ways to deal with multiple energy sources in a decentralized network.

17.5 Benefits of IIoT

IIoT has improved connectivity among devices, improved efficiency, upgraded scalability, reduced operation time, remote diagnosis and cost effective. Connected ecosystem is an advantage with IIoT. Traditional supply chains in industries are linear in nature. To shift the business focus from products to outcomes, new ecosystem should be followed. Digital ecosystems progress at a much faster rate than physical industries. Hence, it can quickly adapt to the changes in the external environments.

Integration of digital and human workforce is another benefit of IIoT. In IIoT, machines become more intelligent. Hence the automated tasks can be done in the industries at lower costs and higher quality level. When humans work with machines, the outcome will be higher overall productivity. IIoT will reform and redefine the skills of the workers.

IIoT will create new job opportunities. The creation of new composite industries such as precision agriculture, digital healthcare system, digital mines etc. will lead to the development of new job opportunities. Highly automated machines will require lesser number of unskilled workers, but will require skilled experts with digital and analytical skills.

Reformation of robots is another advantage. In IIoT environment, robots are featured with 3 capabilities namely sensing, thinking and acting. They will be reformed with the ability to carry out repetitive tasks. Robots will be more intelligent but will work under the supervision of human beings. Robots can be reprogrammed to perform new tasks.

17.6 Challenges of IIoT

The primary challenges in IIoT include identification of objects or things, manage huge amount of data, integrate existing infrastructures into new IIoT infrastructure and enabling data storage. There are several safety challenges which include worker health and safety, regulatory compliance, environmental protection and optimized operations. Challenges related to hazards include handling, storing or using hazardous substances, oxygen deficiency, radiation and physiological stress.

Standardization is another challenge. Standardization plays an important role in the development of the system. The goal of standardization is to improve the interoperability of the different systems or applications and allow the products or services to perform better. The problems related to standardization are interoperability, semantic interoperability, security and privacy and radio access level issues.

Other important concerns related with IIoT are information security and data privacy protection. The devices or things can be tracked, monitored and connected. So there are chances of attack on the personal and private data. For example, in healthcare industry, the medical data of a patient must not be tampered or altered by any person in the middle. Another example is in the food industry where the deterioration of any food item being sent to the company must be kept confidential as it will affect the reputation of the company.

Though IIoT provides new opportunities, new factors may cause hindrance in the path to success such as lack of vision and leadership, lack of understanding of values among management employees, costly sensors and inadequate infrastructure. For example, meeting the challenges of costly sensors can be improved by miniaturization, performance of sensors, cost and energy consumption. The challenges in operational efficiency can be improved through predictive maintenance, savings on scheduled repairs, reduced maintenance costs and reduced number of breakdowns.

17.7 Conclusion

The Chapter explains Industrial Internet of Things (IIoT) in detail. IIoT requirements and design considerations of IIoT is explained in this Chapter. Several applications of IIoT in various domains like manufacturing industry, healthcare service industry, transportation and logistics, mining, firefighting, smart dust, drones, futuristic farming, aerospace and energy networks are explained in detail. Finally benefits of IIoT and challenges of IIoT are discussed in this Chapter.