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Transformative Applications of IoT in Diverse Industries: A Mini Review

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ABSTRACT

By integrating physical objects and facilitating data-driven decision-making, the Internet of Things (IoT) is transforming several sectors. Through the provision of individualised treatment plans, real-time health data analysis, and remote patient monitoring, it is vital to the modernization of healthcare systems. IoT technologies are essential to the development of smart cities, resource allocation optimisation, public safety improvement, and traffic congestion reduction. IoT-driven smart farming automates machinery, optimises irrigation, and monitors crop conditions. As IoT makes it possible to create smart grids, save energy waste, and increase grid dependability, the energy landscape is changing. IoT makes it easier to apply Industry 4.0 ideas in the manufacturing sector, converting conventional factories into networked, intelligent systems. Reducing operating costs and increasing productivity are the outcomes of implementing IoT-enabled sensors, robots, and data analytics to improve supply chain management, predictive maintenance, and production efficiency. Innovation, sustainability, and efficiency are becoming more and more possible as a result of the Internet of Things' integration across many industries. This review also showcases the relevant prospects of IoT applications in the fields mentioned.

1. INTRODUCTION

IoT, or the Internet of Things, refers to the network of interconnected devices that can communicate and exchange data with each other over the internet without requiring human intervention [1]. These devices can range from everyday objects such as household appliances and wearable devices to industrial machinery and infrastructure components. IoT is driven by sensors, actuators, and embedded systems that enable these devices to collect, analyse, and transmit data, creating opportunities for automation, efficiency improvements, and new services across various domains [2].

The rapid growth and adoption of IoT in recent years can be attributed to several key factors. First and foremost, advancements in connectivity technologies such as 5G have significantly expanded the potential for interconnected devices to communicate seamlessly and in real-time, fostering a fertile ground for IoT expansion. Additionally, the decreasing costs of sensors and hardware, coupled with the proliferation of cloud computing platforms, have made it more accessible for businesses and consumers alike to integrate IoT solutions into their operations and daily lives. Furthermore, the promise of increased efficiency, automation, and data-driven insights has spurred widespread interest across industries ranging from

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manufacturing and healthcare to transportation and smart homes. As a result, IoT has become not only relevant but also indispensable in the modern technological landscape, offering immense potential for innovation and transformation across various sectors.

In healthcare, IoT devices can monitor patients' vital signs, track medication adherence, and remotely manage chronic conditions. Wearable devices, such as smartwatches and fitness trackers, can collect real-time health data and transmit it to healthcare providers for analysis. IoT-enabled medical devices can also streamline hospital operations, improve patient care, and enable early detection of health issues. Moreover, IoT plays a crucial role in creating smart cities by improving infrastructure management, optimizing resource utilization, and enhancing public services. Smart traffic management systems use IoT sensors to monitor traffic flow and adjust signals in real-time, reducing congestion and improving safety. Smart waste management systems utilize sensors to optimize garbage collection routes, leading to cost savings and reduced environmental impact. Additionally, IoT can enhance public safety through surveillance cameras, emergency response systems, and environmental monitoring. Besides that, IoT technologies are revolutionizing agriculture by enabling precision farming techniques that optimize crop yields, reduce resource consumption, and mitigate environmental impact. IoT sensors deployed in fields collect data on soil moisture, temperature, and nutrient levels, allowing farmers to make informed decisions about irrigation, fertilization, and pest control. Drones equipped with IoT devices can monitor crop health, detect diseases, and assess field conditions from aerial perspectives, enabling timely interventions and maximizing productivity. Furthermore, IoT facilitates the development of smart grids, which are modernized electrical grids equipped with advanced sensors, meters, and control systems. Smart meters installed in homes and businesses enable real-time monitoring of energy consumption and provide insights for energy efficiency improvements. IoT-enabled grid infrastructure enhances reliability, enables demand response programs, and integrates renewable energy sources more efficiently, contributing to energy conservation and sustainability.

In addition, IoT technologies are transforming traditional manufacturing processes into smart, connected systems known as Industry 4.0. IoT-enabled sensors embedded in machinery and production lines collect data on equipment performance, product quality, and supply chain logistics in real-time. This data enables predictive maintenance, optimized production scheduling, and improved inventory management, leading to cost reductions, increased productivity, and enhanced competitiveness. In the field of education, IoT facilitates personalized learning experiences, enhances classroom management, and improves campus safety. IoT devices such as interactive whiteboards, smart projectors, and digital textbooks enable innovative teaching methods and immersive learning experiences. IoT-enabled campus security systems utilize sensors, cameras, and access control systems to monitor premises, detect threats, and ensure the safety of students and staff.

As IoT is important in enabling the connection and communication of devices and systems, leading to increased efficiency, improved decision-making, and enhanced services across various industries, hence this review paper is aim to provide a comprehensive review of IoT application in the field of healthcare, smart city development, smart farming, smart grid and energy saving, smart manufacturing, and smart education.

2. HEALTHCARE

Research centres, businesses, or institutions can produce creative initiatives that make use of IoT, sensors, and intelligent systems. Prominent technology corporations such as Apple and Telefónica Koa Health concentrate on mobile device data processing and collecting, as well as digital behavioural health solutions [3]. In response to the rising need for digital behavioural health goods, these companies provide intelligent social care and healthcare systems that are enabled by IoT strategy.

In medical institutions, access control plays a critical role in granting or refusing access to restricted areas on a 24-hour basis. Consult rooms, emergency rooms, storage rooms, paediatric and maternity departments, operating rooms, critical care units, pharmacies, parking garages, and server racks are all examples of this. Security becomes a big worry when healthcare facilities expand. In response to emerging dangers, access control technologies like as locks, biometric entry, and door alarms are changing. It is important to have solutions that meet health insurance criteria, such as Health Insurance Portability and Accountability (HIPPA) [4]. Hospitals can rapidly initiate whole or partial shutdowns, schedule appointments, integrate IP and CCTV cameras, and regulate visitor traffic using Kaba access control systems. For a completely integrated solution, several systems offer access control over Ethernet.

Healthcare providers no longer need to visit patients on a frequent basis thanks to the Internet of Things (IoT)-powered In-Hospital Patient Monitoring System. The system analyses and stores patient data using sensors, gateways, and the cloud. It then sends the data wirelessly to doctors. Doctors may access, examine, and recommend the proper medical therapy for their patients' data from any internet-enabled device [5]. By doing away with the need for staff members to handle data gathering and processing, this Internet of Things-based solution improves care quality and lowers expenses. The web page, which is accessed by a physician is shown in Fig. 1.

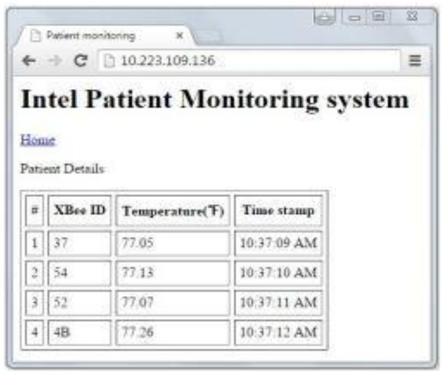

Fig. 1. Patient monitoring system [5].

A three-tier design is commonly seen in remote health monitoring frameworks: processing and analysis nodes, communication and networking, and body sensor network.

Wearable sensors gather information on body temperature, heart health, and blood pressure [6]. The data collecting, transmission, and environment monitoring components of the healthcare system are all included for analysis and research as shown as Fig. 2.

Fig. 2. Healthcare monitoring system architecture [6].

The four protocol domains that make up an Internet of Things (IoT) system are physical, network, middleware, and application. Sensor-embedded devices make up the physical layer, and signals are sent from sensors to cloudlets via the network layer. The data is stored in the middleware layer, while the signals are stored in cloudlets. Analytics and diagnostics are carried out by the application layer [7].

Wearable technology that has sensors to assess important bodily parameters including blood glucose, temperature, and ECG is used in data transmission and gathering. Cloudlet processing entails storing data on mobile devices and in the cloud. Correlating sensor characteristics with clinical data is a key component of analytics and prediction, which makes use of machine learning techniques [7]. New measuring instruments in the medical area might provide difficulties. For efficient prediction, data from IoT smart sensors is visualised using a variety of approaches.

The Internet of Things (IoT) system, with its billions of linked devices, produces large volumes of data and requires flexibility. IoT systems involve a wide range of devices, organisations, and devices, which can lead to interoperability problems. Two major systematisation obstacles are the vast number of connected devices and huge organisations [8].

People often wear restorative sensor-based gadgets to track their health data, thus security is essential. For individuals and organisations to share data, the security of the information collected by these devices in Restorative IoT networks is crucial. Physical security is also very important; in order to secure data, equipment and coordinated computations must be carefully regulated [8].

3. SMART CITY DEVELOPMENT

By using protocols for communication and information sharing, the Internet of Things (IoT) is essential for linking everything to the internet. It makes intelligent management, tracking, monitoring, and recognition possible. Sensing, autonomous control, network infrastructure, and big data analytics are the main areas of study for the Internet of Things. Services like smart houses, parking lots, weather systems, traffic, pollution, surveillance systems, smart energy, and smart grids are provided by IoT-based smart cities. To create applications and integrated solutions for a sustainable society, further research is required [9].

A smart city is an intricate network that employs ICT to improve sustainability and innovation in urban areas. Stakeholders include government agencies, platform developers, citizens, application developers, and the research community. Various ICT technologies, development platforms, maintenance, sustainability, and key performance indicators are all part of the smart city cycle. For the large-scale deployment of heterogeneous infrastructure, IoT solutions are essential [10]. Fig. 3 provides a high-level representation of an Internet of Things-based smart city.

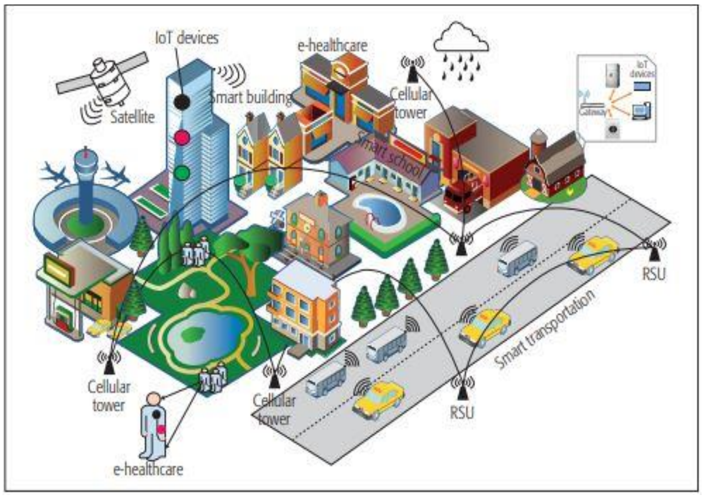

Fig. 3. An illustration of an IoT-based smart city [10].

To facilitate the growth of the Internet of Things, an urban IoT infrastructure combines a variety of technologies with already-existing communication infrastructures. It makes device interoperability possible as well as the realisation of innovative features and services. For authorities to respond more quickly to urban issues and for individuals to participate in public affairs, the data they have gathered must be accessible to both. Fig. 4 lists the elements of an urban IoT system [11].

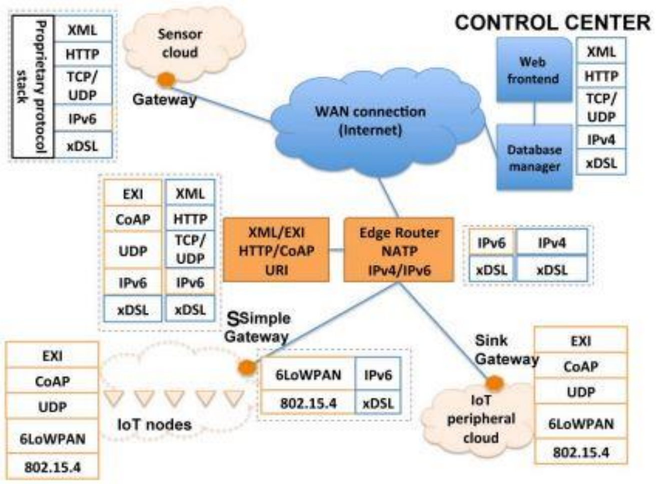

Fig. 4. Conceptual representation of an urban IoT network based on the web service approach [11].

To make city information more accessible and understandable for both municipality employees and residents, a clever front-end application has been created. The programme gathers requests and activities, provides both processed and raw data, and has been verified in an actual setting such as Barcelona. The system ensures effective data processing and display by integrating new and current sensor networks. The newest web technologies are the foundation of the application [12]. Utilising the bibliometric approach, a quantitative study is carried out with an emphasis on the phrases "internet of things" and "smart city." The huge disparity in article volume between the Web of Science (WoS) and Scopus databases makes the Scopus database the recommended choice for analysis. Many benefits come with Scopus, including the greatest collection of peer-reviewed literature, reduced chance of document loss, ease of use, data visualisation and analysis tools, multiple format downloads for samples, and a diverse array of data presentation options. Preferred Reporting Elements for Systematic Reviews and Meta-Analyses (PRISMA) is the model that the sample selection procedure is based on [13]. The procedure followed to select the sample on research in IoT and smart cities is adjusted to the flowchart in Fig. 5.

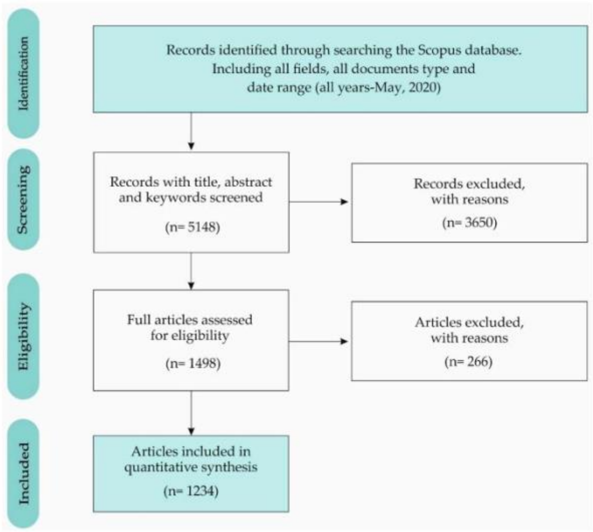

Fig. 5. PRISMA Flowchart [13].

Besides that, IoT is also used on natural disaster monitoring such as flood detection and monitoring in smart city to improve early warning systems, enhance emergency response efforts, and mitigate the impacts of flooding on urban areas [14]. IoT-enabled sensor networks are deployed in flood-prone areas, including rivers, streams, and drainage systems, to monitor water levels, flow rates, and other relevant parameters in real-time. These sensors can include water level sensors, flow meters, rainfall gauges, and weather stations. The sensors collect data on various environmental factors, such as rainfall intensity, water levels, and soil moisture content. This data is transmitted wirelessly to a central control system or cloud platform using IoT communication protocols, such as Wi-Fi, cellular networks, or LPWAN (Low-Power Wide-Area Network). Advanced analytics techniques, including machine learning algorithms, are applied to the collected data to analyse patterns, predict flood events, and assess flood risk levels. Historical data, weather forecasts, and hydrological models may also be incorporated into the analysis to improve accuracy. Based on the analysis of real-time data, early warning systems can be developed to alert authorities and residents about impending flood events. These warnings can be delivered through various communication channels, including mobile apps, SMS alerts, sirens, and digital displays, to ensure timely evacuation and preparedness measures. IoT technology can be integrated with existing urban infrastructure, such as flood gates, drainage systems, and pumping stations, to automate flood mitigation measures. For example, IoT-enabled flood gates can be remotely controlled based on real-time water level data to regulate water flow and prevent inundation of urban areas. IoT-enabled flood monitoring systems can engage citizens in flood detection and response efforts through crowdsourced data collection and reporting mechanisms. Citizens can use mobile apps or web platforms to report flooding incidents, share photos or videos, and provide feedback on the effectiveness of flood management measures. The data collected from IoT-based flood monitoring systems can inform urban planning decisions, infrastructure investments, and emergency response strategies to enhance the resilience of cities to flooding events. This includes identifying vulnerable areas, implementing flood-resistant design measures, and improving evacuation routes and shelters. Overall, IoT technology plays a critical role in flood detection and monitoring in smart city development by providing real-time data, predictive analytics, and early warning systems to mitigate the impacts of flooding and improve urban resilience.

All facets of life, especially in smart cities, will be digitalized thanks to the Internet of Things (IoT). Sensor nodes are being distributed throughout all city districts as part of this digitalization process. Significant obstacles stand in the way of developing and implementing IoT systems in smart cities. Smart sensors, networking, security and privacy, and big data analytics are a few of them [1- 2].

4. SMART FARMING

Precision farming, or smart farming, is the application of IoT devices, cloud computing, and the internet to increase agricultural yield and feed the world's projected 9.7 billion people by 2050. This results from the loss of agricultural land brought about by commercial marketplaces, residential construction, and industrialization. IoT may be used in farming to boost productivity by making it more lucrative, intelligent, and user-friendly for farmers [15]. In addition to lowering labour costs and increasing agricultural yields, smart farming makes farming simpler, more affordable, and more efficient. Additionally, it improves productivity by tackling issues like pests, plant illnesses, and a lack of awareness on necessary nutrients [15]. Farmers may overcome these obstacles and improve farming's profitability and intelligence by integrating IoT. Lower-level devices, intermediate data, and higher application planes make up the various levels of the Agri-IoT data analytics platform. There are software components in each layer that carry out certain tasks associated with modelling, analysis, visualisation, or data collection. Almost all of the needs for smart farming are met by the platform by repurposing existing components from IoT and smart city-related projects. A flexible distributed architecture is provided by each component, which functions as a standalone unit with its own open API. Applications can then combine components from various tiers according to their own requirements. Adhering to IoT principles and semantics, the Agri-IoT framework can integrate, modify, and analyse a broad range of cross-domain streaming data sources in a flexible fashion [16]. Fig. 6 shows the main components of the Agri-IoT framework are described below.

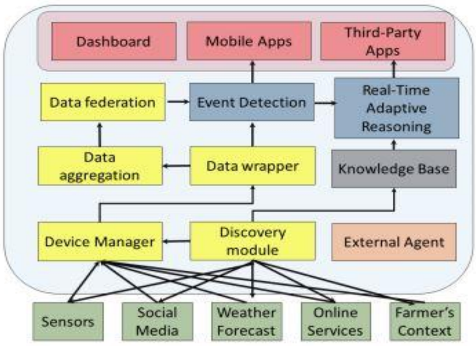

Fig. 6. Agri-IoT Architecture [16].

Microcontrollers, sensors, actuators, and wireless interfaces make up IoT-based agricultural structures. The application layer gives end users the ability to manage and keep an eye on farm operations, while the network layer transmits data via an Internet gateway. For machine learning algorithms to be used in predictive models, high-quality data is essential. Aside from integrating cloud computing services like agricultural mapping and storage, the Internet of Things can gather and handle massive volumes of data from sensors. End-to-end connection and real-time monitoring are made possible by real-time data access from any location at any time. With the ability to help end users make critical decisions based on market trends and projections, the application layer is the most crucial component [17].

The advancement of agriculture and industry through the application of Internet of Things technologies. Intelligent and effective agriculture is made possible by the identification, induction, feedback, and monitoring tools provided by this technology. Technologies like cloud computing, big data, mobile apps, and the Internet of Things are used in modern agriculture. The internet, IoT devices, data processing, data storage, and communication technologies are the four primary components of contemporary agriculture as shown in Fig. 7 [17]. IoT monitoring systems are deployed using communication technology, whereas embedded systems in IoT devices are primarily connected wirelessly.

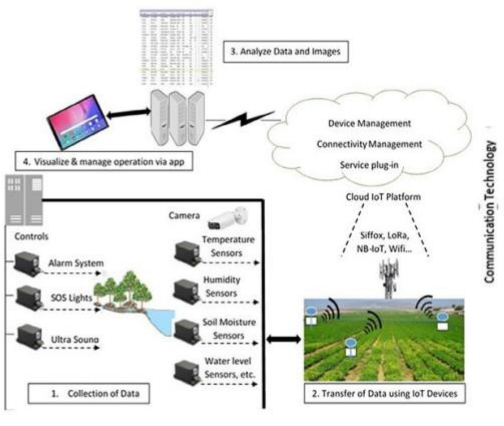

Fig. 7. Agriculture of IoT ecosystem [17].

Big data analytics and cloud models are used by the IoT agricultural network platform to extract valuable information from massive volumes of data. In addition to offering decision support services for agricultural production and optimal cost analysis, it supports growth models and the management of crop diseases. The farmer/user experience, big data analysis, sensing and monitoring, storage services, communication protocols, and physical implementations are the six components that make up the platform. It gathers data on online crop monitoring, weather conditioning, moisturization, and soil fertility. Fig. 8 shows IoT agricultural network platform based on big data analytics [18].

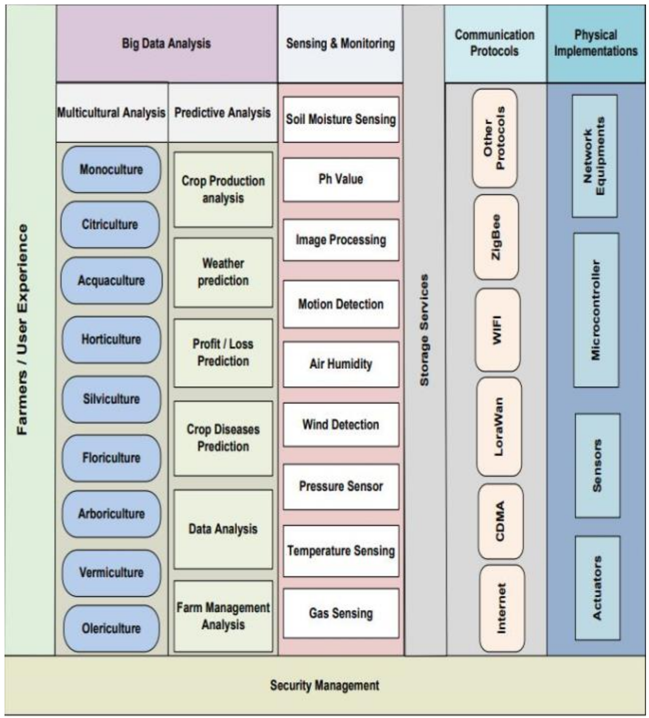

Fig. 8. IoT Agricultural Network Platform based on Big Data Analysis [18].

Furthermore, IoT technology is also often paired with low-power renewable energy systems like direct plant energy harvesting [19-22] and microbial fuel cells (MFCs) [23-25] to enable the deployment of ultra-low power sensors for monitoring environmental stimuli in smart farming. Direct plant energy harvesting is energy harvesting from the bio-electrochemical reaction from electrodes with plant biological entity to generate electricity [19] while and MFCs are bio-electrochemical systems that generate electricity through the metabolic processes of microorganisms [23]. The direct plant energy harvesting systems use living plant photosynthesis and respiration in reaction with electrodes to collect electrons process. On the other hand, MFC uses organic matter, such as waste products or soil organic carbon, as fuel sources for the microorganisms, which produce electrons as metabolic byproducts. These electrons can be captured by an electrode and used to generate electrical power. Ultra-low power sensors are devices designed to operate with minimal energy consumption, making them suitable for deployment in remote or off-grid locations where access to traditional power sources may be limited [21,24]. These sensors are typically used to monitor environmental parameters such as soil moisture, temperature, humidity, light intensity, and nutrient levels. Hence, with the integration of MFC to ultra-low power IoT sensors, the IoT technology can provides the communication infrastructure necessary for collecting, transmitting, and analysing data from sensors deployed in the field. IoT-enabled devices, such as gateways or nodes, communicate with the sensors and relay the collected data to a central server or cloud platform for analysis. This allows farmers to access real-time information about their crops and make data-driven decisions to optimize farming practices. Hence, direct plant energy harvesting and MFCs can serve as sustainable power sources for ultra-low power sensors in smart farming applications [19-25]. These renewable energy systems can continuously generate electricity from organic matter present in the soil or other environmental sources, providing a reliable power supply for the sensors without the need for external power sources or frequent battery replacements. Pairing direct plant energy harvesting and MFCs with ultra-low power sensors offers several benefits for smart farming. Using renewable energy sources reduces the environmental impact of farming operations and promotes sustainable agricultural practices. By powering ultra-low power sensors with renewable energy, farmers can achieve continuous monitoring of environmental conditions without interruptions due to power outages or battery failures. Real-time data collected from sensors powered by direct plant energy harvesting and MFCs can help farmers optimize irrigation, fertilization, and other farming practices to improve crop yields and resource efficiency.

In one of the study which used by investigates the use of Aloe Vera-derived plant-based cells for energy harvesting to power wireless devices for remote sensor activation [19-21]. This research explores the potential of utilizing plant-based cells to generate electrical energy, presenting a novel approach to sustainable energy sources at the intersection of plant leaves, ecology, wireless technology, energy harvesting, and electrical engineering. The research demonstrates a unique method where Aloe Vera-derived plant-based cells are employed for electrical energy generation, indicating the feasibility of leveraging natural resources for technological applications. By assessing the energy generation capabilities of plant-based cells, the study suggests promising eco-friendly power sources for wireless technology. Furthermore, the findings of this research contribute to the existing knowledge on alternative energy sources and underscore the potential of plant-based cells in the field of electrical engineering. By validating the use of plant leaves for energy harvesting, the study paves the way for further exploration and advancement in sustainable energy research. The research sheds light on the potential applications of Aloe Vera-derived plant-based cells for powering wireless devices, emphasizing the significance of innovative and sustainable energy solutions. This work not only enhances our comprehension of energy harvesting technologies but also emphasizes the importance of interdisciplinary research in propelling green technologies for the future.

In another research in [24], it introduces a novel approach to enhancing microbial fuel cell (MFC) performance for low-power sensor modules for IoT sensors for smart farming monitoring purpose. The research focuses on optimizing MFC efficiency through modifications to carbon powder electrodes to improve power generation for applications in low-power sensor modules. The study demonstrates a substantial enhancement in MFC performance as a result of the carbon powder electrode modifications. The research team achieved superior results by improving the anode structure, highlighting the effectiveness of their modification strategy compared to unaltered setups. This advancement showcases the potential for boosting energy generation in MFCs through electrode modifications, providing a promising pathway for enhancing sustainable energy technologies' efficiency. Furthermore, the study's focus on optimizing MFC performance for low-power sensor modules to monitor temperature and humidity for smart farming is highly relevant given the growing demand for energy-efficient sensor technologies. By increasing the power output of MFCs through electrode modifications, the research contributes to the advancement of sustainable energy solutions that can facilitate the operation of low-power sensors across various applications. The research marks a significant progression in the realm of microbial fuel cells and sustainable energy development. The study's concentration on enhancing MFC performance through carbon powder electrode modifications not only enhances our comprehension of energy generation processes but also offers practical insights for improving the efficiency of low-power sensor modules in renewable energy applications.

5. SMART GRID AND ENERGY SAVING

Using embedded technologies and cutting-edge ICT, the Internet of Things (IoT) is a network that connects different systems. In terms of information technology, it is regarded as the third revolution. IoT has been upgraded to the Internet of Energy (IoE), which combines ICT and energy ecosystems. The use of IoT in smart grid components—which employ digital communications technology to identify and respond to changes in local usage. The implementation of smart grids, smart cities, and smart building systems requires the Internet of Things [26-30].

The suggested setup comprises an Arduino 'Node MCU' integrated Wi-Fi module, a programmable circuit board, a web server, MySQL software, a local area network (LAN), and an IoT device. Fig. 9 shows the architecture of the proposed system. Transformers for current and potential are used to link the household appliance, RAC, to the SEC. The Wi-Fi device sends and receives signals over a LAN, and the SEC uses the DR algorithm to regulate the RAC [31].

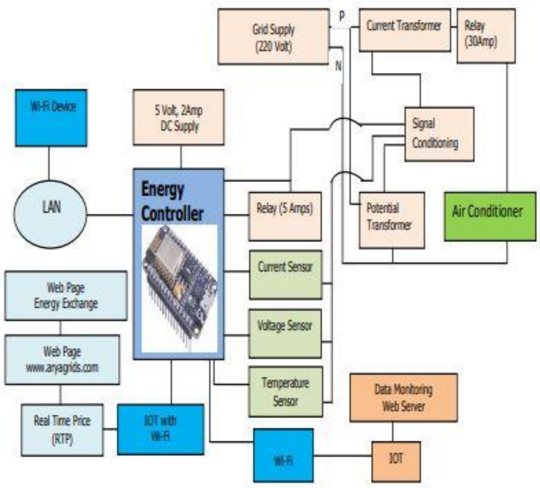

Fig.9. Depicts the System Architecture for Prototype Model [31].

A reliable and effective communication system is created by combining data collection, processing, transmission, and storage through the Internet of Things (IoT), a quickly developing communication technology. Benefits include customised network architectures and communication for intricate situations, lower expenses and power usage, and long-term service viability. The application of IoT in smart buildings, residences, smart cities, and smart grids has increased [32]. Low power wide area networks (LPWAN), LTE, LTE-A, and narrowband IoT (NB-IoT) are examples of novel communication technologies that have been suggested. LPWAN provides long-range communication capabilities over unlicensed bands. Utilising unlicensed frequency bands, LoRa and UNB are the most popular LPWAN technologies. A detailed comparison schemes for the popular communication technologies that are used in IoT are illustrated in Fig. 10.

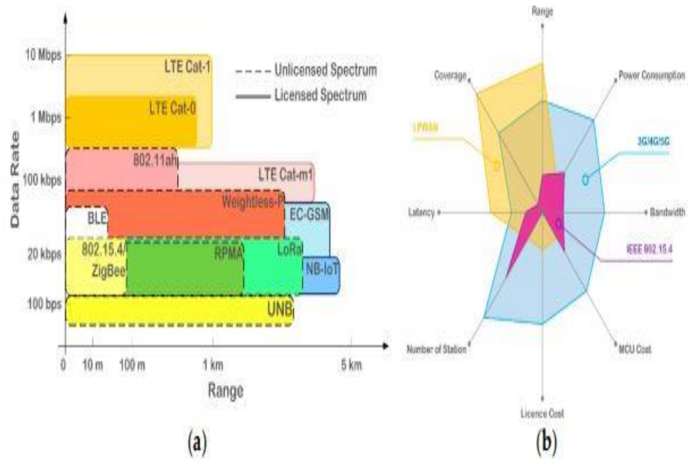

Fig. 10. Communication technologies utilized in IoT applications [32].

The application, network, cognitive, and sensing layers make up the Internet of Things-based energy management system. While the energy edge server controls device connections and communication channels, the sensing layer gathers energy data from the network. Making decisions requires data searching, and in smart cities, the edge server enables hierarchical processing of diverse energy data [33]. Data transfer and job offloading are common uses for communication technologies such Power Line Communication (PLC), LTE, Wi-Fi, and 5G. Software model for the IoT-based energy management system is described as shown in Fig. 11.

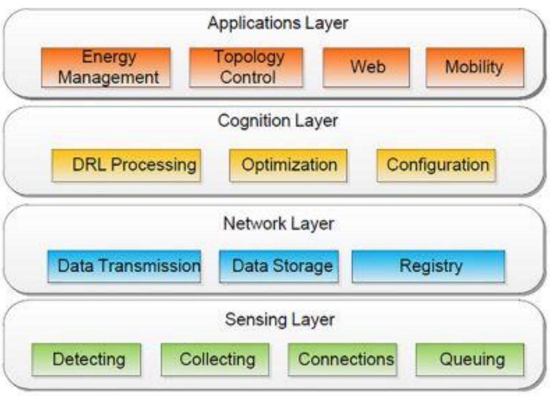

Fig. 11. Model for smart energy management [33].

SCADA-connected transmission systems, enhanced metering infrastructure, pollution monitoring, smart homes, and smart building systems are just a few of the possible uses for IoT technology. Smart home appliance automation and SCADA energy transmission system optimisation are made possible by cutting-edge technologies like fog computing [34].

The management of electrical energy generation, transmission, and distribution networks depends on Supervisory Control and Data Acquisition (SCADA) systems. They gather information and data from the grid and oversee automation procedures to effectively control system parameters. The SCADA system, which consists of four key components—end devices, fog computing devices, and the SCADA system—has grown more effective with IoT technologies like fog computing [34]. The overall architecture of the IoT-based smart energy grid SCADA system is presented in Fig. 12.

Co-simulation systems' capacity to provide accurate large-scale IoT infrastructure and operational scenarios, emphasising the necessity of "what-if" analyses [35]. A real-world model of network behaviours may be explored through simulation, which frequently involves measurement, testing, and analysis. The majority of simulators concentrate on simulating packet-level network operations, such queuing and packet transfer. Source traffic rates and burst size queuing are the main topics of fluid simulations, which ignore small-scale changes. The difficulty, though, is in reproducing dispersed, diverse, complex, and dynamic networks. A vibrant community that supports and develops a general-purpose tool is necessary for it to accomplish this task. Large-scale networks can only use ns-2 and OPNET, two multi-protocol simulation tools [35].

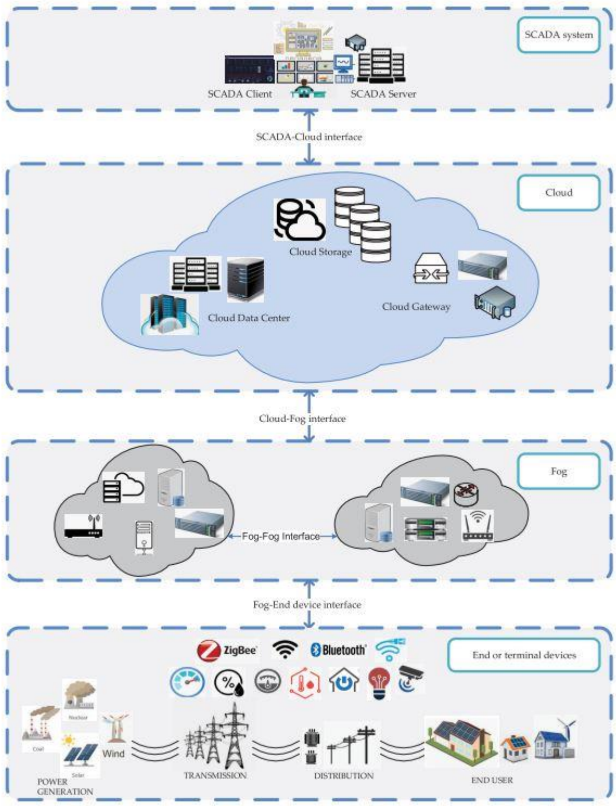

Fig. 12. The overall architecture of Fog-based smart energy grid SCADA system [35].

6. SMART MANUFACTURING

To attain high degrees of autonomy and optimisation in manufacturing businesses, smart manufacturing depends on data-driven technologies. Cyber-physical manufacturing systems are made possible by big data and the Internet of Things (IoT). Data-driven modelling, simulation, and information processing bring the real world into cyberspace. Smart manufacturing cannot be realised without cyber-physical integration and interaction [36-37].

Internet of Things (IoT) systems and technologies that integrate developments in cloud computing, virtual reality, and big data analytics to allow data-driven breakthroughs in smart manufacturing. Along with reviewing IoT cybersecurity concerns and discussing potential and problems in IoMT, it also introduces a new architecture for building virtual machine networks. To progress IoMT technologies, the study seeks to stimulate more interdisciplinary research and thorough analysis [38]. Sensor nodes, embedded processing nodes, and wired or wireless communication nodes are the three major building pieces required to incorporate IoT into smart manufacturing. RFID readers may be used to identify things or persons, while cameras can be used to monitor images. Real-time processing is carried out by the embedded processing nodes, which include hybrid microcontrollers and microprocessors [39]. To perform activities, communication between the two building blocks is sent via wired or wireless communication nodes.

Sensor-actor-machine, shop floor, factory, enterprise, and supply chain are the five levels of the manufacturing Internet of things (IoT). By improving information flow and logistics, these levels can lead to flatter organisational structures, more efficiency, and improved cross-layer interaction. Fig. 14 illustrates the five levels [40]. Interoperable services for physical devices are made possible by the Service Oriented Architecture (SOA) architecture, which is not dependent on specific manufacturers, goods, or technologies. SOA can help IoT, which is built on cooperative communication between heterogeneous devices. In general, research has concentrated on creating multi-layer SOA for IoT, with applications in manufacturing. A three-layer model for IoT, a five-layer model for cyber-physical manufacturing systems, a cloud-based framework for generic IoT, and a real-time information capture and integration framework for IoT applications in manufacturing are some of the earlier concepts. IoT apps are only present at the top layer of these functioning and compatible architectures. [41].

For Internet of Things (IoT) applications in manufacturing, A four-layer SOA that includes levels for sensors and data gathering, networks, services, and applications was suggested. Cloud manufacturing or non-cloud manufacturing can both use the suggested architecture. Certain components of the design have been effectively implemented, despite the lack of an industrial implementation.

Smart Manufacturing (SM) is related with 38 technologies and 27 traits, which are comprehensively illustrated in Fig. 18. It is suggested that these attributes be pursued by present and future manufacturing systems to attain a certain level of intelligence, called "qualities of being" (QoBs) or smart features [42]. The purpose of QoBs is to serve as the essential intelligent characteristics that make a manufacturing system "smart." Some clever characteristics never change even as technology do.

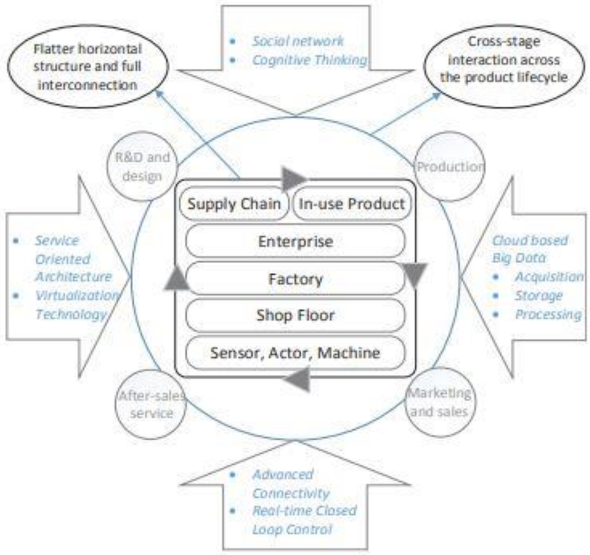

Fig. 13. Impact of IoT on the manufacturing industry [40].

The main drivers behind the implementation of IoT are increased productivity and efficiency; nevertheless, there are technological obstacles to overcome, including those related to security, privacy, connection, interoperability, scalability, flexibility, and resource management [42].

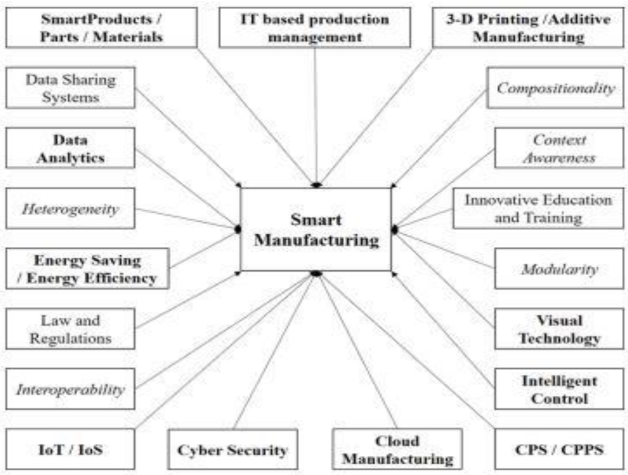

Fig. 14. Visual representation of all characteristics and technologies that can define an SM [42].

7. SMART EDUCATION

Smart education refers to the integration of technology, particularly IoT (Internet of Things), into educational settings to enhance teaching and learning experiences, improve educational outcomes, and increase efficiency in educational processes. This approach leverages various digital tools, platforms, and devices to create interactive, personalized, and collaborative learning environments.

IoT-enabled interactive whiteboards enhance classroom engagement by allowing teachers and students to interact with digital content using touch or stylus input [43]. These devices can integrate with other IoT sensors or devices to display real-time data, multimedia resources, and interactive learning materials [43]. IoT-enabled smart projectors enhance traditional presentations by incorporating interactive features, such as touch interactivity, gesture recognition, and screen mirroring capabilities [43]. These projectors can also connect to IoT devices, such as tablets or smartphones, to facilitate collaborative learning activities.

IoT sensors deployed in classrooms monitor environmental factors such as temperature, humidity, air quality, and noise levels as well as to automate the lighting, fan, air conditioning based on human detection to enable energy saving approach [44]. This data can be used to optimize classroom conditions for learning, improve energy efficiency, and ensure student comfort and well-being. IoT-based attendance tracking systems automate the process of taking attendance by using biometric sensors, RFID (Radio Frequency Identification) tags, or facial recognition technology. This streamlines administrative tasks for teachers and enables real-time monitoring of student attendance. IoT devices and platforms collect data on student progress, preferences, and learning styles to tailor educational content and activities to individual needs. This enables personalized learning paths that accommodate diverse learning styles and abilities, promoting student engagement and motivation. IoT sensors embedded in educational tools, such as online quizzes, simulations, and interactive learning modules, provide real-time feedback and assessment data to students and teachers. This facilitates formative assessment practices, identifies areas for improvement, and enables timely interventions to support student learning.

IoT devices and platforms facilitate blended learning by enabling remote access to educational resources, virtual classrooms, and online collaboration tools. This allows students to engage in self-paced learning activities, participate in virtual discussions, and access instructional materials from anywhere with an internet connection [45]. IoT in E-Learning: IoT-enabled mobile learning apps deliver educational content and activities to students' smartphones or tablets, allowing for anytime, anywhere learning experiences. These apps may incorporate features such as gamification, multimedia resources, and social networking capabilities to enhance engagement and retention. IoT sensors and data analytics tools track student interactions with e-learning platforms, including access patterns, time spent on tasks, and engagement levels. This data can be used to generate insights into student behaviour, identify learning trends, and inform instructional design decisions. IoT-based adaptive learning systems use data on student performance and behaviour to dynamically adjust the difficulty level, pace, and content of learning activities. This personalized approach maximizes learning effectiveness by targeting each student's individual learning needs and preferences either in the classroom or in lab session learning environment [46].

In summary, IoT technology is used in smart education to create interactive, personalized, and collaborative learning environments across various educational settings, including smart classrooms, blended learning environments, and e-learning platforms. By integrating IoT devices, sensors, and data analytics tools into educational processes, educators can enhance teaching effectiveness, improve student engagement and learning outcomes, and provide more flexible and accessible learning experiences for students.

8. CONCLUSION

Many industries, including healthcare, smart cities, agriculture, energy, and manufacturing, and education have been transformed by the Internet of Things (IoT). IoT technologies are optimising decision-making, revolutionising processes, and boosting productivity and sustainability. Smart cities provide safer, more effective surroundings, and remote monitoring and personalised therapies are revolutionising the healthcare industry. Traditional agricultural methods are being changed, while smart networks are increasing energy efficiency. Industry 4.0 concepts are being used to manufacturing to improve supply chain management, increase efficiency, and allow predictive maintenance.

The Internet of Things is changing the world by tackling difficult problems and offering creative answers. Its networked infrastructure of sensors, devices, and systems promotes industrial resilience, data-driven insights, and teamwork. The prospect of a more productive future is nevertheless alluring, even in the face of obstacles like data security and interoperability.

IoT applications are essentially changing not just industries but also how people live, work, and engage with the outside world. As technology develops, the continuing Internet of Things integration is expected to rewrite the rules of what is possible, ushering in a time when intelligence and connection will work together to solve some of the most important problems confronting humanity.

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