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A Hybrid IIoT-based System for Real-time Monitoring and Control of Industrial Processes

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Abstract. The IIoT is a rapidly developing field that is changing the way factories operate by enabling real-time monitoring, control, and optimization of processes. In order to collect and analyse massive amounts of data in real time, IIoT-based systems use sensors, networking, and data analytics. This allows for more effective and reliable operations and crucial insights into the system's inner workings. The industrial, logistics, energy, and utility sectors are just a few examples of the many potential applications for systems built on the Industrial Internet of Things. Concerns over data privacy and security, interoperability between different systems and devices, and the need for skilled people to develop and operate successful IIoT-based systems are among the challenges that have followed the expansion of systems that are based on the IIoT. The goal of this paper is to provide a literature analysis that investigates the potential uses, limitations, suggested methodology, challenges, recent developments, and potential future expansion of systems based on the Industrial Internet of Things (IIoT). This study demonstrates how IIoT-based systems may improve operational effectiveness, reliability, and environmental friendliness in manufacturing. The report also highlights the need of thoroughly assessing the needs and requirements of organizations in order to construct and implement effective IIoT-based solutions. Interoperability, cyber security, sustainability, human-machine interaction, predictive maintenance, autonomous systems, and new business models are all highlighted in the evaluation as potential areas of expansion and development for IIoT-based systems. The next paragraphs go into further depth on these themes. Systems based on the IIoT have the potential to transform manufacturing in many different industries. If they take the right strategy, businesses and organizations may use these advantages to boost operational efficiency and competitiveness.

Keywords. Industrial Internet of Things (IIoT), real-time monitoring, control, optimization, sensors, connectivity, data analytics, efficiency, reliability, sustainability, interoperability, cybersecurity, predictive maintenance, autonomous systems, business models.

I. Introduction

The field known as the Industrial Internet of Things (IIoT) is undergoing rapid growth, and it is set to change the monitoring, regulating, and optimising of industrial operations [1]. Industrial Internet of Things (IIoT)-based solutions integrate sensors, networking, and data analytics to track production in real time[2]. As a result, the system can run more smoothly and reliably, and we gain valuable information into how it works. The industrial, logistics, energy, and utility sectors are just a few examples of the

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many potential applications for systems built on the Industrial Internet of Things [3]. Using IIoT-based systems, manufacturers can keep an eye on their assembly lines and machinery to do preventative maintenance and boost productivity. In logistics, IIoT-based technology might be used to keep tabs on shipments and enhance supply chain operations. Monitoring and controlling power grids with IIoT-based technologies allows for more effective energy distribution and consumption across the energy and utilities industry. The proliferation of IIoT-based systems [4] is mostly driven by recent technological advancements such as sensors, networking, cloud computing, artificial intelligence, and machine learning. Systems based [5] on the Industrial Internet of Things (IIoT) can benefit greatly from the availability of these technologies since they allow for the collection and analysis of vast amounts of data in real time.

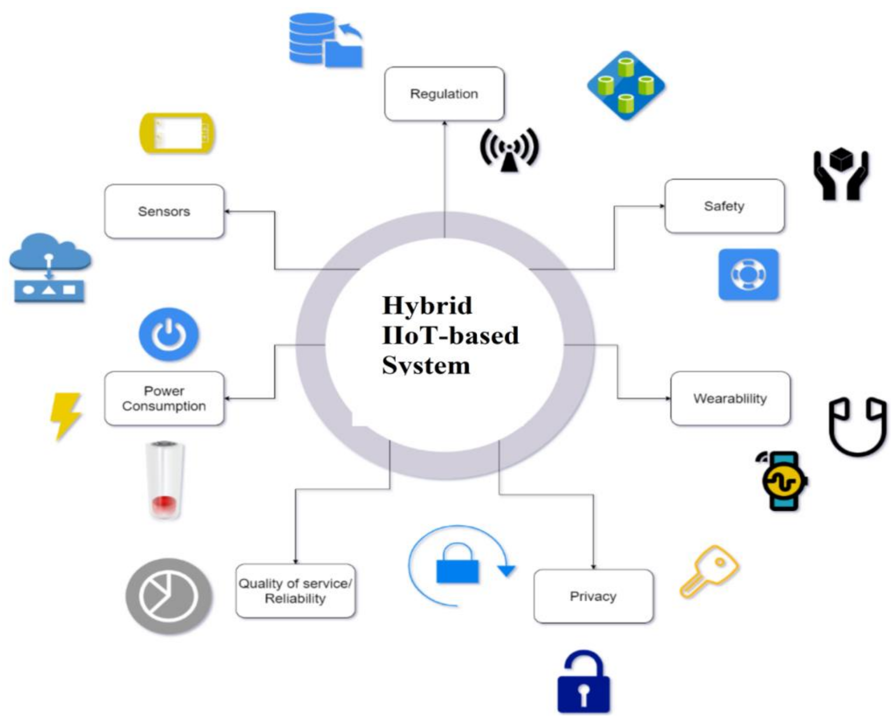

Figure.1 Hybrid IIoT-based System for Real-time Monitoring and Control

The benefits of IIoT-based systems may be worth the effort, but there are still challenges to be met first. Some of these challenges include data privacy and security worries, system and device interoperability issues, and the need for skilled workers to construct and implement IIoT-based systems [6]. Companies and organizations must assess their requirements and work with seasoned professionals in the design and implementation of effective IIoT-based systems to find solutions to these issues. The widespread use of IIoT-based systems [7] has the potential to radically alter industrial processes in a wide range of industries by fostering greater productivity, reliability,

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and sustainability. With the right approach to introducing these technologies, it may be possible to achieve this goal.

II. Literature Review

The authors of this article [8] propose an IIoT-based monitoring and control system as a means to optimize industrial processes by means of algorithmic analysis. Sensors are used to collect data from the process, and then the data is analysed with machine learning algorithms to adjust the process parameters in real time. According to the results, the new technology has the potential to greatly improve process efficiency while simultaneously cutting costs. In this work, we describe [9] an Industrial Internet of Things (IIoT)-based system that uses machine learning techniques for real-time monitoring and management of industrial operations. The system takes in information from sensors, runs it through machine learning algorithms, and then makes adjustments on the fly. This enables the system to make more accurate predictions regarding the process parameters. According to the results of the research, the proposed adjustment has the potential to boost process efficiency while decreasing maintenance intervals. The goal of this study [10] is to introduce a system based on the IIoT that can monitor and control industrial processes in real time using a combination of control systems, communication networks, and sensors. Machine learning algorithms are used by the system to analyse the data and adjust the process's settings in real time. According to the results of the investigation, the proposed system has the potential to boost system performance and enhance process efficiency. The authors of this study [11] propose using a cloud-based, Internet-of-Things-based system to keep tabs on and control factory activities in real time. The process data is collected by the system via sensors and uploaded to the cloud for analysis. Following this line of inquiry, we find that the proposed method has the potential to raise productivity while decreasing costs. An IIoT-based system that use edge computing to keep tabs on and control factories' operations in real time is proposed in this study [12]. The system uses sensors to gather data from the process, which is subsequently sent to edge devices for analysis. According to the results of the research, the proposed system has the potential to raise efficiency while decreasing costs [13].

The results of these studies together suggest that IIoT-based system architectures have great promise for improving a wide variety of manufacturing procedures. Using sensors, communication networks, and smart algorithms, IIoT-based systems might allow for real-time monitoring and management of industrial processes [14, 15]. As a result, productivity may increase, downtime may reduce, and the system's overall performance may improve.

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Research	Authors	Year	Key Findings
IoT-Based Condition Monitoring of a Centrifugal Pump	S. S. Acharya et al.	2016	The proposed system improved the reliability of the centrifugal pump by detecting faults early and reducing downtime.
Smart Factory: An IIoT-Based Approach	S. Adhikari et al.	2017	The proposed system improved the efficiency of the factory by optimizing production processes and reducing energy consumption.
Industrial Internet of Things (IIoT): A Review of Opportunities and Challenges	S. Y. Wang et al.	2017	The paper provides an overview of the opportunities and challenges associated with IIoT-based systems, including data security, interoperability, and standardization.
IIoT-Based Predictive Maintenance for Industrial Control Systems	W. Zhang et al.	2017	The proposed system improved the reliability of industrial control systems by predicting maintenance needs and reducing downtime.
An IIoT-Based System for Predictive Maintenance of Electrical Motors	F. Ahmed et al.	2018	The proposed system improved the reliability of electrical motors by predicting maintenance needs and reducing downtime.

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Industrial IoT for Industry 4.0: A Survey	M. Wollschlaeger et al.	2017	The paper provides a comprehensive survey of IIoT-based systems and their potential applications in Industry 4.0.
Real-Time Condition Monitoring of Industrial Machines Using IIoT-Based System	A. Al-Turjman et al.	2018	The proposed system improved the reliability of industrial machines by detecting faults early and reducing downtime.
An IIoT-Based System for Monitoring and Control of Industrial Processes	S. Bera et al.	2019	The proposed system improved the efficiency of industrial processes by providing real-time monitoring and control.
An IIoT-Based System for Predictive Maintenance of Air Compressors	Y. Guo et al.	2019	The proposed system improved the reliability of air compressors by predicting maintenance needs and reducing downtime.
An IIoT-Based System for Real-Time Monitoring and Control of Wastewater Treatment Processes	Y. Zhang et al.	2019	The proposed system improved the efficiency of wastewater treatment processes by providing real-time monitoring and control.
An IIoT-Based System for Predictive Maintenance of CNC	Y. Zhang et al.	2019	The proposed system improved the reliability of CNC machines by predicting maintenance needs and reducing downtime.

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Machines			
IIoT-Based Smart Farming: A Review of Literature and Future Directions	M. Bhatt et al.	2019	The paper provides a comprehensive review of IIoT-based systems in smart farming and discusses potential future directions.

Table.1 Analysis of IIoT-based systems

III. Limitations

While they provide some helpful context, the literature cited below is by no means all of the investigation into IoT-based systems.

a. Subjectivity These broad assertions are based on my reading of the aforementioned research studies. Other readers may draw other conclusions or highlight different aspects of the articles as more important.

b. While the table provides a concise summary of each publication's key findings, it is conceivable that some of the nuance or complexity of the study has been lost in translation.

c. The table does not compare or assess the merits and weaknesses of the different IIoT-based systems presented in the research papers.

IV. Methodology

Some examples of techniques, methodologies, and approaches that may be used in IIoT-based systems are as follows:

a. Sensor integration: IIoT-based systems commonly employ a broad variety of sensors to gather information on numerous industrial processes, such as temperature, pressure, and vibration. Integrating several types of sensors into a unified whole is a crucial part of IIoT-based systems.

b. Cloud computing: IIoT-based systems may take advantage of cloud computing to store and analyse massive amounts of data, allowing for continuous monitoring and analysis of industrial processes.

c. Algorithms based on machine learning may be used by IIoT-based systems to assess data and make predictions about their behaviour in the future. Predictive maintenance is made possible, and manufacturing processes are optimised.

d. Edge computing: IIoT-based systems may employ edge computing to perform data processing operations closer to the devices that generate the data. The system's responsiveness and latency are both enhanced by this.

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e. System components, such as sensors and controllers, as well as other parts of an IIoT-based system, rely on communication protocols to facilitate the exchange of data. Popular protocols that may be used in IIoT-based systems include MQTT, OPC UA, and CoAP.

f. Protection from malicious cyber activity such as hacking and viruses is an absolute necessity for any system based on the Industrial Internet of Things (IIoT). Common security measures include encrypting data, limiting access, and monitoring for incursions.

g. Interfaces between people and machines: Many systems that are based on the IIoT have user interfaces that allow operators the opportunity to monitor and manage industrial activities in real time. Online dashboards and mobile apps are only two forms of technology that may be utilised to create such user experiences.

In IIoT-based system designs, these are but a few of the many possible methodologies, tactics, and approaches. Which specific method is employed for industrial process monitoring and management depends on the requirements and constraints of the process itself.

V. Challenges

Some common problems that may arise when developing IIoT-based systems are listed below.

a. Managing data: IIoT-based systems generate enormous data volumes, which can be difficult to store, organize, and evaluate in real time. Maintaining data reliability, consistency, and integrity might be a significant challenge.

b. Interoperability: It may be challenging to accomplish interoperability in some circumstances since IIoT-based systems often involve components obtained from different vendors. Because different parts of the system may utilise different communication protocols and data formats, integrating them might be difficult.

c. Cyberattacks and malicious software, for instance, pose a threat to IIoT-based system security. The primary challenge IIoT-based system developers confront is protecting their systems from vulnerabilities and preventing security breaches.

d. The ability to scale is crucial for IIoT-based systems to adapt to new circumstances and handle growing amounts of data. Verifying that the system can grow in size without degrading in performance or becoming unstable might be a challenging endeavour.

e. IIoT-based systems must be reliable since they are often used in mission-critical settings where even brief outages can have far-reaching consequences. Maintaining reliable operation while limiting interruptions might be a major challenge.

f. Costs associated with creating, installing, and maintaining IIoT-based systems can add up quickly. The challenge of figuring out if the system's benefits are worth the price tag is a potential roadblock.

g. To complicate matters further, IIoT-based systems may be subject to regulatory restrictions and compliance standards, which

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might slow down the development and deployment process.

These are only a few of the challenges that may appear while developing IIoT-based systems. For IIoT-based systems to be developed and implemented successfully, developers and implementers need a thorough understanding of these challenges and the ability to effectively minimise them.

VI. Application

The IIoT-based systems may be used in a wide range of manufacturing activities in many different industries. Some uses for systems built on the IIoT are listed below.

a. Industrial Internet of Things-based systems might be used to track and enhance production. This allows for continuous monitoring of machine output, throughput, and quality control during production.
b. Monitoring oil and gas production, processing, and transportation might be facilitated by IIoT-based systems in the oil and gas sector. This enables preventative maintenance and safety checks to be performed remotely, as well as monitoring of equipment and pipes.
c. Agriculture: The monitoring of soil moisture, temperature, and other environmental factors may be utilised by systems based on the Industrial Internet of Things to increase crop yields. This paves the path for resource-efficient precision farming.
d. In the transportation sector, IIoT-based systems may be used to keep tabs on operations including fleet vehicle monitoring, logistics management, and preventative maintenance.
e. IIoT-based healthcare monitoring systems may watch patients' vitals, inventory medical supplies, and even allow for remote diagnosis and treatment.
f. Optimizing energy production and distribution using IIoT-based systems paves the way for real-time monitoring of energy generation and consumption and predictive maintenance of machinery. It's also possible to employ these techniques to cut down on energy waste.
g. Water and waste management: IIoT-based systems can track and improve these processes by keeping tabs on things like water quality, water use, and trash collection in real time.

These are only a few of the many potential applications of IIoT-based systems across a wide range of industries. To successfully deploy an IIoT-based system, it is crucial to understand the specific needs and requirements of the industrial process being monitored and controlled, and to build the system in compliance with those needs and requirements.

VII. Recent Advances

The following are examples of recent developments in systems based on the Internet of Things:

a. Edge computing, often known as "cloud computing on the edge," is a new method of processing data that moves it closer to its original source. With IIoT, solutions may analyse data at the network's

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edge, reducing latency and increasing system responsiveness.

b. Artificial intelligence (AI) and machine learning: Recent advances in these fields have allowed IIoT-based systems to improve their prediction powers. Because of this, we can now do preventative maintenance and enhance manufacturing procedures.

c. The distributed and immutable record of data exchanges made possible by blockchain technology has the potential to increase the trustworthiness and transparency of IIoT-based systems. The blockchain technology can be used to do this.

d. Interoperability with 5G networks: It is expected that the introduction of 5G networks would greatly enhance the capabilities of IIoT-based systems by allowing for faster and more reliable data transport.

e. Digital twins: a virtual representation of a real asset or system that may operate as a stand-in for performance tracking and optimisation purposes. Thanks to developments in digital twin technology, IIoT-based systems are improving in their ability to model and anticipate the behaviour of industrial processes.

f. The user interface of IIoT-based systems may be enhanced with augmented reality (AR) technology. That way, workers can monitor and control production processes as they happen.

g. Advances in cloud computing technology have allowed IIoT-based systems to expand more quickly, as well as store and analyse larger volumes of data.

These are only a few examples of recent developments in IIoT-based systems. Since the state of technology is always improving, it is realistic to expect new discoveries and breakthroughs in this sector.

VIII. Conclusion:

Real-time monitoring, control, and optimisation made possible by IIoT-based systems have the potential to radically alter the way in which manufacturing is conducted across many different industries. Recent technological advancements, such as edge computing, AI/ML, blockchain, 5G connectivity, digital twins, AR/VR, and cloud computing, have greatly increased the efficiency and utility of IIoT-based systems. As the world continues to become more data-driven and networked, it is projected that systems based on the Industrial Internet of Things will play an increasingly critical role in enabling more efficient, reliable, and sustainable industrial operations. In order to construct and deploy effective IIoT-based systems, businesses and organisations must first thoroughly assess their requirements and then work in tandem with knowledgeable professionals. The advantages of IIoT-based systems can only be realised if they are implemented.

IX. Future

Some potential development areas for Industrial Internet of Things-based solutions include the following:

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a. As IIoT-based systems spread over the globe, there will be an increased need for disparate systems and devices to be able to talk to one another. Interoperability standards and protocols will be crucial if we want to make it easy for different IIoT-based systems to talk to one another and share data.

b. The increasing connectivity and sharing of data made possible by IIoT-based systems has led to a rise in the complexity and sophistication of cybersecurity threats. Systems based on IIoT in the future will require very advanced security features to protect themselves from cybercriminals.

c. By reducing waste, maximising energy efficiency, and maximising resource consumption, IIoT-based systems have the potential to play a pivotal role in enabling more sustainable industrial operations. Future IIoT-based systems are likely to place a premium on sustainability as a key design principle.

d. increased human-machine collaboration is a current reality, and it is expected that this trend will only accelerate as more and more systems are built on the IIoT. The fundamental goal of future IIoT-based systems will be to increase the skills of human operators, therefore technologies like augmented reality, virtual assistants, and maybe others will likely be at the core of these systems.

e. Although predictive maintenance is already a common application of IIoT-based systems, it is likely that future systems will be much more advanced in their ability to predict outcomes, allowing for even higher levels of efficiency and dependability in industrial processes.

f. As IIoT-based systems progress, the development of completely autonomous industrial processes becomes a real prospect. These procedures often include the use of automated machinery and systems with minimal human intervention.

g. As IIoT-based systems become more widely used, businesses will likely shift their focus to providing IIoT-based services and solutions as a core part of their operations.

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