Industrial Internet of Things – An Overview

C. Sailaja

Technology Principal & Discipline Head-I&C, Tata Consulting Engineers Ltd, Chennai

E-mail: shailajai@tce.co.in

Abstract

Internet of Things (IoT) is a network of intelligent objects (smart sensors) that are connected and accessible to the Internet through devices such as routers to exchange data. Many useful applications can be developed using IoT. IoT has brought a change in such a way that everything around us can be turned into smart devices e.g., smart cars, smart homes, smart parking, smart cities etc., thereby connecting human, machine & things seamlessly. The advent of cheaper processing power, communication cost and some marketing have created the IoT of today. When the principles of IoT are applied to Industries, it is termed as Industrial IoT. Smart sensors and Industrial Internet of Things (IIoT) are modern tools which drive Industry 4.0. The use of smart sensors and IIoT have a positive impact in enhancing the quality & value of products and improve efficiency. The combination of smart sensors with its processing & networking capabilities help in transferring the process data to the centralized database for further analysis. Thus, digitalization has helped industry to reimage the business with the transformation brought about by IIoT. This paper discusses some of the applications of IIoT such as Remote Monitoring & Service, AI & ML based predictive analysis and Closed loop Digital twin using IoT sensors.

Keywords: Asset management, command control centre, digital transformation, digital twin, IIoT, platform, sensors, smart city

1. Introduction

Internet of Things (IoT) comprises of physical objects referred to as 'Things' which are embedded with sensors, software, and other technologies to get connected to each other or to other objects in order to collect and exchange data through the internet. IoT architecture bridges the gap between the physical and virtual world.

DOI: https://doi.org/10.36548/jismac.2022.4.003
Received: 09.10.2022, received in revised form: 17.11.2022, accepted: 20.12.2022, published: 30.12.2022

The four stages of IoT architecture as depicted in Fig. 1, comprises of,

- Stage 1: Sensing layer comprising of Smart Sensors and Actuators
- Stage 2: Networking layer comprising of Gateways
- Stage 3: Networking layer or Edge IT
- Stage 4: Application layer comprising of the Cloud Server

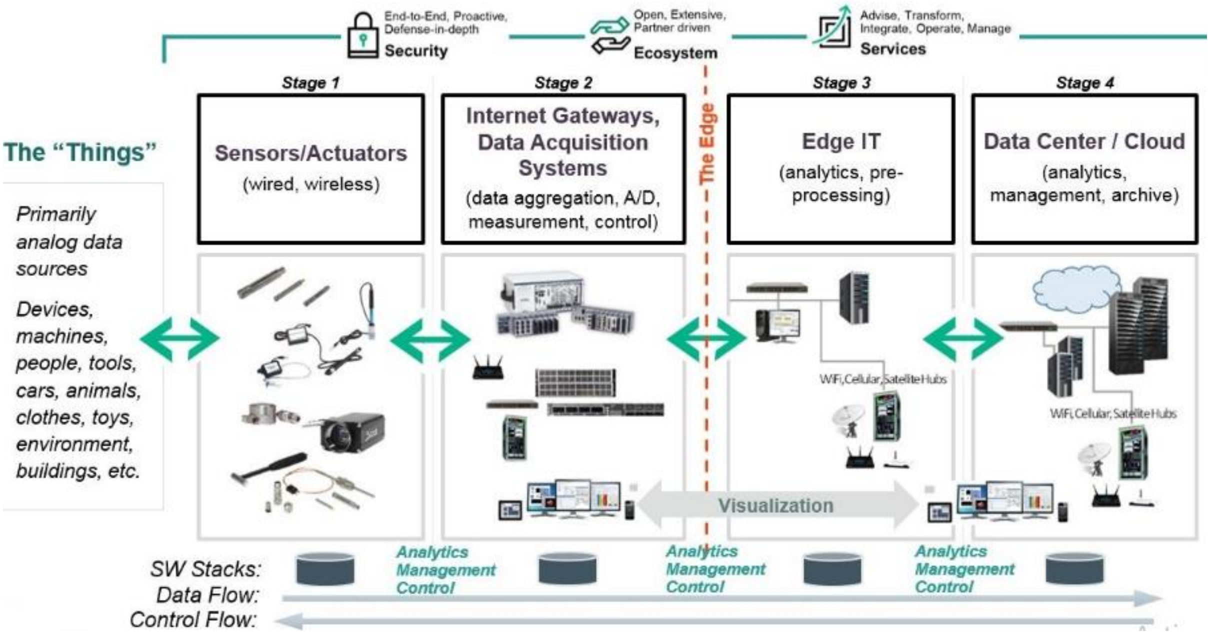

Figure 1. IoT Architecture [1]

IoT includes devices such as smart appliances, fitness bands, smart watches and other consumer products that are not critical even if something goes wrong. IoT adds value by increasing the efficiency, monitoring the health parameters and creating better experiences. [2] Industrial IoT (IIoT) is considered to be a subset of IoT. IIoT has applications in sectors such as,

- Power plants, Manufacturing, Oil & Gas, etc.
- Automotive
- Aerospace & Defence
- Agriculture

As IIoT applications are connected with larger clientele, data collected is huge and hence called Big Data. IIoT applies techniques such as machine learning and big data analytics on the sensor data to get more insight into the manufacturing processes for improvement in efficiency, increase in productivity, and to achieve financial and operating benefits [3].

Table 1. Architectural differences between IoT & IIoT

S No.	IoT	IIoT
1	Short product life cycle	Long product life cycle
2	Human Oriented (Personal application such as wearable, home automation etc.)	Machine oriented (Industrial applications such as manufacturing, agriculture etc.)
3	Less reliable and secure systems	Critical reliability and security requirements
4	Low scalability	High scalability
5	Independent devices – No interoperability	High Interoperability between multiple devices
6	Volume of data is low	Volume of data is very high
7	IoT is a revolution with creation of new protocols & standards.	As IIoT is a subset of IoT, it is an evolution utilizing the existing protocols & standards.

1.1 Factors affecting the choice of an architecture

The choice of the architecture is an important challenge, as IIoT is based on networking of sensors, devices & other things. Since IioT involves transmission of data in digital format, choosing the right architecture plays a critical role. Factors to be considered while selecting the architecture include,

- Adaptability & Scalability
- IIoT Platforms
- Security
- Maintenance & Updates

1.1.1 Adaptability & Scalability

The IIoT architecture should be capable of interfacing with all types of protocols using suitable gateways for its analytical functions. Therefore, IIoT systems are required to be adaptive & scalable through software to integrate with the overall solution.

Adaptability is a feature of the system that adapts automatically to its users according to the changing conditions. Any change in technology of the sensors, the network must adapt to the change and accept it [4].

Scalability is an attribute of IIoT to handle the influx of demand, and changing needs and trends. Scalable IIoT is more advantageous because it is more adaptable to the changing requirements or demands of the users and clients.

1.1.2 IIoT Platforms

A platform comprises of a set of hardware & software facilities that connects devices& equipment with the internet to support applications for industrial companies. IIoT platforms bring together connectivity, cloud, Big Data, analytics and application development capabilities. There are a number of platforms for a variety of applications. The focus should be to use connected technologies in tandem with the cloud-based analytics to drive a new business model [5].

1.1.3 Security

As the volume of data increases, so also the security & compliance risk. By moving the computing power & analytics to the Digital Edge i.e., closer to the things, people and ecosystems that are generating & using the data, will solve the concern. Edge refers to the computing infrastructure that exists close to the source of data. The role of edge computing is to acquire the data, store, sort and send data to cloud systems. This power of the sensor and the edge device to store, compute and analyze the data at the edge itself makes edge computing a viable solution for Industrial applications. Thus compliance, regulations or cyber security constraints can be overcome.

1.1.4 Maintenance & Updates

IIoT systems are required to be maintained & modified to match the upgrades in hardware & software. As new features are added, the software requires to be updated. This new system has to integrate with the original system and also other connected systems.

1.2 Key features of IIoT

- IIoT has brought about improvements in the industrial working conditions, the product quality, and machine health, thereby extending its lifetime, automatic fault detection and maintenance.

- IIoT concerns primarily with digitizing the existing systems by applying the IoT techniques as applicable to the industry.
- IIoT links automation systems with enterprise, planning and product lifecycles, thus enabling interconnection of physical and virtual things through advanced communication technologies.
- It is a model which enables devices or machines (things) to talk to each other and take intelligent decisions based on the available data.
- It optimizes industrial operations by integrating with advanced technologies such as Augmented Reality (AR) and Virtual Reality (VR) using cloud computing, 3D printing, Machine to Machine (M2M) communication, Digital Twin etc.

1.3 Enabling Digital Transformation

The power of the Internet to transform the data from the sensors to knowledge is called Digital transformation. It's the way in which the data and intelligence are combined to power innovative and transformational smart services. This is enabled by using big data analysis, the cloud and other related technologies such as AI, ML, VR & AR. Hence, The Internet of Things can also be coined as Internet of Transformation. Digital transformation without the Internet of Things is impossible. Edge computing is soon gaining importance in IIoT equation to accelerate digital transformation [6].

1.4 Smart Sensors

Smart sensors are not the conventional type which convert physical parameters to electrical signal. They are now more intelligent and sophisticated. Smart sensors are built as IoT components that convert the real-world parameters into digital data and transmit through gateway to cloud or server for data analytics. These smart field sensors/ instruments form the universal intelligent base unit of Industry 4.0; nothing goes without sensor systems.

Smart sensors are typically characterized by inbuilt intelligence and the ability to communicate via digital network. Smart sensors cover a wide range of interdisciplinary areas like Agriculture, Drone communications, Healthcare, Intelligent transport system, Security etc. While the number of connected devices continues to grow at a rapid rate, IoT is no longer just about monitoring equipment behaviour. Increasingly, the value of IoT comes from collecting machine data to identify actionable strategies that drive industrial manufacturing efficiencies.

Data streams from machines, industrial equipment and other devices create a massive amount of data. Pre-processing and analysis of low & high frequency data at the edge is required to get valuable data insights for condition monitoring and predictive maintenance. Valuable information like the health status of machines or the performance of a production process can be obtained, and root cause analysis can be performed [7, 8].

The Edge device transfers data and ensures connectivity with the cloud. The edge device shall support different protocols in order to collect the data. The data is transmitted through secure internet connection to cloud based applications and services.

2. Related Works

Table 2. IIoT models of different applications

S. No.	Application	Findings	Reference
1	Digital transformation in manufacturing industry through IIoT.	IoT framework in subject did not take into account the criteria that similar tasks on different machines gave different results due to communication latency, completion time etc.	Senthil Murugan Nagarajan et al. 2020 [9]
2	Applications of IIoT in environment monitoring, agriculture, solar assisted systems, supply chain management systems, construction industries, smart Homes/Buildings, disaster management. IIoT can be used to automate equipment and devices.	Though theoretically the IIoT applications in various sectors is proposed by a certain methodology, practical implementation at the actual sites is difficult due to safety concerns and risk of failure of the sensor.	Praveen Kumar Malik et al. Nov 2021 [10]
3	IoT-based system using Big Data analytics for smart city development and urban planning.	Implementing IoT modules of smart city and urban planning will generate a huge amount of data for analytics. Such an integrated system may have latency issues due to network traffic. Hence, this type of system with full functionality does not currently exist. However, the existing system can be scalable on need basis.	M. Mazhar Rathore et al. June 2016 [11]

2.1 Existing Works

A few examples of IIoT as applicable to infrastructure, process and industrial sectors are discussed below.

2.1.1 Smart City

The application of IoT platform at various segments are displayed in Fig. 2. Smart City solutions include the functional modules which fall under various categories as depicted in Fig. 3. These functions can be integrated to monitor & control from the Command Control Centre which is depicted in Fig. 4.

Figure 2. IoT Platform

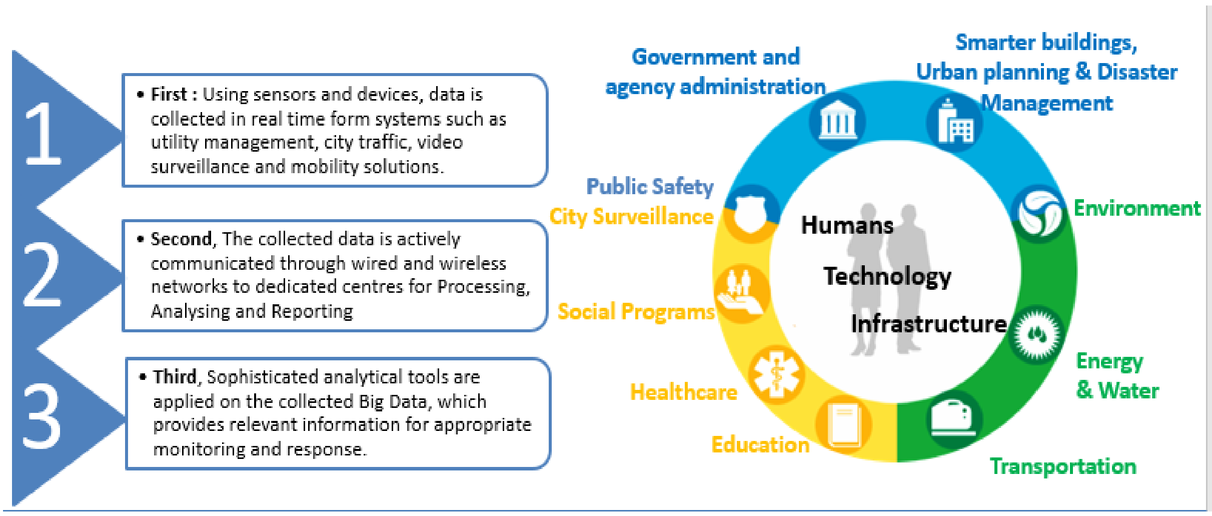

Figure 3. Modules in Smart City

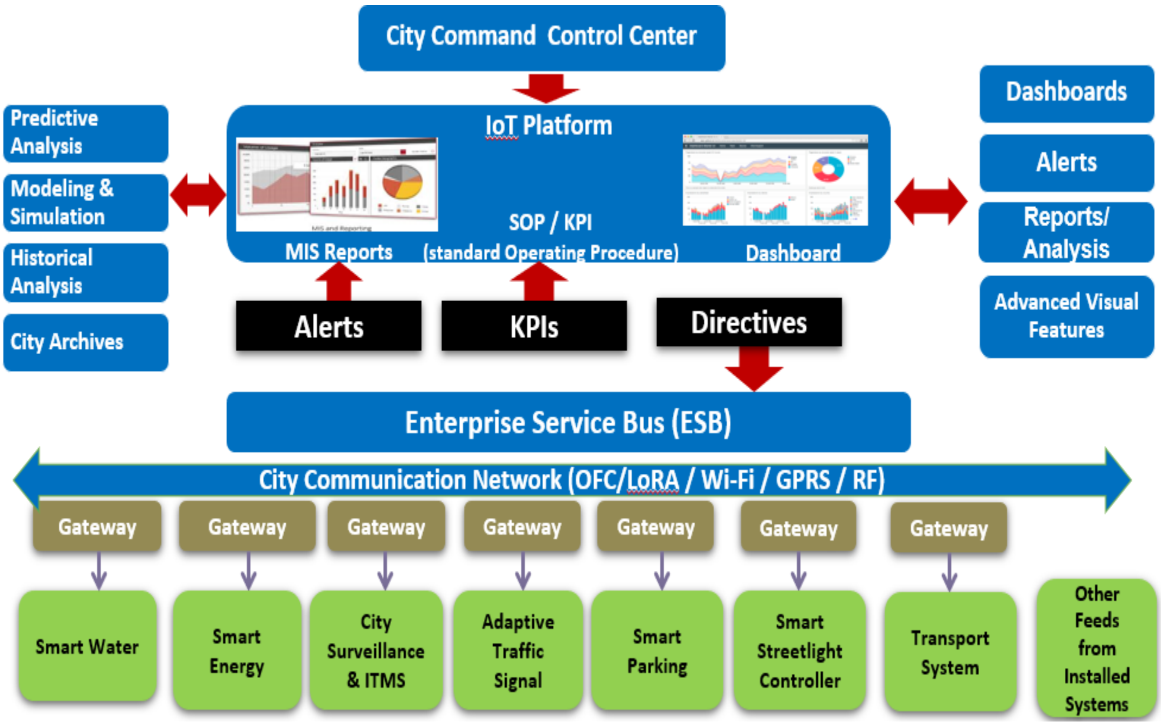

Figure 4. City Command Control Centre

The various applications implemented for smart city projects include:

- City Surveillance system
- Integrated Traffic Management system
- Integrated Transportation system
- Smart Parking System
- Smart Street Lighting system
- Smart Metering & Smart Utility
- Integrated Command Control Centre
- Smart Solid Waste Management system

The advancement of physical infrastructure and efficient communication have aided the smart city management in real time decision making. IoT has connected the various objects of different applications in order to enhance the quality of communication and availability of voluminous real time data for further analysis. This information is exchanged between various smart city applications using IoT sensors and cloud platform.

2.1.2 Remote Machine Monitoring

In the earlier days, machine performance in process plants required personnel to physically visit the site and take measurements or check the healthiness of the equipment.

Now, with the implementation of IIoT in process plants, the healthiness of the equipment in real time can be monitored remotely. This can be achieved by providing smart sensors on the machine for measurement of additional parameters and connecting them to the cloud server. Data required for performing the Root Cause Analysis (RCA) is identified and sensors are provided on the equipment accordingly. Analysis of the data acquired from the sensors is utilized to generate patterns, thus enabling RCA.

Data can be analysed and by studying the patterns, the reasons affecting the equipment effectiveness and production can be derived, and the performance can be optimized. This can be applied for all equipment in the plant thereby increasing the efficiency of the plant and reducing the downtime.

KPIs such as Overall Equipment Effectiveness, Total Effective Equipment Performance, planned-vs-actual output, defects, count etc. are the key indicators to measure the effectiveness of IIoT implementation.

Some of the key processes and KPI's involved are:

- Monitoring & Reporting**:** With the provision of smart sensors on the equipment, voluminous data is available in the server. A digital image of the physical equipment called a 'Digital Twin' is created. A complete digital view of the manufacturing process comprising of equipment, piping, associated instrumentation and material flows is simulated. The information available can then be organized, manipulated, simulated and analysed. Real time patterns can be compared with the Standard patterns available with the OEM / standards, alarms and notifications about the deviation in process can be triggered and required actions can be taken.
- AI-Assisted Operation**:** In addition to forming the 'Digital Twin' and comparing the patterns, further value can be added by using techniques such as Machine learning and AI on the data**.** Algorithms can be written by using the process values, deviations, operator input and suggest corrective actions. This will enable the model to detect anomalies, alarm & alert the operator, predict system behaviour and reduce unplanned downtime.
- Autonomous Operation**:** Advanced control systems utilize the techniques of ML & AI and set up a rule based feedback control to enable a near autonomous operation. Complete plant operation can be achieved with minimal human intervention.

2.1.3 IoT based Energy Management

IoT based energy management systems utilize the smart energy meters and get the real time power consumption details to help optimize the use of electricity by applying sustainable energy consumption strategy based on the usage patterns. Energy management with Industrial IoT utilize the real time power consumption data. Based on the operating parameters such as temperature, pressure, and operating speed for the machines on the shop floor, the usage pattern is derived. Decisions to shift heavy energy usage machines to different time of the day and developing corporate sustainability goals are possible with the implementation of Energy Management System.

2.2 Proposed Work for future Enhancement in Advanced Asset Management (AAM)

Advanced Asset Management that comprises of a suite of software and services having the features of work process automation and digital twin analytics, helps to optimize the asset performance and O&M efficiency across equipment and the entire plant.

Objectives of AAM solutions are,

- Operational and process efficiency improvement for improved productivity and profit.
- Maintenance optimization to ensure asset availability, reliability and inventory optimization.
- Enterprise level integrated single window view of real time production and business data with intelligent decision support.
- O&M Personnel empowerment / Personnel optimization.

AAM suite of applications include,

2.2.1 Data management Infrastructure and Data Historians

It is a system platform with enterprise data historians (time series and transactional). The data historian is hosted on cloud with local historians per plant unit to capture and maintain data for minimum 3 months to avoid data loss in case cloud connectivity is interrupted. It is an enabler for all the four AAM objectives mentioned above.

2.2.2 Centralised Unified Monitoring System (CUMS)

CUMS is an enterprise digital solution for providing the operation and business intelligence across the plant units to achieve specified enterprise level KPI's, enterprise MIS, enterprise level visualization / dashboarding on videowalls and a decision support system from field operators to senior management.

2.2.3 Enterprise Asset Performance Management (EAPM)

This includes Reliability Cantered Maintenance solution for Maintenance optimization, Predictive Analytics based operational efficiency improvement which uses Advanced Pattern Recognition technique and predictive models-based data analytics. Motor Current Signature Analysis identifies faults in the initial stage for preventing damage and diagnosing motor failure and monitors the entire drive train for any anomaly. This can be applied to major variable speed drives as well as fixed speed motors. EAPM meets the AAM objectives a) & b) stated above.

2.2.4 Asset Information Management (AIM)

AIM is a central repository for information storage and retrieval to facilitate day-to-day information accessibility to the users preferably via web-based interface and for future engineering modifications and upgrades during plant operations. It integrates plants 3D and 2D data with direct navigation facility from a chosen asset of interest. AIM is an information digital twin and meets the specified AAM objectives c) & d) explained above.

2.2.5 Digital Worker (DW)

DW includes Mobility tabs, Digital helmet with integration to SAP, EAPM and AIM solution suite. DW is a mobile application for viewing, modifying data and documents to support the site worker in activities of MRO (Maintenance, Repair and Overhaul). DW supports worker in site navigation, and visualizing POI (Point of Interest) areas on site. DW meets the specified AAM objective of d) mentioned above.

2.2.6 Operator Training Simulator (OTS)

AR/VR based training platform enables the worker for specialised equipment operation and its maintenance. OTS training is envisaged for the major equipment/systems in the plant. OTS meets the AAM specified objective of d) stated above.

The above systems can be integrated on to a platform to view the complete AAM solution at centralised enterprise level on video wall and on client’s machines located across plant areas.

3. Challenges & Gaps in the Implementation of IIoT

The deployment of IoT ranges from consumer -based applications to industries having mission critical applications leading to Industry 4.0 compliance. IIoT has led to the digitization of production processes transforming the physical objects / devices to the digital & intelligent devices within the factory. Common applications are predictive maintenance, intelligent measurement technology, asset management and fleet management. The challenges of implementing IIoT as depicted in Fig.5 are:

3.1 High investment cost

In order to comply with the Industry 4.0 practices, intelligent sensors, network components, analytics software etc. are required to be procured. Initial implementation without much knowledge on the subject and its ROI is a challenge.

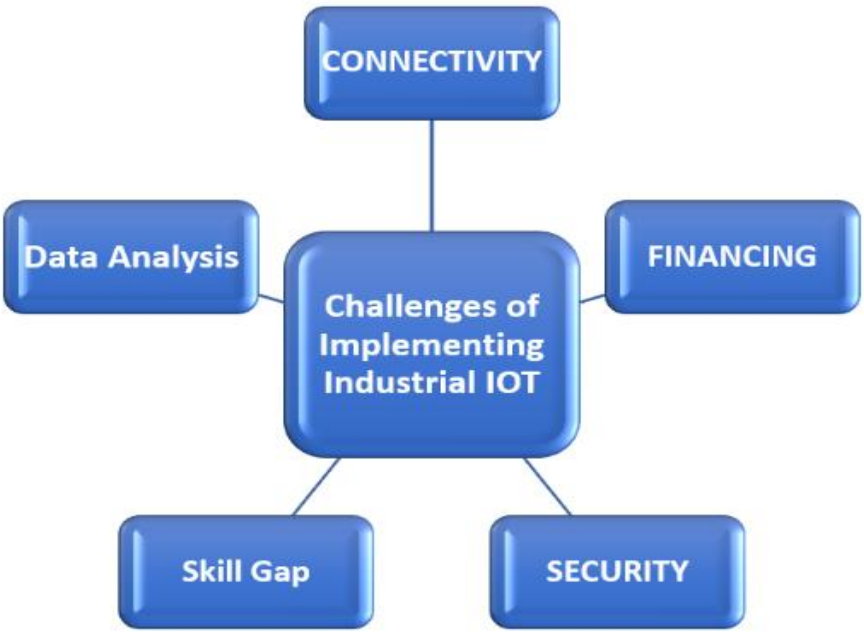

Figure 5. Challenges of Implementing IIoT [12]

3.2 Connectivity

Implementation of IIoT requires a good & reliable internet connectivity. Existing legacy sensors do not support data driven tools & connectivity. The number of connected devices is growing rapidly as compared to the capacity, speed & bandwidth of the network coverage. Hence internet may not be available at the desired speed and connectivity issue can be a challenge for implementation of IIoT. Thus, for Industrial IoT applications, a scalable IoT network which can connect devices & servers is critical.

3.3 Cybersecurity

Cyberattacks are on the rise. In case of such an attack on Industrial IoT, the sensitive data can get exposed causing huge physical damage to machines and could bring the entire production to a standstill. Thus, security challenge is the biggest cause of concern which affects both individuals and organizations leading to financial loss and operational damage.

3.4 Data Analysis

Digitalization in IIoT expands manufacturing facilities with tools for data acquisition, analysis and visualization which transforms raw data from sensors into usable insights. The analysis of this voluminous data requires skilled resources as the job is multidisciplinary, and critical business decisions need to be taken effectively.

3.5 Skill Gap

The most challenging issue with IIoT is the need for a skilled resource. Many companies are finding it hard to hire technically competent staff and this has been a concern in adopting IoT. Skilled resource is required for the analysis of the voluminous data from the sensors, maintaining the industrial networks, and to update and transform business operations.

4. Conclusion

Industrial IoT (IIoT) is the developing technology which will change the industrial working processes completely. Hence it is necessary to understand the IIoT technology and its uses in the industry. It is a collaboration of many existing technologies and now it is being used with big data, sensor data & cloud computing with the intent of automating the monitoring, maintenance, logistics and process management. With the attempt to miniaturize the size of the sensors, actuators, RFIDs and embedded systems, IIoT applications are getting increasingly powerful and less expensive. IIoT devices in future shall be developed to support the current emerging technologies such as Artificial Intelligence, Machine Learning, Virtual Reality & Augmented Reality. Such devices should be available in good numbers at a reasonably affordable price for the industry to take advantage of the opportunities. With the inclusion of these advanced features in the IoT devices, the installation and deployment of the network becomes simpler and the system can be implemented & proven with minimum manual & physical interactions. However, everything good comes with a price. With the advancement in technology, substantial production complexities, security, connectivity, reliability and compliance issues have to be overcome to meet the demand for the next generation IoT devices.

References

1. Amin, Aasif, Saied Riyaz, Abid Ali, and Zubair Paul. "Review of iot data analytics using big data, fog computing and data mining." Int J Comput Sci Mob Comput 6 (2017): 33-39.
2. Lou, David Zhe, Jan Holler, Ericsson Cliff Whitehead, Rockwell Automation, Sari Germanos, B&R. Michael Hilgner, and Wei Qiu. "Industrial networking enabling IIoT communication." IIC: WHT: IN23: V1. 0: PB: 20180829 (2018).
3. Gupta, Vijay Prakash. "Smart sensors and industrial IoT (IIoT): a driver of the growth of industry 4.0." In Smart Sensors for Industrial Internet of Things, pp. 37-49. Springer, Cham, 2021.
4. Misra, Sudip, Chandana Roy, and Anandarup Mukherjee. Introduction to industrial Internet of Things and industry 4.0. CRC Press, 2021.
5. Gusmeroli, Sergio, Oscar Lazaro, Željko Pazin, Chris Decubber, Paolo Pedrazzoli, Didier Vanden Abeele, Sara Tucci-Piergiovanni et al. "Industrial Internet of Things and the Innovation Processes in Smart Manufacturing." In Building the Hyperconnected Society-Internet of Things Research and Innovation Value Chains, Ecosystems and Markets, pp. 145-187. River Publishers, 2022.
6. Gupta, Deepak, Victor Hugo C. de Albuquerque, Ashish Khanna, and Purnima Lala Mehta. Smart Sensors for Industrial Internet of Things. Springer International Publishing, 2021.
7. Munshi, Usha Mujoo, and Neeta Verma, eds. Data Science Landscape: Towards Research Standards and Protocols. Vol. 38. Singapore: Springer, 2018.
8. Rathore, M. Mazhar, Awais Ahmad, and Anand Paul. "IoT-based smart city development using big data analytical approach." In 2016 IEEE international conference on automatica (ICA-ACCA), pp. 1-8. IEEE, 2016.
9. Xu, Xiaoxiao, Mingdan Han, Senthil Murugan Nagarajan, and Prathik Anandhan. "Industrial Internet of Things for smart manufacturing applications using hierarchical trustful resource assignment." Computer communications 160 (2020): 423-430.
10. Malik, Praveen Kumar, Rohit Sharma, Rajesh Singh, Anita Gehlot, Suresh Chandra Satapathy, Waleed S. Alnumay, Danilo Pelusi, Uttam Ghosh, and Janmenjoy Nayak.

"Industrial Internet of Things and its applications in industry 4.0: State of the art." Computer Communications 166 (2021): 125-139.

11. Rathore, M. Mazhar, Anand Paul, Awais Ahmad, and Gwanggil Jeon. "IoT-based big data: from smart city towards next generation super city planning." International Journal on Semantic Web and Information Systems (IJSWIS) 13, no. 1 (2017): 28-47.
12. http://www.xorlogics.com/2020/08/31/top-5-challenges-of-implementing-industrial-iot/