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A Review of Applications, Enabling Technologies, Growth Challenges and Solutions for IoT/IIoT

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Abstract—**The Internet of Things (IoT) defines ubiquitous connectivity between the internet and common objects. The functionality of IoT is based on the deployment of millions of smart devices in real-life and industrial ecosystems. These internet in devices collect the data from surrounding ecosystems, perform required processing tasks on data obtained and transmit process datasets through reliable and secure channels of communication. Recent trends and advancement in communication networks, software and hardware have fundamentally enhanced the lifestyle of humans in terms of cost, energy and time savings. IIoT (Industrial Internet of Things) defines the application of convectional IoT elements in factory application. IIoT enhances manufacturing processes by allowing efficient and sustainable technological developments in an industrial ecosystem. In this paper, a review of IoT and IIoT applications; enabling technologies for IoT/IIoT, growth challenges and solutions of IoT and IIoT; and recommendations on the IoT and IIoT growth and performance has been provided. This paper provides a basis for the establishment and advancement of IoT/IIoT use in an industrial environment.**

Keywords—Machine Learning (ML), Artificial Intelligence (AI), Internet of Things (IoT), Industrial Internet of Things (IIoT)

I. INTRODUCTION

Intelligent manufacturing systems require novel solutions to enhance sustainability and the quality of industrial procedures while minimizing costs. In the modern industrial ecosystem, technologies driven by Artificial Intelligence (AI) and enabled by 14.0 KET (Key Enabling Technologies) such as cloud computing, complex embedded systems and Internet of Things (IoT), virtual reality, augmented reality, big data and cognitive systems are poised to enhance novel industrial paradigms. "Artificial Intelligence" was initially established in 1990s by John McCarthy as "the science and technology of developing intelligent machines, especially smart computer programmes," and this definition is still relevant today. As a general rule, the word "Artificial Intelligence" refers to a computer's ability to do tasks traditionally performed by humans, such as learning and problem-solving.

There are 16 broad categories within artificial intelligence. Reasoning and programming are only two of the many things that pop into people's heads when they think about these topics. The things humans do when they think about logic and programming will also be discussed. Engineering, science, education, medicine, business, accountancy, finance, commerce, and other aspects of the economy, stock market, and legislation are all included in the twenty-first century. After having had such a significant impact on business, governments, and society as a whole, artificial intelligence has broadened greatly in scope. The broader trends in sustainable construction are also affected by their actions. In the quest for more environmentally friendly industrial methods, artificial intelligence (AI) holds great promise (for instance, the optimization of energy resources, logistics, the supply chain, and waste treatment). As a result, there is a growing trend in smart manufacturing to use Artificial Intelligence (AI) in environmentally friendly manufacturing processes. According to [1], "If we properly apply AI, we might witness a transformation in sustainability,"

In the industrial revolution 4.0, artificial intelligence will be the driving force. Because of this, today's tech giants are focusing on AI subspecialties such as deep learning, computational linguistics, image analysis, and data mining. Artificial Intelligence (AI) is a hot topic in science right

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now, because to the rapid advancements in technology. Rapid progress has been made in the area of Machine Learning (ML) as part of artificial intelligence (AI). It is currently used in a wide range of industries, including industrial automation, health research, pharmaceuticals, agribusiness, archaeological, gaming, and commerce, to name a few examples. The IIoT industry is now seeing significant expansion and rising adaptability as many sectors undertake digital changes. Increasingly, large corporations across the globe are putting their money into the IIoT because of the strong partnerships formed and the convergence of interests between IIoT participants and new applications. The IIoT industry is predicted to grow by up to $110.6 billion USD by 2025, according to [2].

IIoT systems' interconnectedness has increased rapidly throughout the fourth industrial revolution. Smart applications in the Internet of Things (IoT) rely significantly on the smart processing of huge data. As a result, IIoT networks need frameworks for intelligent information processing in order to analyse large amounts of data. An IIoT system may benefit greatly from the application of artificial intelligence (AI), especially deep learning (DL) methods, to provide useable results from massive data sets. A good example of how DL works is in the ability of the system to learn from its mistakes. The features and type of the data and the effectiveness of the training set both influence the efficiency and efficacy of a DL solution. The selection of a DL algorithm for a certain application might be difficult. Understanding how different deep learning algorithm's function and how they may be used in real-world scenarios such as smart homes and cities as well as in the healthcare and transportation industries as well as in sustainable agriculture and corporate operations is thus critical. The latest and most cutting-edge research in this subject may reveal the potential of DL in IoT and IIoT applications.

TABLE I. OPERATIONAL DISTINCTIONS BETWEEN IIOT AND IOT SYSTEMS

Concentrations	IoT	IIoT
Maintenance	Client preferred	Planned and scheduled
Resilience	Not needed	High Fault Tolerance (HFT) needed
Output	Utilization and convenience	Operational effectiveness
Programmability	Easy offsite programming	Remote onsite programming
Accuracy and precision	Effectively surveyed	Synchronization with milli-seconds
Scalability	Low scale networks	Large-scale networking system
Interoperability	Autonomous	CPS-integrated
Risk and security measures	Utility centric	Robust and advanced
Focus developments	Intelligent devices	Industrial system
Areas of focus	General application	Industrial application

There is a distinction between the IoT operations and IIoT operations as shown in Table I above. ML and AI operations are critical to maximising the value of industrial internet of things (IIoT) and IoT systems. In spite of the enormous volume of IoT data collected, enterprises are falling short of their business performance management targets due to AI and ML being unable to handle real-time difficulties. The promise of improved operational effective may be realised if industries address the issue of AI/Ml workload scalability right from the start. In this paper, a review of IoT and IIoT applications; enabling technologies for IoT/IIoT, growth challenges and solutions of IoT and IIoT; and recommendations on the IoT and IIoT growth and performance has been provided. For systematic presentation of this aim, this paper has been arranged as follows: Section II presents an overview of AI, ML, IoT and IIoT. Section III outlines the major contributions of this research. Section IV presents a critical analysis of the work, while Section V draws conclusions to the research.

II. OVERVIEW OF AI, ML, IOT AND IIOT

A. *Artificial Intelligence (AI)*

In contrast to the natural intelligence produced by animals, including humans, Artificial Intelligence (AI) is the intelligence demonstrated by robots [3]. Intelligent agents, as defined by most leading AI textbooks, are any systems that are able to comprehend their surroundings and take actions to maximise their chances of succeeding. According to certain popular accounts, robots that simulate "cognitive" processes like "learning," "problem solving," and so on, are referred to as artificial intelligence. This definition, on the other hand, is rejected by the majority of AI scientists. Artificial Intelligence and robotics are advancing at an accelerating pace across a wide range of industries: search engines (Google, YouTube, Amazon, Netflix), recommendation systems (e.g., Alexa and Siri), and autonomous vehicles (e.g., Tesla), autonomous decision-making, and high-level strategic gaming system (e.g., Battlefield) (such as chess and Go). The so-called "AI effect" occurs when jobs that were formerly regarded to need "intelligence" are progressively excluded from the concept of AI as technology advances. For example, Optical Character Recognition (OCR) is often left out of discussions on Artificial Intelligence (AI) despite its widespread usage.

When artificial intelligence was first established as an academic study in 1956, there was a rush of euphoria, which was quickly followed by disillusionment and the lack of funding (referred to as an "AI winter"). Although various ways have been attempted from the beginning of AI research (such as modelling human problem solving and replicating the brain), many of these approaches have been rejected. Mathematical and statistical machine learning has become the most popular in the early 21st century. Many difficult challenges in business and academics have been successfully addressed using this approach.

Research in artificial intelligence is broken down into a number of distinct subfields, each with its own specific aims and techniques. An important aspect of Artificial Intelligence (AI) research is the development of systems that are able to make decisions based on their own understandings of the world around them. Historically, these have been some of the aims of AI research. One of the long-lasting purposes of the domain is general intelligence (the capability to mitigate any issue. Formal logic, Search and Optimization algorithms, and Artificial Neural Network (ANN) [4], and approaches based on statistics, probabilities, and economics have all been modified and combined by AI researchers to overcome these difficulties. Many other disciplines, in addition to computer science, are also relevant to AI. Initially, the area was founded on the belief that human intellect could be "completely characterised such that a computer may be made to behave like it." " As a result, a slew of philosophical questions regarding the nature of consciousness and the propriety of building intelligent machines arise. Since antiquity, myth, literature, and philosophy have examined these topics. Artificial Intelligence (AI) has been predicted in science fiction and futurology to be a danger to mankind because of its immense power and potential.

B. *Machine learning (ML)*

Computerized systems that can learn and improve themselves via experience and the utilisation of data are known as Machine Learning (ML). It's considered a component of AI. In order to generate predictions or judgments without being explicitly programmed, machine learning algorithms construct a model using training data. ML approaches are used in a broad range of applications, such as email filtering, medicine, voice recognition, and machine learning, when traditional algorithms are either ineffective or hard to build. As a subset of machine learning, computational statistics employs computers to make predictions, although not all machine learning is statistical. The discipline of machine learning gains new techniques, theories, and application fields from the research of mathematical optimization. Unsupervised learning and exploratory data analysis are two related fields of research. Data and neural systems are used in certain machine learning implementations in a manner that resembles biological brain functions. Predictive analytics is a term used to describe the use of machine learning to solve business challenges.

If a strategy, algorithm or inference functioned well in the past, it's a good bet that it will work well in the future, as well. For example, “since the sun has risen each morning for the past ten thousand days, it is probable that it will rise again tomorrow”. For instance, “X% of families integrate geographically distinct species with variations in color, hence there is Y% probability that unknown black swan is present." Programs that use machine learning to complete tasks do not need to be explicitly coded. In order to do specific jobs, computers must learn from the data that is presented to them. It is feasible to write algorithms that teach computers how to do all of the steps necessary to solve the issue at hand; computers do not need to learn how to do this. The creation of algorithms for increasingly complex jobs by hand might be difficult for a person. For practical purposes, it may be more efficient to let the machine figure out how to do things on its own rather than relying on human programmers. Machine learning is a branch of computer science that uses a variety of techniques to educate computers to do jobs for which there is no totally suitable solution. There are several ways to deal with a question that has a large number of possible solutions. So that the computer's algorithms that decide accurate responses may be improved, this data can be utilised as training. Digital character recognition systems often train on the MNIST dataset, which contains handwritten digits.

C. *Internet of Things (IoT)*

IoT offers a wide range of applications, including ecological, industrial, private/public, transportation, medical, etc. IoT has been described in a variety of ways by researchers with varying specialties and points of view. The IoT's potential and strength may be observed in a variety of use cases. In the past few years, a number of key IoT initiatives have taken the industry by storm. Some of the most significant IoT projects that have dominated the industry are shown in Table II. Table II shows the worldwide distribution of IoT solutions across Asian and Pacific areas, European and American region. The American region contributes significantly to the medical services and the supply chain design initiative whereas the European continent contributes effectively to the smart

TABLE II. GLOBAL MARKET SHARE OF IOT APPLICATIONS

IoT project	City Distribution – Project No.		
	America	Europe	APAC
Interconnected firm	40	70	90
Smart urban environments	30	80	90
Smart power	50	70	100
Interconnected vehicles	40	70	90
Smart farming	50	80	90
Interconnected buildings	50	80	90
Interconnected healthcare	60	90	100
Smart retail	50	80	90
Smart supply chain	55	90	95

Smart vehicles, smart energy, smart cities and industry automation all have a vital market share when compared to the other IoT applications.

One of the hottest areas of IoT application right now is smart cities, which includes home automation as well. Home appliances, heating and cooling systems, TVs, and audio/video streaming devices all connect with each other to deliver the optimum comfort, stability, and energy usage in a "smart" home. The Internet of Things (IoT)-based central control unit handles all of this connectivity. Smart cities" have been a hot topic of discussion and study since they emerged in the previous decade. By 2022, the home automation business industry is expected to be worth more than $100 billion [5]. Smart houses not only make life easier inside, but can also save their owners money in other ways, such as lowering their monthly power bill due to their decreased energy usage. Smart automobiles are another component of the smart city, in addition to smart residences. Intelligent gadgets and sensors are now standard equipment in most modern automobiles, and they regulate everything from the headlights to the engine. Car-to-car and car-to-driver wireless communication is being developed by the Internet of Things (IoT) to enable predictive maintenance and a safe and pleasurable driving experience.

TABLE III. GLOBAL SHARES OF IOT PROJECTS IN THE GLOBE

IoT project	Global shares of IoT projects
Interconnected firm	23
Smart urban environments	21
Smart power	14
Interconnected vehicles	14
Smart farming	7
Interconnected buildings	6
Interconnected healthcare	6
Smart retail	5
Smart supply chain	5

Smart city applications may benefit from IoT systems for smart energy control, according to [6]. They said that at this point, IoT is only being used in a handful of sectors to benefit both technology and humans. In the coming years, IoT will indeed be able to cover practically all application domains because of its enormous breadth. The IoT can aid in the development of a smart energy management system that saves both energy and money, according to the report. For the smart city idea, they proposed an IoT architecture that incorporates sensors. The instability of IoT software and hardware is also a challenge, according to the authors. They opined that these problems must be addressed if the Internet of Things is to be dependable, efficient, and easy to use.

To deal with the problem of urbanisation, urban regions are becoming more crowded as people relocate from rural areas to cities. Because of this, smart solutions for transportation, energy, medicine, and infrastructure are required. Table III provides a representation of the global shares of IoT projects in the globe. For IoT developers, smart cities are a significant area of focus. There are several concerns that are addressed, including traffic control, air quality strategic planning, public health and safety solutions, parking management, smart lighting, and smart garbage collection. They said that the Internet of Things (IoT) is striving hard to address these concerns. Entrepreneurs in the area of smart city technology have been able to take advantage of the rising demand for smart city infrastructure and urbanisation. As a result of their research, the authors in [7] came to the conclusion that IoT-enabled technologies is critical to the creation of long-term smart cities.

D. Industrial Internet of Things (IIoT)

The terminology "industrial internet of things" (IIoT) alludes to a network of integrated sensors, analyzers, and other devices used in transportation and industrial management that are linked to computers for industrial purposes. It is possible that increased production and effectiveness, and other economic advantages, will result from this newfound connectedness. IIoT process controls may be made more efficient and accurate by using cloud computing, which is a development of distributed control systems (DCS). As a result of advancements in technologies like cybersecurity, cloud technology, wireless technology and machine-to-machine (M2M) communication and sophisticated robotics (such as 3D printing), IoT is being developed. The following are five of the more significant ones.

- Cyber-physical systems (CPS): The fundamental technical foundation for the IoT and IIoT, and as a result, the primary facilitator for connecting previously isolated physical equipment. Software and communication dynamics are included into CPS, which provides abstractions as well as modeling, design and analysis tools.
- Cloud computing: Instead of connecting directly to a server, IT resources and services may now be stored and accessed through the Internet via cloud computing. Cloud-based storage systems may be used instead of local storage devices for storing files.
- Edge computing: A computing model in which data storage is moved closer to the point of use, using a distributed computing architecture. Instead of relying on centralized data processing, edge computing utilizes distributed processing at the network's perimeter. An edge-plus-cloud framework rather than a purely consolidated cloud is needed for the industrial internet to convert productivity, products, and services.
- Big Data Analytics (BDA): BDA refers to the procedure of evaluating big and diversified data collections, or "big data," in order to get insights.
- and machine Learning (ML) and Artificial intelligence (AI): As a branch of computer science, artificial intelligence (AI) creates intelligent robots that behave and respond like people. AI relies heavily on machine learning to improve software's ability to make educated guesses about the future. In order to deliver industrial edge intelligence solutions, artificial intelligence and edge computing may be combined.

The Industrial Internet of Things (IIoT) [8] is often thought of as a layered, modular digital technological infrastructure. CPS, sensors, and machines all fall within the device layer. In the service layer, which is comprised of applications that alter and combine data, the network layer comprises of network buses, cloud computing, and communication protocols that aggregate and transmit data. The user interface or content layer is the topmost layer of the stack (see Table IV).

TABLE IV. LAYERING OF THE MODULAR IIOT ARCHITECTURE

Layers	Components

Devices	Hardware – Sensors, machines, CPS
Networks	Communication protocols – Cellular networks, LoRa, Bluetooth, and Wi-Fi
Services	Applications software for data analysis, and transformation to actionable data
Contents	Devices for user interface – Smart surfaces, smart glasses, tablets, PoS stations, computer sensors.

This section provides an introduction to the fundamental concepts and features of the IIoT. It's possible to think of the industry 4.0 and IIoT as the same phenomena, but with somewhat different labels because of their slightly distinct realms. Fig. 1 summarizes the most important aspects/components of the IIoT. This paradigm's key characteristic is a high degree of interconnectivity across various industrial entities, one of IIoT's main aims being the connection of physical things through Internet. In conjunction with intelligent software, this is a key element that enables the development of increasingly sophisticated technological systems that can be monitored and controlled remotely through software programs. It is also expected that new software algorithms that may optimize systems autonomously would be implemented as part of the IIoT paradigm to enhance operating characteristics (time efficiency, cost reduction, energy consumption).

The Industrial Internet Consortium (IIC) [9] provided a standard architecture for IIoT when it was first presented. The edge, platform, and enterprise levels of this reference design are conceptually separated. The edge tier is in charge of gathering data from the edge nodes and sending it to the platform layer. This is the layer that is responsible for the delivery of BDA and operations, as well as management of industrial assets, to the platform. End-users will interact with the enterprise tier through a variety of decision support and application systems. There is a plethora of other architectures in the literature, all of which cater to a certain application area. There are a large number of suggested designs based on Software-Defined Network (SDN). In line with the IIoT concept, Chen, Guo, Li, and Shi [10] describe a five-layer design for distributed networked control systems. As a result of their suggested design, the control process in dispersed networks is facilitated and the construction of agents is possible. For example, [11]. presented numerous methods for making water infrastructure-based sensors self-powered via the use of water-based energy.

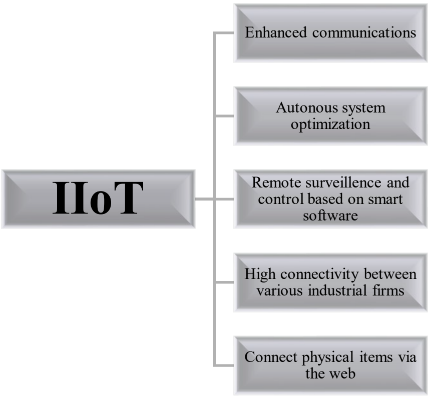

Fig. 1. Major components of IIoT

When it comes to smart meters, Lang et al. [12] have developed a prototype that can connect through CAN interface or radio and operate as a repeater for data collected by other sensors. It also monitors electrical power in both directions (active and non-active energy). Authors in [13] present multiple communication protocols employed in an IIoT environment: Advanced Message Queuing Protocol (AMQP), Constrained Application Protocol (CoAP), Message Queuing Telemetry Transport (MQTT), Hypertext Transfer Protocol (HTTP), and OPC Unified Architecture (OPC UA).

The major contributions of this research paper have been presented in Section III below.

III. MAJOR CONTRIBUTION

The main contributions of this research include:

- Review the major components of the research i.e., ML, AI, IoT, and IIoT;
- Discussing the applications of IoT, and IIoT;
- Defining the growth challenges and potential solutions; and
- Recommendations for future growth and performance enhancement.

IV. CRITICAL ANALYSIS

A. Application of IIoT/IoT

1) Digital Health /Telemedicine/ Telehealth (Connected Health): The Internet of Things (IoT) may be used in a number of ways in the healthcare industry, from remote access to machine integration to smart sensors. It has the capability to transform the manner in which physicians handle patients while also maintain a safer and healthier ecosystem. Health IoT allows users to spend much time interacting with caregivers, hence increasing the engagement of doctors with patients. Healthcare IoT presents new tools that are up to date with the latest ecosystem technology, helping to produce better healthcare. These tools range from personal fitness devices to surgical robots. Patients and healthcare providers benefit from the Internet of Things (IoT) because it offers practical, low-cost solutions. The Internet of Things' sleeping giant, connected healthcare, is still inert. The concept of a connected healthcare system and smart medical equipment has enormous potential for both corporations and the general public. Health care is expected to benefit greatly from the Internet of Things (IoT). Individuals will be able to lead healthier lives thanks to IoT in healthcare. In order to better understand the health of each individual and devise personalized strategies for combating disease, the collected information will be used to create an individual profile. Here's an example of how the Internet of Things (IoT) might have a significant impact on medical care.

2) Smart City: Another intriguing use of IoT is in smart cities, which has piqued the interest of people all around the globe. In the context of smart cities, internet of things technologies includes smart surveillance equipment, smarter power management, automated transport networks, potable water, urban security, and environmental control. Major urban issues such as air pollution, traffic jams, and energy shortages will be alleviated thanks to the Internet of Things. Smart Belly garbage can provide notifications to municipalities when a bin ought to be emptied through cellular connectivity. Sensors and web-based apps may be used by residents to locate open parking spaces around the city. Sensors also detect tampering with meters, general failures, and any installation problems in the power system.

3) Connected Cars: The digital technology in automobiles has centered on improving the internal operations of cars. As a result, an increasing amount of focus is currently being placed on ways to improve the in-car experience. On-board sensors and internet connection allow a connected automobile to improve its own operation, repair, and passenger enjoyment. Large automakers, as well as some daring entrepreneurs, are developing linked automobile technologies. Google, Apple, BMW, Tesla are just a few of the well-known companies aiming to usher in a new era of transportation. The system of sensors, embedded software, antennas and other technologies, which make up connected automobile technology is large and comprehensive. It helps drivers navigate our increasingly complicated environment. It is tasked with making choices consistently, accurately, and at a rapid pace. It must also be dependable. In the future, when humans relinquish control of the steering wheel and brakes to autonomous or automated cars, these needs will become even more crucial.

4) Smart Home: The Smart Home is now the revolutionary rung on the domestic success ladder, and it is expected that Smart Homes will be as popular as smartphones. When we think about the systems of IoT, smart automation is the most vital and effective application, which leaps out every time. Smart Home firms have received more than $2.5 billion in investment to far, a figure that is expected to rise steadily. What if you could activate the air conditioning or turn off the lights before you even get to your house? Alternatively, you may provide temporary access to friends' doors even if you aren't at home. Make no mistake: With the Internet of Things (IoT) gaining traction, businesses are developing devices that make your life easier and more pleasant. Owning a home is by far the most expensive investment a person can make. Time, energy, and money are all said to be saved by using smart home technology. Several smart home technology businesses, such as Nest, Ecobee and Ring will soon be household names, and they have big plans to provide consumers with an experience like no other.

5) Smart Farming: Smart farming is an underappreciated IoT use case. In contrast, distant agricultural operations and a huge number of cattle can be traced by IoT that will affect the manner in which agriculturalists operate and help them better manage their operations. However, this concept has failed to gain widespread traction. Nevertheless, it is one of the IoT applications that should not be undervalued at this point. Smart farming has the potential to be a significant application field, particularly in countries that export agricultural products.

6) Smart Retail: Increasing sales, decreasing theft, improving inventory management, and improving the shopping experience of customers are just a few of the benefits that retailers have begun implementing IoT solutions and IoT embedded systems for. The Internet of Things (IoT) gives brick-and-mortar retailers a leg up on their online counterparts. In order to reclaim the lost share of the market, they can possibly interact with customers to store, hence making it easier for them to purchase more and store funds with ease. IoT has huge promise in the retail industry. Using the Internet of Things (IoT), retailers can connect with their customers and improve the shopping experience in the store. Retailers will be able to keep in touch with their customers even when they are not in the shop thanks to smartphones. Beacon technology and smartphones can help retailers better serve their customers. The layout of a store can be improved by following the path taken by customers and placing high-end items in the most visible areas.

7) Smart Supply Chain: For the last several years, supply networks have been becoming more intelligent. Some of the most popular services include enabling suppliers communicate inventory information and providing solutions for challenges like monitoring items while they are in route. An IoT system enables manufacturing tools with integrated sensors to possibly exchange data about different features, e.g., temperature and pressure, and the use of machines. It is possible for IoT systems to process the operations and adjust the settings of equipment to improve performance.

B. Enabling Technologies

1) IoT: In this section, we will go through some of the core IoT technologies in production in this part.

a) Wireless Sensor Networks (WSN): Running wires on a manufacturing floor is difficult because of the dangers and expenses involved. These problems are made worse by increasing separation between the connecting nodes. Remote monitoring of environmental or physical factors is made possible by WSNs, which provide a large number of geographically dispersed sensor nodes that are wirelessly linked through gateways. Sensor interface, analogue circuit, micro-controller, battery and radio are the elements of a typical WSN node that is self-contained. Power-hungry gadgets are generally the consequence of high data rates. The scale of the manufacturing plant, the number of physical assets that need to be monitored, and their placement in the plant all have a role in the selection of communication technology for the shop floor.

b) Smart Sensors: Since its inception, sensors have developed from large, single-purpose devices to tiny, multi-variable sensors. All data that may be used to make business choices is gathered by sensors. Using local processing power, a smart sensor can process raw data in real time and avoid network latency difficulties. This function is largely reserved for specific hardware in certain smart sensors. In the industrial industry, sensors are already being utilized to keep tabs on machinery and processes. 35 percent of the manufacturing sector in the United States is already utilizing data from smart sensors implanted in equipment to improve operational efficiency, according to a recent PwC poll.

c) Big Data Analytics: It is predicted that each plant generates over 1000 Exabytes (or 1 Zetabyte) of raw data each year, which is projected to rise in the future years as more sensors are used. In order to detect trends among process variables and outputs, this huge volume of data, known as "big data," must be evaluated in an effective and timely way. Big data analytics has already had a significant impact on industrial decision-making, and a number of new businesses are aiming to capitalize on this.

d) Cloud Computing: By removing upfront costs for localized computer resources and substituting this with lower-cost "pay-as-you-use" computing via the Internet, cloud technology is transforming the way businesses conduct business. This makes cloud computing a perfect platform for big data analytics since it can be scaled up and down on the go, making it a flexible solution. In response to the scalability, improved resource usage, and plug-and-play heterogeneous device networks of cloud computing, "Cloud Manufacturing" has emerged. With cloud manufacturing, hardware and software operations are virtualized to create a scalable, "elastic," virtual manufacturing company that can easily set up and shut down as needed. The Internet of Things (IoT) concept is predicted to benefit greatly from this.

2) IIoT: Enabling an array of initiatives of IoT, cloud computing, BDA, AI and cyber-physical systems—as well as augmented reality and virtual reality—as well as Humane–to–Machine and M2M communication—creates the foundation for IIoT.

a) IoT: A connected manufacturing scenario requires real-time data gathering and actuation, and IoT devices help with this. In the IIoT, these devices are the most important component, since they keep track of production assets all over the world. The whole manufacturing process, from raw materials to finished goods, is monitored by IoT devices in order to reduce labour costs and manual system administration significantly. Every manufacturing facility, from warehouses to manufacturing plants and distribution centres, is linked to an IIoT system that includes IoT devices. It is a difficult process that requires the use of highly skilled technical personnel in order to configure, install, monitor, and maintain these gadgets.

b) Blockchain: As the IIoT becomes a reality, critical technologies like as blockchain will play an increasingly crucial role. Academics and businesses are doing extensive study on the use of blockchain technologies in a variety of industries, including the financial sector, healthcare delivery, supply chain management, and vehicle insurance. Data generated by IoT-enabled industrial equipment is enormous. The data produced by these IoT equipment is multifunctional; it is collected and interpreted for device performance analysis, outlier detection, diagnostic tests, proactive maintenance, asset surveillance, and monitoring of the complete product life span from raw materials to finished goods and distribution to end users. Sharing this vital information with all parties participating in the IIoT system, nevertheless, is a difficult undertaking. IIoT is well-suited to blockchain technologies because of its unique features, such as its decentralized nature, provenance, resilience, trust, encryption, and intrinsic authenticity of data. In recent times, blockchain technology has been used to update IoT device software and regulate access.

c) Cloud Computing: In order to handle, process, analyse, and store the huge amounts of data generated by IIoT, distributed high computing systems are required. In an IIoT system, computation, networking, and storage are all provided via cloud computing. There is a direct link between the devices and the backend clouds. For example, private (owned and administered by the IIoT employees) or public (owned and operated by third-party data suppliers) cloud service models are available (a combination of the two service models). Private cloud service models are not a realistic choice for new entrant and/or small and medium-sized businesses because of the significant costs associated with building data centres and hiring technical employees. In order to combat corporate espionage and maintain a competitive edge, major and well-established transnational corporations choose to use private clouds.

d) Big Data Analytics: The IIoT devices and systems create enormous amounts of data, which necessitates the use of high-performance computing models capable of analyzing and processing big data. Because of delays and timeliness in IIoT networks, specifying when, how, and where to handle and analyse massive data may be difficult. IIoT systems allow various technologies for the collection, storage, administration, processing, analysis, and actuation of big data in order to completely coordinate big data analytics solutions. Sensors, smart devices, integrated data collectors, web-enabled information sources, and humane-machine motions in IIoT systems are just a few of the many data sources that may be connected to using the data gathering technologies. Similar to large data storage solutions, cloud settings benefit from cloud-based storage that is on-premises, on-network, in-network, and remote. Big data may be processed at edge devices, in cloud data centres, and near sensors with the help of data administration and processing technology. Data gathering, deep learning, machine learning, and model testing may all be performed at various levels in IIoT systems using different data analysis techniques. Allowing devices to interact with their surroundings, actuation technologies are used in the IIoT. Next-generation IIoT systems rely heavily on big data processing and insights, notwithstanding their complexity.

C. Growth Challenges and Solutions

1) Challenges:

a) High-Investment Cost: Industrial IoT has a number of problems, the most prominent of which is the high adoption costs. It's true that IoT promises to reduce expenses through improving asset management, gaining access to corporate analytics, and increasing productivity. The cost is difficult for organizations to justify when A: they don't know exactly what form of ROI they could project; B: they have not applied interconnected systems before. IoT adoption has been delayed by 29 percent of enterprises due to insufficient resources, Microsoft's 2019 IoT Signals research found.

b) Secure Data Storage & Management: The Internet of Things (IoT) devices create a lot of information. By 2025, according to a 2018 IDC white paper, the globe would have created 160 zettabytes of data, which is 10 times as much data as the world generated at the time the study was written [14]. In order to find patterns in real time, a large volume of data must be analyzed quickly. An organization's data monitoring, administration, and storage must be streamlined to enable for rapid reaction times to threats from the Internet of Things (IIoT). As a result, enterprises must prepare for both short-term (edge computing) and long-term (cloud or data centers) storage solutions, both of which must be safe. The ability to get real-time information is critical to reducing costs and avoiding downtime. Sensors, for example, may be used to monitor the functioning of critical equipment. A wear-and-tear detection system should be able to identify problems as they arise, allowing users to fix them before they cause production concerns that might cost the company money and time [15]. Additionally, software, devices, and sensors might bring with them new sorts of data that an organization may not yet be able to process.

If a manufacturing organization utilizes an ERP or MRP model, which utilizes relational database to maintain the tracks of inventories, SKUs, raw materials, new orders and pricing, this is an example of an ERP or MRP system. Managing heterogeneous data generated by IoT sensors in non-relational databases is a difficulty [16]. IoT insights, customer data and ERP data all have to be integrated into a single perspective in order for enterprises to get the most out of a connected system. One of the biggest IIoT challenges is that even when the firm is capable of integrating all the precise sensors, equipment, software, its ROI could only be attained if the firm has both proper skills and tools in place [17].

c) Connectivity Outage: Before embarking on a major IIoT transition, organizations need to keep in mind that there is a requirement for continuous, uninterrupted connection. Even if internet uptime is all you're after, it's almost hard to achieve 100 percent availability. Even whether it's due to a maintenance issue or anything else, the connection may be lost at some time. Organizations must thus choose an appropriate provider to satisfy connection needs in order to minimize downtime. Sadly, industry-specific standards differ widely. It has been found that enterprises must take into account factors like range, the locations (i.e., connections between different workstations or factories, and power use. A long-range low-power can be a major option for tracking assets for many years, while cellular connections could be the best option in case the system necessitates more bandwidth. Outages in the IIoT present a number of risks that go well beyond the inconvenience of a brief WiFi outage. Outages may be life-threatening when sensors are being utilized to identify dangers like gas leaks. The whole neighborhood might be left without electricity if the smart grid goes down.

d) Blending Legacy and IIoT Infrastructure: It's more likely that your IT and OT teams have complete insight and control over the whole IIoT ecosystem the more sophisticated it is. It becomes more difficult for workers to oversee and monitor and end-to-end operations whenever firms install IIoT devices onto the legacy tools and devices that have been produced by various vendors. No standards exist for how businesses should exchange data across different devices and technologies at this time. Interoperability and security of a system including equipment that was never intended to be "smart" are not addressed by any standard. However, it is possible for IT professionals to engage with the operations and management team to utilize similar standards they have employed for many years to guarantee hardware performance and security [18].

2) Solutions: In an effort to transform IoT's real-time production and process data into outcomes quicker, many firms are adopting edge AI efforts. To analyze and make suggestions using AI and ML models, companies implementing IIoT and IoT must deal with the obstacles of transporting the enormous amounts of integrated data to datacenters or centralized cloud platforms of their own design [19]. Edge AI solutions are becoming more popular as a strategy for tackling IoT's development issues because of the expensive expenses of expanding datacenter or cloud storage, bandwidth limits, and growing privacy concerns.

a) Smart Endpoints: Ambient intelligence can only be provided via a system of IIoT and IoT edge devices, not by themselves [20]. IoT and IIoT systems powered by edge AI will become the de facto norm in businesses that depend on supply chain transparency, speed, and inventory conversion period over the next three years or less. "Edge AI" is a key component of the IoT and IIoT ambitions of CIOs and IT executives in the financial products, logistics, and industrial industries. Contextually intelligent endpoints are needed by corporate IT and operational teams to increase transparency across real-time IoT sensing devices. Edge AI-based technologies will deliver real-time performance enhancement suggestions based on ML model outputs in the build-out plans.

b) Modeling Architectures: Rather than being an afterthought, AI and ML modelling should be a basic part of an IIoT/IoT design. Any IIoT or IoT system that attempts to include AI and ML modelling as an afterthought will only achieve minimal success. Reduced network latency and bandwidth are the primary concerns when designing an IIoT/IoT architecture that can enable model processing at many levels. When it comes to their IIoT/IOT designs, those who have achieved this state that their terminals are most secured, The Zero Trust Security architecture allows them to use a less privileged approach to gaining access to data.

c) Device Adaptability: The architecture of IIoT/IoT devices must be flexible enough to accommodate algorithm updates. To establish and maintain real-time synchronisation throughout a whole network, it is necessary to propagate algorithms down to the device layer across an IIoT/IoT network. It is, however, difficult to update IIoT/IoT endpoints with new algorithms, particularly for older devices and networks. In order for an AI edge strategy to be successful, it is critical that this difficulty be addressed in any IIoT/IoT network. There are thousands of Programmable Logic Controllers (PLCs) in use today, enabling control algorithms and ladder logic on production floors throughout the globe. IIoT devices with integrated Statistical Process Control (SPC) logic give process and product data in real time that are critical to the success of quality management. Since sensors are so good at detecting noises, fluctuations, and any change in process performance, the IIoT is being widely embraced for machine monitoring and maintenance. Machine interruption prediction and asset longevity are the ultimate goals of predictive maintenance. AI-based research by McKinsey asks, "What does Germany's industrial sector stand to gain by smartening up with AI?" Machine dependability may be increased by more than 20% using IIoT data paired with AI and ML, according to [15]. According to the research, yearly maintenance expenses may be lowered by up to 10% while inspections costs can be cut by 25%.

d) Vertical Market Analysis: The most popular IIoT/IoT systems are those that concentrate on a certain market niche. If an IIoT/IoT platform wants to grow, it has to focus on a certain vertical market and offer the tools to monitor, analyse, and operate complicated processes. This is where the specialisation comes in. When the prospect of IIoT/IoT development meets the complex requirements of a given market, an overhang of laterally oriented IoT platform providers must depend on partners to offer the depth that these markets demand. Most IoT platform suppliers have difficulties in achieving further market verticalization since their systems are designed to meet the demands of a wide range of customers. With its broad experience in retail and commercial structures, commercial manufacturing, life sciences, networked worker technologies and corporate performance monitoring, Honeywell Forge is an alternative to the rule. It is more normal for Ivanti Wavelink to acquire an IIoT system from its technological and channel partner WIIO Group. The acquisitions, mergers, and joint operations in IIoT/IoT sensor technologies, infrastructure, and networks are expected to rise in light of the revenue and cost savings organisations are obtaining across a wide range of sectors today.

e) Knowledge Transfer: Knowledge must be disseminated at a large scale. Knowledge transfer has become a strategic goal when employees retire and firms leave the conventional apprenticeship model. Smart phones that are contextual smart enough to deliver real-time data about present situations while giving contextual knowledge and background data are the ultimate objective for the next generation of employees. Present and future service employees will be able to depend on AI and ML-based technologies that index collected information and deliver answers to their inquiries in seconds, even if they lack years of experience and sophisticated skills in how to maintain machines. The key to answering the queries of present and future employees is to use AI and machine learning to extract information from departing workers. Contextualizing the expertise of departing employees will allow those on the front lines to better operate, maintain, and repair systems and equipment.

D. Recommendations For Growth: As per Microsoft's IoT Indicators Edition 2 report, a whopping 90% of business decision-makers feel that IoT is vital to their success. As shown in Table V, 76% of companies using IoT consider AI as either a primary or a secondary element when it comes to Predictive maintainability. Incorporating AI into IIoT/IoT strategies and tactics is primarily for 3 motives: enhancing user experiences, predicting maintenance needs, and preventing failures before they occur.

TABLE V. AI IN ADOPTION OF IOT

Purpose for AI in adoption of IoT	**Usage (%)**	**Considering Usage (%)**	**Usage/Considering Usage (%)**
Natural language processing and recognition	43	28	71
Visual image recognition & interpretation	44	28	72
Predictive maintenance	46	30	76
Client experience	46	27	73
Prescriptive maintenace	48	28	76

Artificial intelligence, digital twins, cloud technologies, and IIoT/IIoT technological capabilities in the workplace are all examined in Microsoft's IoT Indicators Edition 2 study. The following suggestions are based on interviews with industrial, supply chain, and logistics executives as well as an examination of the use cases presented in the Microsoft IoT Indicators Edition 2 research.

- Successful business arguments often involve revenue increases as well as expense savings. With the help of IIoT, manufacturing executives found that cost reduction projections were not enough to persuade their board to invest in tracking and tracing throughout their supply chains. There was less opposition to financing trials when the business case demonstrated how better insight faster inventory turns, increased cash flow, freed up working capital, or attracted new customers. A network's approval is more likely to be granted if more IIoT/IoT networks provide the data platform needed to allow real-time reporting and analysis for corporate performance management.
- Architect for the proliferation of AI-enabled edge devices now. Endpoint devices that can adjust

algorithms while ensuring least privileged access will be dominant in the future of IIoT/IoT networks. It is becoming more common for sensors to pose a major danger to networks because of their increasing intelligence and ability to monitor processes in real time. Today, smart manufacturing facilities are successfully implementing microsegmentation and imposing least privileged access to the particular sensor.

- AI and ML systems that can be used in finance and accounting from activities should be developed today, rather than later. The head of a production IIoT project indicated that top leadership and the board were sold on the initiative because of the capacity to interpret what's happening on the shop floor in real time on financials. The key to increasing productivity and yield rates is to understand how decisions about suppliers, equipment, and staffing affect those outcomes. In addition, everyone on the shop floor knows whether they met or exceeded expectations for the day. Using IIoT data to make instant trade-offs on product quality analysis reduces variability in real project costs.
- Design from the outset to assist the training of machine learning models. ML models become more beneficial as they get more context-independent, which means that a device's contextual intelligence may be more independent as well. An important part of the process is determining how and where changes might be made in a particular process using real-time data analysis. Data curation and contextualization may be provided by device-level algorithms today. It's possible to train ML models continuously using the data collected by autonomous cars' sensors.

V. CONCLUSION

In order for digital transformation programs to succeed, IoT data should provide the necessary information. AI and ML modeling contexts, workloads, and solutions at scale are not supported by older technological architectures and platforms, which restrict the utility of IoT data. A new IoT platform designed specifically to enable new digital business models is thus required for enterprises collecting large volumes of IoT data, particularly manufacturers. In this paper, a review of IoT and IIoT applications; enabling technologies for IoT and IIoT; growth challenges and solutions of IoT and IIoT; and recommendations on the IoT and IIoT growth and performance has been provided. In conclusion, this paper has provided a basis for the advancement of IoT/IIoT use in an industrial environment. Allowing the industry to gather and analyse a significant quantity of data, the Industrial IoT (IIoT) systems may be utilised, monetized, and enhance overall system performance for additional technologies. Research initiatives in the IIoT have been emphasised in this publication.

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