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IoT Based Real Time Industrial Automation System

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Abstract: The Internet of Things (IoT) has emerged as a transformative force in industrial automation, enabling real-time monitoring, control, and optimization of complex systems. This paper presents the development and implementation of an IoT-based real-time industrial automation system designed to enhance operational efficiency, reduce downtime, and ensure seamless integration across diverse industrial processes. The system integrates sensors, actuators, and cloud-based analytics to provide predictive maintenance, fault detection, and energy optimization. The results of the experimental setup demonstrate significant improvements in process efficiency and resource utilization, highlighting the potential of IoT to revolutionize industrial automation. IOT network is proposed in the current research paper which can detect chemical leakage, gas leakage, fire/ boiler temperature, humidity, energy monitoring by various smart sensors. The IOT enabled network will automatically update the current situation to the authorised person and immediate control action can be taken to protect industrial appliances, minimise financial losses and save many lives.

Keywords: *Internet of Things (IoT), Industrial Automation, Real-Time Systems, Predictive Maintenance, Sensor Data Acquisition, Smart Manufacturing*

1. Introduction

The rapid pace of technological development has given rise to a transformative era of industrial innovation, significantly shaped by the Internet of Things (IoT). IoT, as a transformative paradigm, connects devices, sensors, and systems across the globe, enabling seamless communication and data exchange. In the context of industrial automation, IoT serves as a cornerstone for achieving real-time monitoring, control, and optimization of operations. This convergence of IoT and industrial processes forms the backbone of Industry 4.0, often referred to as the Fourth Industrial Revolution [1-5]. Industrial automation involves the use of advanced control systems, such as computers and robots, to operate machinery and processes with minimal human intervention. Traditionally, these systems were limited by the lack of real-time communication and integration capabilities. However, IoT addresses these limitations by introducing smart, interconnected devices capable of collecting and transmitting data in real-time. This integration not only enhances efficiency and productivity but also paves the way for innovative applications such as predictive maintenance, fault detection, and energy management [6-8].

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This paper explores the design and implementation of an IoT-based real-time industrial automation system. The proposed system is structured to address critical challenges in modern industrial environments, including downtime reduction, process optimization, and energy efficiency. By leveraging IoT technologies, such as advanced sensors, edge computing, and cloud-based analytics, the system ensures seamless connectivity and reliable performance in dynamic industrial settings. A core feature of the proposed system is its ability to operate in real-time, enabling instant data acquisition and analysis [9-10]. Real-time capabilities are crucial for mission-critical applications where even minor delays can result in significant financial and operational losses. The system achieves this through the integration of edge computing, which processes data locally to minimize latency, and advanced communication protocols that ensure reliable data transmission across devices. Another essential aspect of the system is its predictive maintenance functionality. Unlike traditional maintenance strategies that rely on scheduled inspections or reactive responses to equipment failures, predictive maintenance leverages IoT-enabled sensors and machine learning algorithms to monitor equipment health in real-time [11-13]. This proactive approach minimizes unplanned downtime and extends the lifespan of machinery. Furthermore, the system incorporates energy optimization techniques to reduce operational costs and environmental impact. By monitoring energy consumption patterns and adjusting processes accordingly, the system ensures sustainable industrial operations [14-15].

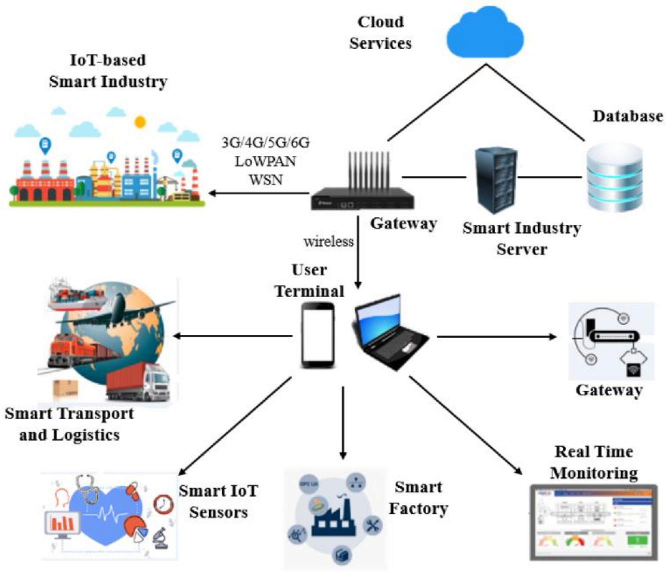

Figure 1: Industrial IoT trends show recent applications for industrial IoT

This paper is structured as follows: the subsequent sections review related literature to provide a comprehensive understanding of IoT's role in industrial automation. The methodology section details the system's architecture and components. Implementation of IOT system, results and analysis demonstrate the system's performance in real-world scenarios, followed by a discussion and future scope. Finally, the conclusion highlights the significance of IoT in transforming industrial automation and outlines potential areas for further research. By addressing these aspects, this paper aims to contribute to the growing body of knowledge on IoT-based industrial automation and provide a framework for implementing real-time, efficient, and sustainable solutions in diverse industrial domains.

2. Literature Review

Industrial automation has evolved significantly with advancements in Internet of Things (IoT) technology, fostering enhanced connectivity, real-time data processing, and intelligent decision-making. This section reviews existing research on IoT's role in industrial automation, focusing on real-time applications, predictive maintenance, and process optimization. Gubbi et al. (2013) outlined the foundational architecture of IoT systems, emphasizing the role of sensors, actuators, and cloud-based analytics. Their work serves as a cornerstone for understanding IoT's integration into industrial frameworks. Similarly, Xu et al. (2018) explored Industry 4.0 and IoT's transformative impact, highlighting its capability to connect disparate industrial systems seamlessly. Real-time capabilities are critical for mission-critical industrial applications. Yin et al. (2020) discussed the challenges of achieving low-latency and reliable communication in IoT-enabled predictive maintenance systems. Wan et al. (2017) proposed using software-defined networking to enhance real-time communication in industrial IoT systems, ensuring consistent performance even under varying network conditions. The shift from reactive to predictive maintenance has been a key driver of IoT adoption in industries. Kaur et al. (2019) reviewed emerging trends in predictive maintenance using IoT, identifying key technologies such as edge computing and machine learning. These approaches significantly reduce downtime and operational costs, as demonstrated by Lee et al. (2015), who implemented a cyber-physical systems architecture for predictive maintenance in manufacturing. Edge and fog computing have emerged as critical enablers of real-time IoT applications.

Thakur and Gokhale (2016) analyzed the integration of fog computing in industrial settings, highlighting its role in reducing latency and enhancing computational efficiency. Kamble et al. (2018) extended this discussion by examining big data analytics in edge-enabled industrial IoT systems, showcasing their potential for predictive analytics and fault detection. Reliable communication protocols are essential for IoT-enabled industrial automation. Li et al. (2018) conducted a survey on 5G IoT applications, emphasizing its potential to revolutionize industrial automation by providing ultra-low latency and high bandwidth. Anggorojati et al. (2013) explored capability-based access control models, ensuring secure and efficient communication in IoT systems. Energy efficiency is a critical concern in industrial automation. Raj and Moorthy (2021) demonstrated how IoT-based systems can optimize energy consumption through real-time monitoring and control. Their findings align with Kang et al. (2016), who reviewed smart manufacturing techniques that integrate IoT for sustainable industrial operations. Despite significant progress, IoT in industrial automation faces challenges such as data security, interoperability, and scalability. Monostori (2014) identified cyber-physical production systems as a potential solution, integrating IoT with advanced analytics to address these challenges. Zhong et al. (2017) proposed intelligent manufacturing frameworks to enhance system adaptability and resilience. The reviewed literature underscores the transformative potential of IoT in industrial automation. By addressing current challenges and leveraging emerging technologies like edge computing and 5G, IoT-based systems can significantly enhance industrial efficiency and reliability. This comprehensive review provides a foundation for further research on optimizing IoT applications in real-time industrial automation.

The existing systems for automation face significant limitations in terms of cost, installation complexity, and maintenance. Bluetooth-based automation systems are hindered by limited range, high power consumption, and a restricted number of connectable devices. While Zigbee-based systems address some Bluetooth drawbacks, they also suffer from range limitations. GSM-based automation systems, though more power-efficient and standalone, encounter reliability issues when GSM networks fail to deliver commands promptly, which can lead to critical problems. Furthermore, these systems often lack scalability and standards for industrial applications. To address these challenges, we propose an IoT-enabled industrial automation system capable of remotely monitoring and controlling various appliances, offering a more cost-effective, flexible, and reliable solution.

3. Methodology

The Internet of Things (IoT) architecture forms the backbone of modern industrial automation systems, enabling seamless communication and interaction between devices, processes, and systems. This architecture is designed to address the complexities of real-time operations in industrial environments, ensuring reliability, scalability, and efficiency. This section provides a detailed exploration of IoT architecture and its applications in industrial automation.

3.1 IoT Architecture for Industrial Automation

IoT architecture typically consists of multiple layers, each responsible for specific functions that collectively ensure efficient system operations. The primary layers of IoT architecture are as follows:

1. Perception Layer (Sensors and Actuators)

- The perception layer is the foundation of IoT systems, comprising sensors, actuators, and embedded devices.
- Sensors: Devices that collect real-time data, such as temperature, pressure, vibration, humidity, and energy usage, from the industrial environment.
- Actuators: Devices that perform physical actions based on system commands, such as opening a valve, adjusting a motor's speed, or initiating emergency shutdowns.
- This layer ensures that the system has a continuous stream of real-time data for analysis and control.

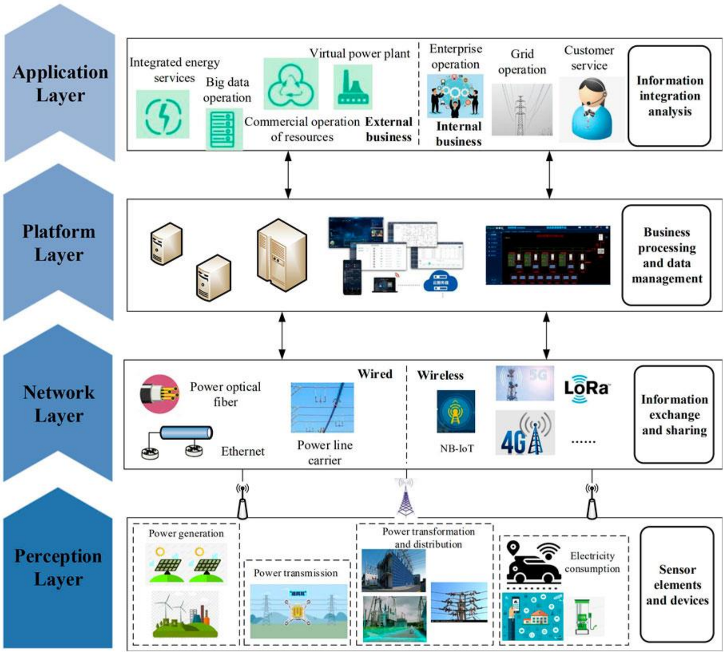

Figure 2: primary layers of IoT architecture

2. Network Layer (

Communication)

- The network layer is responsible for transmitting data collected by the perception layer to the processing layers.
- Communication protocols such as Wi-Fi, Bluetooth, Zigbee, LoRaWAN, and 5G are used to establish connectivity.
- In industrial applications, wired options like Ethernet and industrial bus protocols (e.g., Modbus, PROFIBUS) are also prevalent for high reliability and low latency.
- This layer ensures secure, efficient, and reliable data transfer between components.

3. Edge Layer (Processing at the Edge)

- Edge devices, such as industrial controllers and gateways, process data locally, reducing the need for data transmission to centralized systems.
- Edge computing minimizes latency and ensures real-time responsiveness, which is crucial for mission-critical industrial applications.
- Functions include data preprocessing, anomaly detection, and localized decision-making.

4. Processing Layer (Cloud and Data Centers)

- The processing layer handles advanced data analysis, storage, and application management.
- Cloud computing platforms analyze large datasets using machine learning algorithms to derive actionable insights, such as predictive maintenance schedules or energy optimization strategies.
- This layer also facilitates remote monitoring and control of industrial systems.

5. Application Layer (User Interaction)

- The application layer interfaces with users, providing dashboards, analytics, and control mechanisms.
- It enables operators to monitor processes, receive alerts, and make informed decisions.
- Examples include SCADA (Supervisory Control and Data Acquisition) systems enhanced with IoT capabilities and mobile applications for on-the-go management.

6. Security Layer

- Security mechanisms are integrated across all layers to protect industrial systems from cyber threats.
- Encryption, authentication, and anomaly detection systems ensure the integrity and confidentiality of data.

3.2 Components of Industrial Automation system

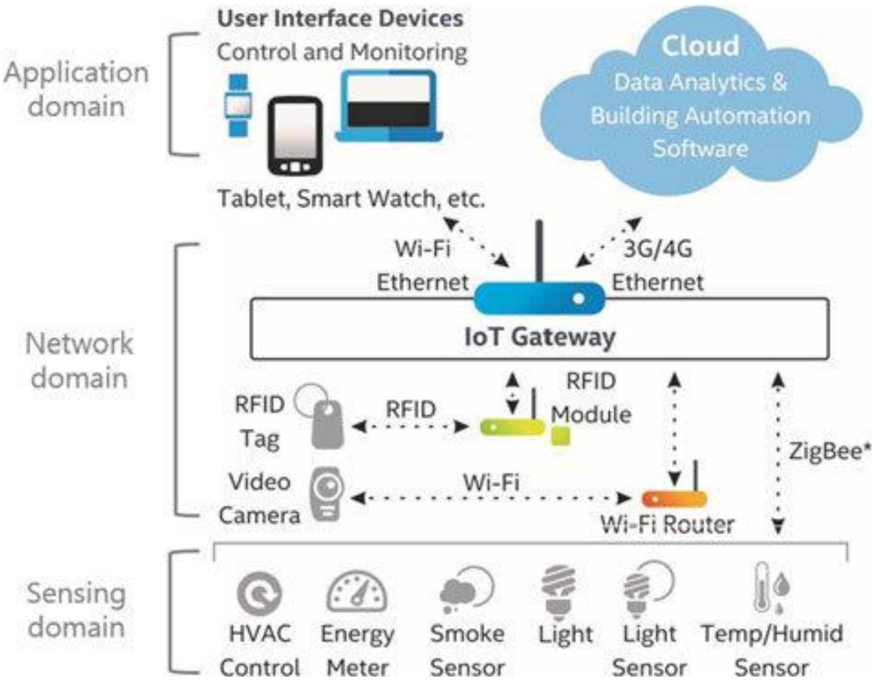

Figure 3: components of IoT based system

Key Components and Interactions:

- Industrial Sensors**:** Collect data from various points in the industrial process (temperature, pressure, flow rate, etc.).
- PLC/Controller: A Programmable Logic Controller (or other industrial controller) processes sensor data and executes control logic.
- Actuator/Machine: Carries out the control actions determined by the PLC (e.g., adjusting valves, controlling motor speed).
- IoT Gateway/Edge Device**:** Aggregates data from sensors and PLCs, performs local processing, and communicates with the cloud.
- The Cloud: Provides data storage, analysis, remote monitoring, and control capabilities. This could include dashboards, alerts, and remote control interfaces.
- Network Connectivity: Connects all components, typically using industrial protocols (e.g., MQTT, OPC UA) and wireless technologies (e.g., Wi-Fi, 5G, or wired connections).

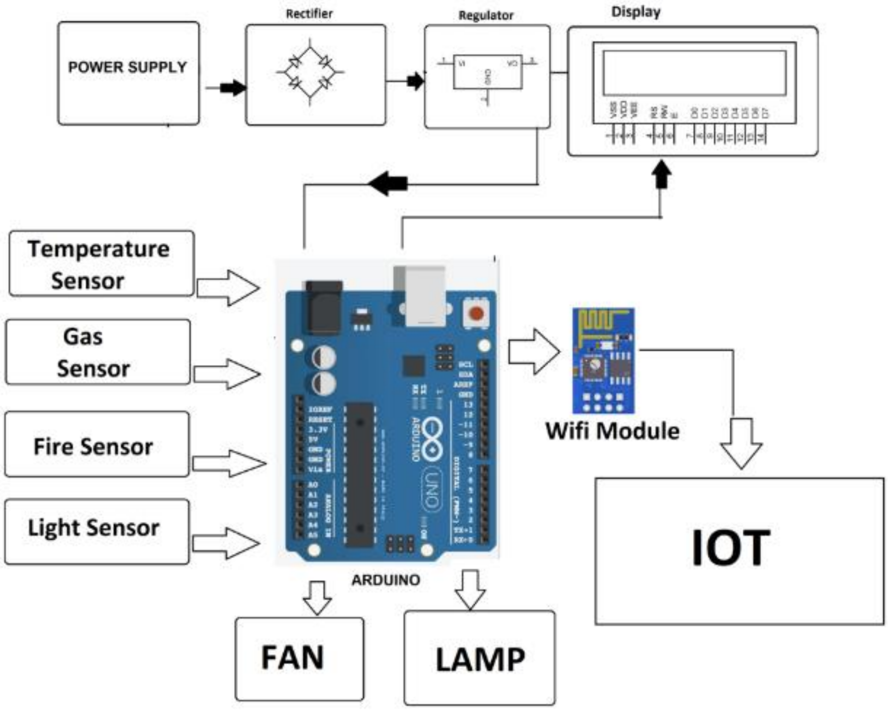

Figure 4: Block diagram of proposed system

4. Implementation, Result and Discussion

In our proposed scheme we are using Arduino as a main controller as shown in Figure 4. Controller gets the data from industrial environment and process the data to run the industrial appliances smoothly. Normally temperature in industrial environments are high when compared to normal situation because industrial machines produces more heat, which affects the machineries. Temperature sensor monitors the temperature and give the values to Controller. Based on the value either the fan is switched ON or OFF through Relay Module. Further we can monitor and control the industrial appliances through internet. The components used in the system is described below.

A. Arduino

Arduino/Genuino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.

B. Wi-Fi module

The WiFi module used in our system will help us to operate the web page for a customer. The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.

C. Temprature And Humidity Sensor

DHT11 Temperature and Humidity Sensor include a temperature and stickiness sensor complex with an adjusted computerized flag yield. By utilizing the selective advanced flag securing strategy and temperature and dampness detecting innovation, it guarantees high unwavering quality and astounding long haul soundness. This sensor incorporates a resistive-type moistness estimation part and a NTC temperature estimation segment, and interfaces with an elite 8-bit microcontroller, offering amazing quality, quick reaction, hostile to impedance capacity and cost-viability.

D. Gas Sensor

The Gas sensor composed by micro AL2O3 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-2 have 6 pin, 4 of them are used to fetch signals, and other 2 are used for providing heating current. The MQ6 gas sensor detects concentration of gas in ppm and outputs analog value which can be converted to digital measure using in-built Analog to Digital Convertor of Arduino. The value of the digital measure will be 10-bit long and varies from 0 to 1023. The project allows user to set the dangerous level for leakage based on the same digital measure. When the value set by the user matches with that of the value detected by the sensor, it invokes the alarm. The MQ6 sensor can be calibrated by interfacing a load resistance of fixed value with the sensor.

E. Pressure Sensor

A pressure sensor is a device which senses pressure and converts it into an analog electric signal whose magnitude depends upon the pressure applied. Since they convert pressure into an electrical signal, they are also termed as pressure transducers Since a long time, pressure sensors have been widely used in fields like automobile, manufacturing, aviation, bio medical measurements, air conditioning, hydraulic measurements etc.

F. Relay Module

A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current. The heart of a relay is an electromagnet (a coil of wire that becomes a temporary magnet when electricity flows through it). The control circuit functions as the coupling between the input and output circuits. In electromechanical relays, the coil accomplishes this function. Relay Output Circuit is the portion of the relay that switches on the load and performs the same function as the mechanical contacts of electromechanical relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one switch.

G. Flame Sensor

A flame detector is a sensor designed to detect and respond to the presence of a flame or fire, allowing flame detection. Responses to a detected flame depend on the installation, but can include sounding an alarm, deactivating a fuel line (such as a propane or a natural gas line), and activating a fire suppression system. When used in applications such as industrial furnaces, their role is to provide confirmation that the furnace is working properly; it can be used to turn off the ignition system though in many cases they take no direct action beyond notifying the operator or control system. A flame detector can often respond faster and more accurately than a smoke or heat detector due to the mechanisms it uses to detect the flame.

H. Light Sensor (LDR)

Light dependent resistors (LDR), are light sensitive devices most often used to indicate the presence or absence of light, or to measure the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices.

I. Touch Sensor

A touch sensor is an electronic sensor used in detecting and recording physical touch. Touch Sensors are the electronic sensors that can detect touch. They operate as a switch when touched. These sensors are used in lamps, touch screens of the mobile, etc… Touch sensors offer an intuitive user interface.

J. LCD

LCD stands for liquid crystal display, which is used to show the status of an application, displaying values, debugging a program, etc.A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. The 16 x 2 intelligent alphanumeric dot matrix display is capable of displaying 224 different characters and symbols. This LCD has two registers, namely, Command and Data.

K. Wi-Fi ESP8266 Connectivity With Smart Device

The Android phone is used in connection of sensors to Wi-Fi. ESP8266 has the advantage of working with android application without any dependency on any microcontrollers but it can’t be used in automation. Arduino software has inbuilt library function of Wi-Fi ESP8266 Shield which enables the connectivity of Wi-Fi to the Android devices. The Arduino code opens up a network connection, then it is detected by the Android W-Fi and it doesn’t require any other modules. Arduino board enables the automated program code to be implemented in the ESP8266 and is set to automatic detecting and connecting to the network.

Software Used: ARDUINO IDE

Arduino Software is an open source programming that has various inbuilt library functions and keywords. Arduino.cc is easy and simple to code and upload onto the Arduino board. Arduino requires a platform to perform its operation which means an Arduino enabled Integrated platform is needed. Arduino uses the Integrated Development Environment (IDE) which is coded with C/C++, Arduino web editor can also be used in this process. IDE provides the working environment for Arduino programs. Ethernet shield is used to connect the Arduino board to the Internet which has access to the Arduino sever, it has all the functions to operate any sensors and modules without any need for the codes that are pre-programmed by the users

Figures 5, 6, and 7 illustrate the real-time monitoring capabilities of the IoT-based industrial automation system. Figure 5 displays the temperature readings on the LCD, while Figure 6 shows the humidity values, both obtained from connected sensors. Figure 7 demonstrates the LCD indicating the transmission of sensor data to the cloud, showcasing the system's ability to relay real-time environmental metrics for remote access and analysis.

Figure 5: LCD Showing the Temperature value

Figure 6: LCD Showing the Humidity value

Figure 7: LCD showing sensor data sending to cloud

5. Future scope

The future of IoT-based industrial automation is shaped by transformative trends that promise to redefine efficiency, collaboration, and sustainability across industries. One of the most significant advancements is the evolution of communication networks, with 5G and beyond enabling ultra-low latency, high-speed connectivity, and massive device integration. This infrastructure will power real-time applications, such as autonomous robots and augmented reality, enhancing operational precision. Alongside this, edge and fog computing are emerging as critical technologies for decentralized data processing, reducing latency and improving real-time decision-making while decreasing dependence on centralized cloud infrastructure. The integration of artificial intelligence (AI) and machine learning (ML) further complements these developments by enabling predictive analytics and autonomous operations, significantly boosting adaptability and efficiency in automated systems.

Emerging innovations like digital twins and IoT and blockchain integration are also paving the way for advanced industrial applications. Digital twins, as virtual replicas of physical systems, provide real-time simulations and predictive insights, optimizing performance and reducing downtime. Blockchain, on the other hand, ensures secure and transparent data transactions, fostering trust in multi-stakeholder environments. As sustainability takes center stage, green IoT devices and energy-efficient systems contribute to eco-friendly manufacturing. Moreover, the rise of IoT-enabled collaborative robots (cobots) highlights the potential for seamless human-machine collaboration, enhancing safety and productivity. Trends like IoT as a Service (IoTaaS) and hyperautomation will democratize IoT adoption and drive extensive process automation, enabling industries to scale operations, enhance security frameworks, and achieve unparalleled operational efficiency.

6. Conclusion

In this paper, we presented the design and implementation of a cost-effective, flexible, and wireless solution for real-time industrial automation. The system ensures secure access, preventing unauthorized usage and safeguarding operations. It serves as a versatile platform for industrial appliances, offering the capability for remote monitoring and control via the internet. Extensive testing validated the system's functionality, including seamless wireless communication between Wi-Fi modules and Arduino. Future work will focus on optimizing energy consumption and further simplifying the implementation process to enhance efficiency and scalability in industrial environments. IoT-based real-time industrial automation systems are transforming industries by enhancing efficiency, productivity, and sustainability. Despite challenges like data security, interoperability, and scalability, advancements in technologies such as 5G, AI, edge computing, and blockchain are paving the way for smarter and more resilient systems. By addressing these challenges and leveraging emerging trends, industries can achieve optimized operations, reduced costs, and sustainable growth. IoT's integration into industrial automation is not only shaping the present but also driving a future of innovation and industrial excellence.

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