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Internet of Things: A Revolutionary Approach to Attain Sustainability

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ABSTRACT
UN's sustainability prioritizes present needs without jeopardizing the future, covering planetary protection, social advancement, and climate mitigation. IoT, linking devices for data exchange, bolsters sustainability in resource management, agriculture, and environmental monitoring. Its growth is fueled by lower sensor costs, wider internet access, and enhanced computing power. IoT aids weather tracking, pollution monitoring, and agriculture efficiency. Challenges include complexity, privacy, connectivity, and investment hurdles. Despite obstacles, IoT drives sustainability, enhancing efficiency, safety, and quality of life, promising a more sustainable future through positive change.

KEYWORDS: Sustainability, IoT, Future

I. INTRODUCTION

Sustainability was defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" by the United Nations Brundtland Commission in 1987. It also entails stopping climate change, advancing socioeconomic development, and safeguarding the environment. It includes actions and procedures meant to lessen their negative effects on the environment, encourage social responsibility, and guarantee economic sustainability. The term "Internet of Things" (IoT) describes a network of interconnected, internet-connected devices that may gather and send data wirelessly without the need for human interaction. Kevin Ashton coined that term in 1999. It is the process of connecting everything to the internet. The Internet of Things (IoT) is a network of real-world "things" that have sensors, electronics, software, and network connectivity incorporated in them so they can trade and gather data. The term "Things" in Internet of Things typically refers to IoT devices with distinct identities and the ability to sense, act, and monitor remotely. IoT devices have the ability to process and exchange data with other connected devices and applications, as well as gather and process data from other devices. IoT makes it possible for people to engage in more environmentally friendly, economical, and intelligent behaviours, which is vital in advancing sustainability in a variety of industries.

II. REVIEW OF LITERATURE

Dimitrov (2016) stated that as more people are utilising IoT to handle their health needs, IoT is revolutionising healthcare services. The ability to monitor and counsel patients remotely using a remote health monitoring system is one of the greatest features of the Internet of Things in the healthcare sector. Another important strategy that IoT provides is real-time location services. Working together will be the primary objective of the clinicians and Digital Health Advisors as the organisation transitions to IoT-enabled infrastructure.

Alshamsi *et. al.* (2017) focused on the growing issue of toxic gases resulting from industrial processes. In order to identify the presence of undesirable gases in the air in residential areas close to industries and industrial activity, they installed sensors. The sensors continuously monitor and record data about air pollution; Internet of Things technology is then used to report and analyse the results.

Shaikh *et. al.* (2017) proposed a system that focuses suggested a system that focuses on rapidly locating relevant IoT things for the user in order to reduce the amount of labour they have to do at home utilising home automation systems. This will enable the user to assess the state of the kitchen safety unit, grocery monitoring unit, and application defect detection unit in the house at any time.

Sharma *et al.* (2017) stated that mobile Android systems can communicate with smart home

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automation systems. Wi-Fi allows the system and mobile to communicate with one another. the instructions for turning on and off electrical accessories like lights, fans, air conditioners, and so on. When users give orders, the home automation system carries them out and reports the outcome. Additionally, the user can view the results of commands on an Android mobile application.

Saha *et. al.* (2018) concluded that drones have a great deal of potential for use in agriculture, boosting crop management in its early stages, increasing productivity, and using less energy. Their benefits are manifold, ranging from precision seed planting and nutrient delivery to soil analysis. They are better able to determine crop health and watering requirements thanks to advanced sensor technologies. Drones are vital to accomplishing the data-driven objectives of precision agriculture.

Sikder *et. al.* (2018) revealed that how to create a Smart Lighting System (SLS) in a smart city by integrating advanced sensors and communication channels with the lighting system. The purpose of an SLS is to create a self-sufficient and more effective lighting management system. They discovered that smart lighting systems with Internet of Things potential can lower power usage by up to 33.33% in both indoor and outdoor environments.

Ayaz *et. al.* (2019) identified the opportunities of IoT and wireless sensors in agriculture along with the difficulties that may arise from combining these technologies with conventional farming methods. This led to the conclusion that, in order to maximize agricultural yield, every square inch of cropland is crucial. However, using sustainable IoT-based sensors and communication technology is essential to handling every inch appropriately; it is not a substitution.

Khanna and Kaur (2019) concluded that the Internet of Things (IoT) has significantly improved efficiency and facilitated remote farm management in modern agriculture. The next generation of IoT brings even bigger breakthroughs as technology keeps developing. Accurate handling of data supplied by sensors is essential. Agriculture will soon undergo a transformation thanks to the extensive Internet-based integration of sensors and equipment, which will save time, reduce labour costs, and boost output and profitability. The field of precision agriculture and IoT research is still in the early stages, but it has enormous potential to serve society.

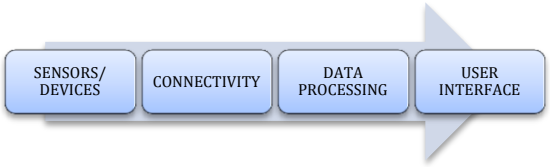
Farooq et. al. (2022) conducted a survey that offers a cutting-edge summary of IoT-based greenhouse farming applications, sensors/devices, communication protocols, and technologies that serve as the backbone of the IoT and assist farmers in raising crop yields. As a result, the government and other large organizations started financing the development of innovative IoT-based smart greenhouse farming techniques.

Obaideen *et. al.* (2022) found that there is a lot of promise for improving irrigation efficiency, managing resources, and solving water scarcity with IoT and sensor systems. IoT-integrated smart irrigation systems lower costs and allow real-time monitoring for precision farming; nonetheless, successful irrigation management involves balancing benefits and drawbacks.

Babu *et. al.* (2023) focused on improving crop yield, cutting waste, and increasing profitability via IoT-based agricultural equipment. The use of IoT-based technology is expected to increase as digital infrastructure grows and with government support. If IoT-based agricultural technology continues to advance and grow, the Indian agriculture sector may shift and farmers' lives may be better.

Saadh *et. al.* (2023) focussed on how the Internet of Things framework can be used to improve aquaculture in India by raising the quality of water in aquariums that use aquarium sewage to grow plants. During response, water that has been neutralised for acidity and ammonium by hydrogen granules in the garden bed returns to the tank. Using a secondary strategy, the potential applications of this IoT equipment are emphasised for improving India's fish farming in the future by raising the water quality.

III. IOT– HOW IT WORKS



Sensors/ Devices: These gadgets establish connections with the outside world. They gather and store the data resulting from external changes. When the environment changes, a sensor notices it and records it. With IoT applications, this feature makes sensors very helpful. For instance, your phone has sensors—like GPS—that allow it to track your whereabouts and direct you to your destination. In order to take photographs, cameras detect human movement.

Connectivity: The link between any particular IoT ecosystem's sensors, routers, gateways, user apps, and platforms is known as connectivity. Choosing

the appropriate connectivity method is essential since it gives you control over the entire Internet of Things system. Large-scale data transmission is made possible by cellular networks like LTE and 5G, Bluetooth, and WiFi.

Information Processing: After all of the data has been transmitted to the platform, operations are carried out on it to process it and return the required outputs. To put it another way, data analysis happens. The most crucial stage in IoT technologies is this one. For improved outcomes, the analysis must proceed quickly.

User Interface: The last phase is the user interface. This step provides the output that consumers view on their screens and is in close proximity to the user.

IV. FACTORS SPURRING RAPID IOT EXPANSION

Falling sensor costs: Advancements in technology and manufacturing processes have significantly reduced the costs of sensors used in IoT devices. These sensors are essential as they gather data from the environment, making them more affordable to integrate into various devices and applications.

Falling cost of data collection and storage: The costs associated with collecting and storing vast amounts of data have decreased dramatically. Cloud computing solutions, scalable storage options, and efficient data management systems have made it more feasible for businesses and individuals to collect, process, and store data generated by IoT devices.

Widely expanding internet connectivity: The continuous expansion and improvement of internet infrastructure, including the rollout of 5G technology and increased broadband accessibility, have been pivotal in fostering IoT growth. Reliable and high-speed internet connections enable seamless communication between IoT devices, facilitating real-time data transmission and enabling more sophisticated applications.

Increasing computing power: Advancements in computing capabilities, particularly in edge computing and microprocessors, have empowered IoT devices to process data more efficiently. This increased computing power allows devices to perform complex tasks locally without relying solely on centralized servers. It enhances response times, reduces latency, and enables quicker decision-making, which is critical for time-sensitive applications.

Increasing smartphone and tablet penetration: The widespread adoption of smartphones and tablets has created an ecosystem where these devices often act as a hub for controlling and monitoring IoT devices. Mobile apps provide user-friendly interfaces to interact with IoT systems, allowing individuals to manage and receive information from connected devices regardless of their location. The prevalence of these devices has significantly contributed to the integration of IoT into everyday life.

V. APPLICATIONS OF IOT IN DIFFERENT AREAS

IoT In Home Automation

One essential component of contemporary home technology is home automation, which comprises a range of networked devices designed to monitor and control different aspects of the house. Smart thermostats, which allow for remote climate management, are one example of how the integration of Internet of Things (IoT) devices gives consumers the opportunity to remotely monitor and adjust various home features. In addition, the integration of IoT-based mechanisms, like smart lighting systems, promotes cost-effective and sustainable energy practices by enabling optimised energy utilisation. By utilising energy-efficient products like smart refrigerators and washing machines, this combination not only promotes energy and financial savings but also makes a substantial contribution to environmental conservation efforts. IoT-enabled surveillance systems, such as door locks and smart security cameras, enhance security, a top priority, by facilitating remote monitoring and access control. Moreover, personalised IoT devices—like voice-activated entertainment systems and adjustable smart beds—address increased user comfort and represent the transition from a traditional home to a smartly automated one.

IoT In Health Care

IoT (Internet of Things) integration in healthcare is a revolutionary strategy that redefines medical practices by utilising smart devices, sensors, and connections. Real-time data capture is made possible by this innovation, which improves patient care and streamlines healthcare procedures. IoT applications include smart medical devices providing real-time patient data for informed decision-making and remote patient monitoring for ongoing health tracking. Within healthcare systems, smooth information flow is ensured by effective data management. Vital signs are tracked via wearable technology, such as smartwatches, which promote proactive healthcare and behaviour monitoring. IoT additionally secures temperature

compliance for pharmaceuticals and helps monitor mood and sadness. These varied applications, which support accuracy and individualised healthcare solutions, include gadgets like connected inhalers, glucose monitors, and heart rate monitors.

IoT in Cities

IoT (Internet of Things) devices, like linked sensors, lights, and metres, are used in smart cities to collect and process data that is essential for improving public services and urban infrastructure. The incorporation of IoT technology results in a variety of uses for urban environments. By using IoT-enabled sensors embedded in parking spaces, smart parking systems offer real-time mapping of available spaces, easing traffic congestion and cutting down on emissions from cars looking for a place to park. In addition, smart lighting solutions are another way that IoT is being implemented in cities. These solutions use sensors to automatically alter brightness levels in streetlights based on movement and ambient light, saving energy and enhancing safety in well-lit areas. Furthermore, Internet of Things (IoT) devices positioned on roads gather and distribute essential information related to traffic patterns, road circumstances, and collision identification, supporting effective traffic control, anticipating traffic jams, and planning ahead for preventive maintenance. IoT-powered crowd monitoring devices, gunshot detectors, and surveillance cameras are useful for public safety efforts because they enable law enforcement organisations to keep a close eye on public areas. Moreover, by monitoring whereabouts and vital indicators, wearable IoT devices for emergency responders guarantee their safety. IoT sensors incorporated into infrastructure identify structural weaknesses in an emergency, rapidly notifying authorities to avert mishaps and accelerate life-saving measures. This extensive IoT connection with municipal systems embodies a proactive approach to resource optimisation, urban development, and maintaining the efficiency and safety of urban environments.

IoT in Environment

The use of the Internet of Things (IoT) to environmental monitoring is an organised method that employs sensors and networked devices to continuously collect information and measurements from the surrounding environment. Numerous applications that are essential for managing and monitoring the environment are produced by this connection. Real-time temperature, humidity, wind speed, and precipitation data are gathered by IoT-based weather monitoring systems, which make it easier to forecast weather trends, issue severe weather alerts, and prepare for natural catastrophes. Furthermore, IoT sensors positioned throughout cities keep an eye on air quality by identifying contaminants such as CO2, particulate matter, and nitrogen dioxide. This allows for the detection of pollution sources and levels as well as the development of mitigation techniques. Another aspect of the Internet of Things is sound sensors, which track urban noise pollution and help with zoning loud areas, enforcing noise control measures, and monitoring compliance with noise laws. IoT sensors placed in forests also work as early warning systems for forest fires, spotting variations in temperature, humidity, and smoke to provide quick reactions that lessen the impact and prevent significant damage. IoT sensors that monitor water levels along riverbanks provide real-time data that is essential for anticipating and identifying floods, allowing authorities to promptly issue warnings and put in place efficient flood control measures. This thorough incorporation of IoT technology in environmental monitoring highlights how important it is to manage and protect natural ecosystems in a proactive manner while reducing the dangers that may arise from environmental threats.

IoT in Retail

The retail industry is witnessing a revolutionary change with the introduction of Internet of Things (IoT) technology, which aims to improve customer experiences and operational efficiency. IoT applications appear in this domain in a variety of retail management contexts. Sensor-based systems improve the in-store experience by enabling smooth navigation and controlling temperature, lighting, security, and inventory. RFID-tagged smart shelves with weight sensors and other features optimise the inventory process by preventing stockouts, reducing theft, and guaranteeing inventory correctness. Store managers may optimise layout and strategically locate products by using sensor and video analytics insights. Additionally, occupancy sensors provide vital information about customer behaviour that helps with premium product placement decisions. Amazon Go is a prime example of checkout automation, which simplifies the shopping experience by enabling cashierless transactions through the use of IoT-driven sensors and smartphone applications. Furthermore, environmental sensors support cold chain monitoring, guaranteeing food freshness and reducing waste, and IoT-enabled on-site sensors

keep an eye out for repairs and maintenance requirements. By giving customers access to real-time stock availability, this intricate integration of IoT technology in retail extends to omnichannel experiences, seamlessly linking online and physical retail. All things considered, IoT in retail proves to be a powerful instrument for increasing operational effectiveness, improving customer pleasure, and maximising retail performance.

IoT in Agriculture

Monitoring of climate conditions: Smart agriculture devices, notably weather stations, stand as prominent tools in monitoring climate conditions within agricultural landscapes. These stations integrate an array of smart farming sensors dispersed strategically across fields to gather diverse environmental data. These sensors meticulously collect information pertinent to the surroundings and subsequently transmit this data to cloud-based platforms for analysis and storage. This comprehensive amalgamation of sensors within weather stations facilitates the acquisition of multifaceted environmental data crucial for informed decision-making in agricultural practices.

Greenhouse automation: Greenhouse automation embodies a fundamental facet of modern agricultural practices, delineating structures designed to provide a meticulously controlled environment conducive to optimal plant growth. Functioning on the principle akin to the 'greenhouse effect', these structures feature roofs constructed from glass or plastic, allowing the passage of light while effectively trapping it within, creating an environment conducive to plant growth. Integral to this system are IoT sensors strategically placed within the greenhouse, facilitating the acquisition of real-time and precise data regarding climatic parameters such as lighting, temperature, soil conditions, and humidity. Leveraging this data, weather stations integrated into greenhouse automation systems enable automatic adjustments to the environmental conditions, ensuring alignment with predefined optimal parameters. This amalgamation of IoT-driven sensors and automated systems within greenhouse environments exemplifies a sophisticated approach aimed at maintaining and optimizing the conditions essential for fostering healthy plant growth.

Crop Management: In crop management, field-placed sensors collect vital crop-specific data, spanning temperature, precipitation, leaf water potential, and overall crop health. This data enables ongoing monitoring of crop growth and early anomaly detection, pre-emptively averting potential diseases or infestations that could compromise yield. The strategic use of sensors stands as a proactive approach to safeguard crop health and optimize productivity in agriculture.

Cattle monitoring and management: The adverse effects of unfavorable environmental conditions on animal productivity pose a significant concern in agriculture. IoT-based livestock management solutions emerge as pivotal tools aiding farmers in refining farming methodologies, enhancing livestock welfare, and optimizing dairy product output. Analogous to crop monitoring, IoT agriculture sensors find application in animal farming by affixing them to animals, enabling comprehensive health monitoring and performance logging. Notable IoT-based applications in livestock monitoring include the assessment of animal temperature, detection of heat stress levels, recognition of physical gestures, monitoring heart rates, and GPS-based tracking. These sensors play a crucial role in identifying ailing animals, allowing prompt isolation from the herd to prevent contamination and mitigate potential health risks. This integration of IoT technology in livestock management epitomizes a proactive approach to bolstering animal health, improving farming practices, and ensuring the quality of agricultural output.

Agricultural drones: Agricultural drones, or UAVs (unmanned aerial vehicles), represent a significant stride in agritech, offering unparalleled capabilities in data collection for smart farming practices. These drones excel in diverse agricultural applications, notably soil and field analysis, enabling assessment of moisture content, terrain conditions, erosion, nutrient levels, and soil fertility. Their role extends to crop monitoring, facilitating timely fertilization, pest detection, and weather impact assessment, crucial for ensuring timely harvests, particularly with seasonal crops. Moreover, drones equipped with high-resolution infrared cameras serve in livestock management by swiftly identifying sick animals. They streamline crop spraying processes with reservoirs for efficient application of fertilizers and pesticides, significantly reducing operational time. Their proficiency in constant crop health monitoring, enabled by infrared mapping, ensures comprehensive assessments of soil and crop conditions in a fraction of the time taken by manual surveys, mitigating human errors. Furthermore, drones play a pivotal role in curbing chemical overuse by precisely detecting and quantifying pest attacks, aiding farmers in optimizing chemical application. Their weather forecasting capabilities

assist in proactive crop planning and management, while multispectral imaging ensures accurate crop growth monitoring and identification of subtle differences between healthy and stressed crops. Additionally, their geofencing capabilities, equipped with thermal cameras, offer protective measures against nocturnal animal threats, safeguarding fields from external damage. The integration of agricultural drones epitomizes a transformative leap in precision farming, optimizing agricultural practices and resource utilization.

Smart Irrigation: Smart irrigation systems, employing IoT devices equipped with soil moisture sensors, represent a pivotal advancement in precision agriculture, orchestrating optimal crop irrigation while mitigating water wastage. These systems function by assessing soil moisture levels and releasing water flow through irrigation pipes exclusively when moisture levels dip below predetermined thresholds. The benefits of smart irrigation systems span multifaceted advantages within agricultural landscapes. They contribute to increased soil nutrient levels, facilitated by controlled and targeted irrigation practices. Moreover, these systems offer substantial water conservation benefits, minimizing pesticide usage, and reducing water contamination through diminished runoff. Additionally, their operational efficiency leads to reduced resource utilization costs, enhancing overall productivity and yielding significant savings in water usage. The implementation of smart irrigation not only optimizes land use but also augments crop production, epitomizing a sustainable and efficient approach in modern agriculture.

IoT in Aquaculture

Smart aquaculture, leveraging IoT technologies and data-driven methodologies, represents a paradigm shift in enhancing the efficiency, sustainability, and productivity of aquaculture systems. IoT devices, encompassing sensors and cameras, play a pivotal role in monitoring fish behavior, growth patterns, and overall health. These devices gather intricate data on swimming behaviors, feeding habits, and abnormalities, facilitating early detection of potential diseases. Moreover, the amalgamation of IoT-generated data on fish behavior and environmental conditions enables machine learning algorithms to predict disease outbreaks or epidemics, aiding in proactive intervention. Continuous monitoring of critical water quality parameters like dissolved oxygen levels, pH, temperature, ammonia, and salinity by IoT sensors ensures optimal conditions for fish growth and health. Furthermore, IoT devices extend their monitoring scope beyond aquaculture setups, encompassing external environmental factors such as weather conditions, water currents, and pollution levels, accentuating their role in ensuring a holistic approach to aquaculture management and sustainability.

VI. BENEFITS OF ADOPTING IOT

Increased Efficiency and Automation: Internet of Things (IoT) devices help automate activities and procedures, which lowers the need for human interaction and simplifies operations. Higher productivity and more effective resource use result from this.

Better Monitoring and Control: IoT-enabled real-time data gathering and analysis allow for accurate equipment, system, and environment monitoring and control. This facilitates timely decision-making based on information, performance optimisation, and potential problem prevention.

Increased Safety: By monitoring circumstances in a variety of contexts, including public and industrial areas, Internet of Things sensors and devices augment safety protocols. They are able to identify irregularities, threats, or hazardous circumstances, which helps to avert mishaps and guarantee a more secure atmosphere for people.

Energy Savings: By controlling consumption in response to current demand and circumstances, IoT-enabled smart systems optimise energy utilisation. To cut down on energy waste, smart thermostats, for example, modify the heating and cooling system according to occupancy.

Cost Savings: IoT-driven efficiency gains, proactive maintenance, and optimal resource use result in cost savings across a range of industries. Predictive analytics lowers maintenance expenses, downtime, and equipment failures.

Improved Quality of Life: IoT promotes daily life by enabling smarter, more connected surroundings. From smart homes with automated gadgets to healthcare systems with remote monitoring, IoT adds to enhanced convenience and healthcare services, eventually boosting the quality of life.

In Agriculture

Every sensor in the IoT ecosystem is capable of precisely detecting several meteorological parameters in real time, including temperature, humidity, and precipitation. The IoT system's implementation in greenhouses has removed the need for human interaction, which has reduced costs and increased accuracy throughout the process. The goal of IoT solutions is to maximise the usage of resources including land, electricity, and water. IoT

in agriculture has improved product volume and quality by assisting farmers in maintaining the fertility of the ground and the quality of their crops. Automation is introduced to agriculture through IoT system solutions, such as demand-based fertilisation, irrigation, and robotic harvesting.

VII. CHALLENGES IN ADOPTION OF IOT

Complexity of Technologies: Implementing IoT involves integrating various technologies, platforms, and devices, which can be complex and require specialized knowledge for deployment and maintenance.

Privacy and Security Concerns: With an increased number of connected devices, there's a higher risk of data breaches, privacy infringements, and cyber-attacks. Safeguarding sensitive data and ensuring secure communication among devices are significant concerns.

Internet Connectivity and Availability: IoT devices rely on stable and widespread internet connectivity. Remote or rural areas with poor connectivity may face challenges in implementing and utilizing IoT solutions effectively.

High Investment: The initial setup costs for IoT infrastructure, including sensors, devices, connectivity, and analytics platforms, can be substantial. This might pose a barrier, especially for smaller businesses or developing regions.

Human Dependence and Untrained Manpower: Despite automation, human intervention is often necessary for management and decision-making based on IoT-generated data. Additionally, the lack of skilled personnel proficient in IoT technologies can hinder effective utilization.

Small, Dispersed Land Holdings: In agricultural settings, small and dispersed land holdings can pose challenges in deploying IoT solutions uniformly across farms. It may be economically challenging to implement IoT systems in such scenarios.

VIII. CONCLUSION

The analysis of IoT's applications across sectors showcases its transformative impact on sustainability, reshaping agriculture, healthcare, urban development, and more. In farming, IoT optimizes resource use through climate monitoring and smart irrigation, revolutionizing traditional practices. Healthcare sees remote monitoring and improved services, while smart cities benefit from traffic management and safety measures. IoT aids in environmental monitoring, retail efficiency, and aquaculture advancements. Challenges like complexity and costs persist, but collaboration and training can pave the way for smoother integration. Ultimately, IoT promises a future where interconnected devices drive efficiency, sustainability, and better living standards across industries.

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