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Study of Real-World Applications of Internet of Things for Sustainable Development

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Abstract: Technology development and environmental sustainability are strongly related, and it is possible that people believe that new developments in technology have a negative effect on the environment. Due to the disconnection of the elements that drive sustainability and digital innovation, the relationship between technology and the environment has changed. Robotics, artificial intelligence, and, most significantly, the Internet of Things have been at the forefront of this technological revolution that is environmentally friendly. These technologies all have the power to alter business and industrial practices while also making them more ecologically friendly. The development of IoT sensor technologies and wireless connectivity has strengthened digital innovation and sustainability in parallel. The advancement of sustainable development can be greatly supported and improved by Internet of Things along with big data applications. Many sectors are being influenced by IoT, including manufacturing, retail, insurance, healthcare, heavy equipment, appliances for home use, aviation and logistics. This work mainly focuses on the study of various real-time IoT applications used for sustainable development. This paper also gives some example of IoT Technologies used for Sustainable development.

Keywords:- Sustainable **Development, Internet of Things, Smart Agriculture, Smart City, Smart Home.**

I. INTRODUCTION

The Internet of Things (IoT) is an emerging technology, which is envisioned as a global network of equipment and gadgets that can communicate with one another. The Internet of Things (IoT) is becoming increasingly popular across many different industries and is acknowledged as one of the most significant areas of future technology. The Internet of Things (IoT) enables the creation of numerous industry- and user-specific applications. IoT applications facilitate robust and dependable device-to-device and human-to-device interactions, while devices and networks offer physical connectivity. Device-based IoT applications must guarantee that messages and data have been received, processed, and acted upon promptly.

By 2050, two thirds of the world's population will live in cities, creating a number of challenges for the infrastructure and natural resource management sectors (such as the scarcity of food and water, rising global temperatures, and energy-related problems). In both urban and rural areas, the Internet of Things (IoT) has great potential for reliable, sustainable, and informed resource management due to its integrated sensing and communication capabilities. The key ideas of sustainable development through IOT applications are discussed here. The IoT and sustainability connections are explored with emphasis on Sustainable Development Goals (SDGs) and communication technologies.

Applications of the Internet of Things for Sustainable Development will provide light on current advancements in the sector and be very interesting to learn about the different areas in which sustainable development is used. Climate change, electrical systems, healthcare systems, and energy are among the sectors of sustainable development that can use IoT to benefit both current and future generations. A variety of problems, possibilities, and challenges facing sustainable development are going to be solved in the future when new hardware, software, and technology are developed. Sensors, intelligent devices, systems, and cutting-edge technical designs create excellent opportunities for development in cities and communities both now and in the near future. Internet of Things applications and their numerous breakthroughs and advancements are unstoppable.

The goal of Internet of Things systems and applications is to naturally integrate the Internet into our surroundings and make it even more immersive. This paper primarily focuses on the applications of Internet of Things (IoT)-enabled sustainable development of society, including low-cost sensor design and protocol design. The study's main objective is to find the potential benefit of IoT to the worldwide objective of sustainable development. The paper is organized as follows. Section II describes Sustainable Development Goals (SDGs) and Objectives. Section III describes the role of IoT in sustainable development. Section IV describes the real-time applications of IoT. Section V gives the conclusion.

SUSTAINABLE DEVELOPMENT GOALS (SDGS) AND OBJECTIVES

"Sustainable development is the development that meets the needs of the present and of future generations to meet their own needs". The goal of sustainable development is to protect the environment, social equality, justice, and sustainable development. Although these three factors might work together harmoniously, it is frequently discovered that they conflict with one another.

The primary goal of sustainable development is to achieve and maintain a particular level of equilibrium between the financial, social, and environmental demands of society in order to promote prosperity for both the present and future generations. Sustainable development emphasizes and focuses on long term implications and consequences of any decisions taken regarding technological, societal, financial or social growth. The fundamental goal is to truly construct a strong and long-lasting social infrastructure by addressing any potential issues with social, economic, and environmental advancements while also protecting important natural and man-made resources.

Fig. 1- Objectives of Sustainable Development

On January 1, 2016, the UN will formally unveil the 17 Sustainable Development Goals (Figure 2), which aim to end a variety of socioeconomic issues by 2030. The objectives emphasize that no one should be left behind and address the needs of individuals in both developed and developing nations. The Agenda's wide-ranging reach encompasses the social, economic, and environmental facets of sustainable development, in addition to significant facets of peace, justice, and efficient institutions. The 17 Sustainable Development Goals are shown in Figure 2. The IoT and

sustainability are explained based on Sustainable Development Goals (SDGs) and communication technologies.

Fig. **2- 17 Sustainable Development Goals Proposed by UN**

The United Nations has created the Sustainable Development Goals (SDGs), and the current wave of technological innovations like IoT has opened doors for new possibilities that must be explored to accomplish them. The planned and structured utilization of IoT concepts to the development and creation of products and services for improving renewable energy sources, energy-conserving computing, power source management, green metrics, assessment tools, and methodologies is necessary to create a sustainable environment globally. These concepts have the potential to drastically change traditional development into sustainable development. By utilizing the most recent advancements, IoT enabled technology has the potential to greatly increase environmental and economic sustainability. The UN Sustainable Development Goals for 2030 can be attained with the aid of IoT.

For the future of our territory, people's health and environmental sustainability are closely related. Technology, sensor networks, intelligent systems, and Internet of Things applications are now necessary for improving human well-being. Modern technical advancements need to be applied and implemented in human-inhabited situations, where energy efficiency and public health are crucial. Smart cities and smart grids should make it easier for people to visit places, provide healthcare, and advance social cohesion and safety. Smart homes, smart cities, smart healthcare systems, and smart agricultural systems are the sustainable possibilities.

II. ROLE OF IOT IN SUSTAINABLE DEVELOPMENT

The implementation of the UN's Sustainable Development Goals (SDGs) depends significantly on IoT. To achieve the SDGs, IoT is crucial and needed. Adopting new and creative IoT solutions to deal with difficulties linked with hunger, water availability, and food security through resource monitoring to cope with the expanding consumption needs of a global population" can assist in achieving sustainable DG's up to a great extent. Achieving the SDGs may be greatly aided by fostering international cooperation and dialogue on the Internet of Things for sustainable development by uniting diverse stakeholders, particularly the academic and research community. We as humans must eliminate all forms of trash, including technological waste, in order to achieve sustainable development. The transition to renewable sources is required under Sustainable Development.

III. REAL –WORLD APPLICATIONS

4.1 Smart Energy Management System

Consumers today place a greater emphasis on environmentally friendly technology. Numerous electricity supply chains can be managed with the aid of IoT devices. This covers the energy supply and consumption of electric utilities from distributors to end users. These intelligent energy management systems assist in lowering carbon emissions in addition to saving energy expenditures. Regarding the monitoring of energy usage, it is observed that data on energy consumption is delivered to building areas, individual assets, and industrial assets using wireless utility meters. These data-driven insights enable businesses and people to track and optimize their energy use in order to achieve environmental sustainability.

Fig. 3–Smart Energy Management system [21]

4.2. Smart Waste Management System

Human waste production is also rising in conjunction with the world population growth. The problem is becoming worse due to the irregular and ineffective collection of garbage. IoT can help with waste and garbage collection problems by giving facility managers access to real-time data about garbage cans through the network of wireless sensors. Once the facility managers are aware of the waste containers' current fill levels, they can determine which ones require emptying first. By eliminating the needless movement of the waste collection vehicles, the waste management businesses can use this information to optimize their waste collection schedule and reduce their environmental impact. Internet of Things (IoT) can provide a better solution for garbage management.

The collective process of managing garbage from its creation to its ultimate disposal is known as a waste management system. No matter what we do, garbage will inevitably be produced. Garbage management has become one of the most difficult jobs of the modern period due to the growing population and the massive growth in garbage generation. Trash cans that are overflowing are already commonplace, and disposing of rubbish by burning it or throwing it outside in the open is become a regular ritual. These elements have had a significant impact on the environment and the earth overall. We require a flexible and efficient waste management system to solve this issue.

Fig. 4 – Smart Waste Management System [16]

In Paper [6] Devasia et al. proposed a Solid waste management generally covers waste generation, on site storage, collection, sorting, transportation and disposal. Pollution of the environment and the spread of illness could result from improper waste handling. Digitalization brings with it the Internet of Things (IoT), which has numerous advantages for both the environment and society. Utilizing a surveillance system for rubbish collection can be an assisting tool for providing high-quality services. The waste bin's innovative smart system makes use of Internet of Things (IoT) technologies like radio frequency identification (RFID), image recognition, and sensors. This is a pretty unique application that makes advantage of mobile technology. Various sensor setups can be used to frame the amount of solid waste, when it is collected, and the types of trash bins.

In paper [7] Ashok Kumar et al. proposed a smart trash management system by integrating the Internet of Things (IoT) into the current waste management system in order to manage our rubbish properly and to create a healthy and clean environment. This paper uses the GSM SIM-900A as an IoT module to monitor waste quality in real time through smart bins based on three parameters: air quality, weight measurement, and dustbin filled status. With the implementation of the Smart Waste Management System, current Waste Management System now includes "real-time monitoring of Quality of Waste."

4.3. Smart Agriculture

With every passing year, the world's population is becoming more and more dependent on natural resources like freshwater and arable land. The yearly poor yields of basic crops have made the situation even more difficult. To meet the world's food demand, sustainable food production through intelligent agriculture holds the key to lowering resource waste and environmental impact. Environmental sustainability can be attained with the use of IoT-powered smart farming systems. Smart devices collect data on several elements that affect crop development, like soil conditions. Analytics of the gathered data offers helpful information regarding different farming techniques, such as irrigation, fertilization, fumigation, and sowing, among others. Farmers are assisted in avoiding circumstances by this data-driven advice.

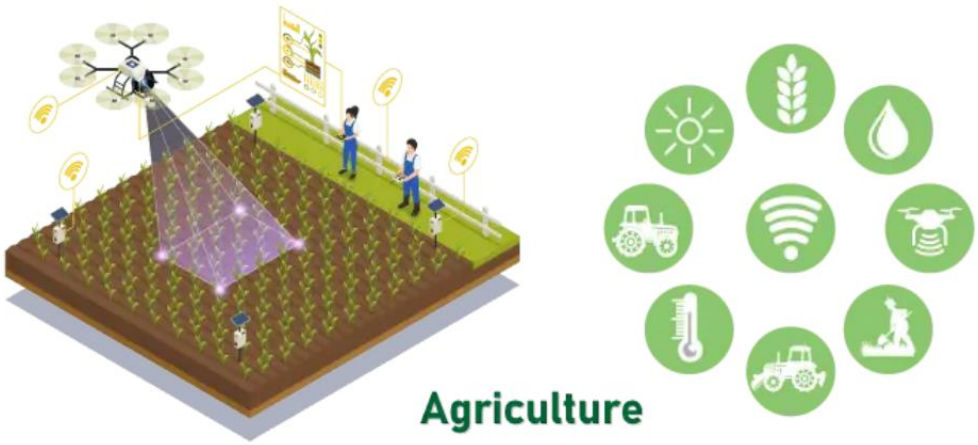

Fig. 5- Smart Agriculture [11]

4.4. Smart Homes

The use of IoT is essential to making your houses smart since it allows the owner to monitor and control their water supply, lights, security, fans, and other household appliances from any of their smart devices. A smart home is an experience that combines current technology with energy, time, and cost savings for its owners.

Fig. 6 – Smart Home [11]

4.5. Smart Health

Healthcare is a vital component of life, particularly in the modern era when infectious diseases continue to claim many lives in areas of poverty and non-communicable diseases like cancer and heart issues are on the rise in large cities. IoT technology may undoubtedly aid in improving the healthcare system in such a scenario, ensuring that everyone receives the best care possible. Microbots are one example of this; they can carry medication anywhere in the body by entering the bloodstream directly. Remote patient monitoring, which allows patients to be watched over around the clock and has emergency responders alerted in case of any issues, is another use of IoT and sensors in healthcare.

Fig.7- Smart Health [11]

IoT uses its connecting features to address healthcare. Smart watches, fitness bands, and stress detectors are a few examples of IoT devices that have applications related to public welfare. An improved healthcare system is also a result of the use of other smart medical equipment in businesses. These medical gadgets give people knowledge about their health and how to enhance it. This application's foundation is the Internet of Things' capacity to link devices, gather data from sensors, and process that data to produce appropriate outcomes.

4.6. Smart Cities

As a matter of fact, about 55% of the world's population resides in cities or other metropolitan areas; this percentage could rise to 70% in the future due to increased urbanization and migration of individuals seeking employment in these locations. However, this implies that in order for cities to maintain a high standard of living while being energy-efficient and environmentally friendly, they must have improved infrastructure and planning. Stated differently, cities must transform into smart cities! This is made feasible by combining the Internet of Things, which gathers data from sensors, with machine learning, which applies the insights gleaned from the data. IoT can be utilized in a variety of ways to improve city efficiency, including traffic management, waste management, air pollution control and smart building development. IoT-enabled smart city use cases are numerous and include everything from optimizing street lighting, improving public safety and promoting a healthier environment.

Fig. 8-Smart City [13]

A smart city develops through the application of innovative smart technology to maintain and enhance a higher standard of living and to raise the general well-being of its population. Internet of Things (IoT) and Artificial Intelligence (AI) play a crucial role in constructing smart cities. Everything in the Internet of Things (IoT) is connected, has a distinct internet address, and can be accessed at any time and from any location. Massive data collection is made possible by IoT, and data analysis and intelligent decision-making are made possible by AI. This method is used in almost every area of a smart city, including smart buildings, smart architecture, smart transportation, smart energy, smart healthcare, smart environment, smart government, and much more.

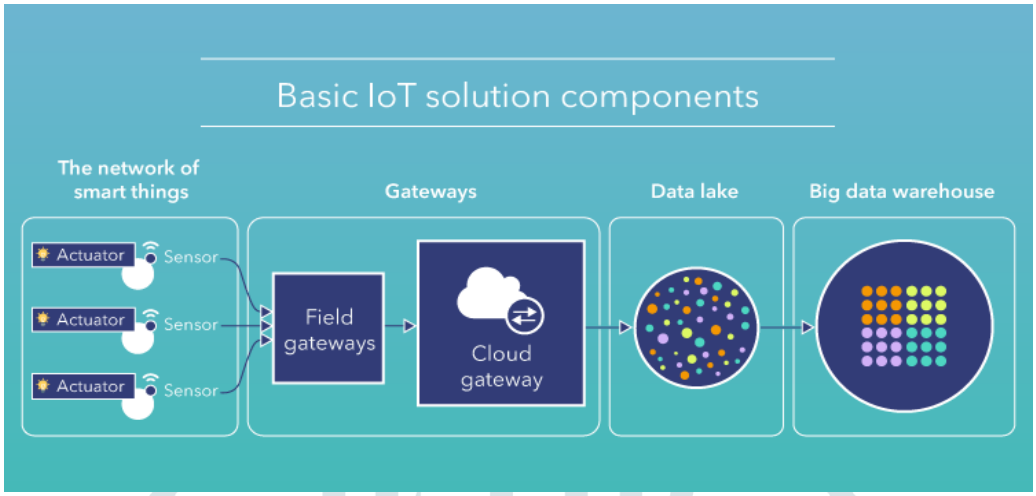

Fig. 9 - A basic IoT solution for smart cities [13]

4.7 Smart Traffic Management

In cities, traffic management is essential to avoid huge traffic congestion in crowded areas and empty roads elsewhere. This is likewise dependent on the layout and construction of the roadways, although it is controllable with intelligent traffic signals. For instance, the traffic lights need to be designed to adjust themselves based on the volume of traffic, extending the duration of green lights during periods of high traffic and shortening them during periods of low traffic. In order to monitor their states and repair them when there is significant wear and tear, sensors can also be incorporated into highways and bridges.

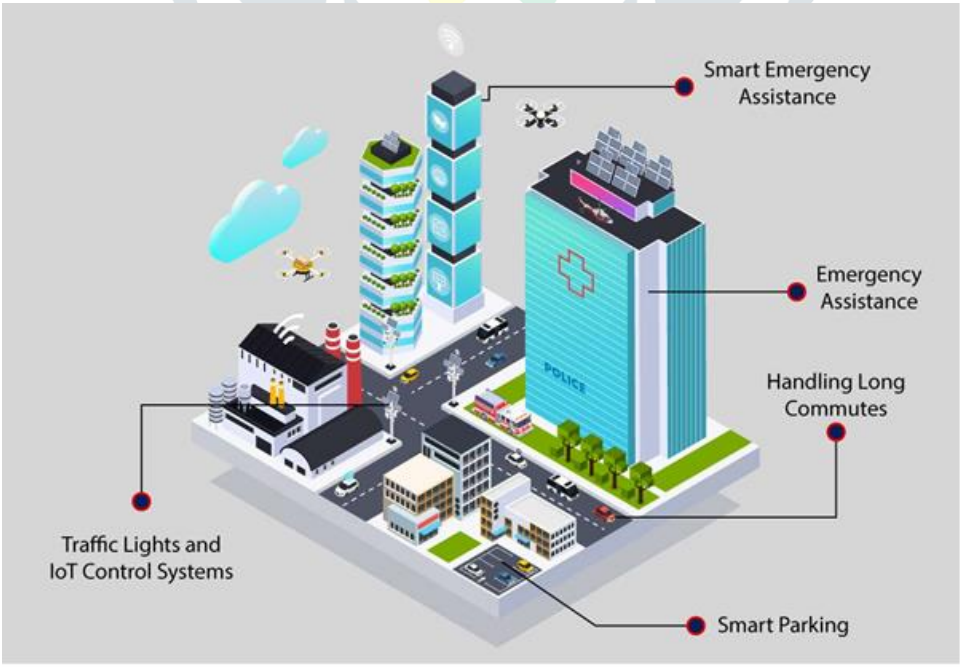

Fig. 10 – Smart Traffic Management System [19]

4.8 Smart Air Pollution

In many large cities, air pollution is a serious issue due to high levels of particles in the air that may eventually damage lungs. However, air pollution can be decreased with the use of IoT and machine intelligence. This is made feasible by using the Internet of Things (IoT) to gather data on city pollution, such as car emissions, pollen levels, airflow direction, weather, traffic volumes, etc., and then generating pollution forecasts to identify trends in pollution so that they may be managed.

4.9 Smart Building

Cities are incomplete without buildings, and larger cities also tend to have a greater number of towers. Currently, the difficulty lies in utilizing IoT to construct smart buildings, where every feature—such as heating, cooling, lighting, and security—can be linked and managed from a single location. This will improve efficiency while lowering building operating expenses. A building's air conditioning and heating systems, for instance, can be configured to adjust the interior temperature in accordance with the outside temperature. Additionally, sensors can be utilized to turn on lights automatically only when people are present and to keep an eye on the building's air quality. These steps will not only lower the electricity cost but also save a significant amount of energy.

Fig. 12 – Smart Building [22]

4.9 Street Lightning

An internet of Things-based smart cities simplifies and reduces the cost of maintaining street illumination systems. The lighting schedule can be adjusted to the illumination zone by installing sensors on streetlights and linking them to a cloud management system. In order to optimize the lighting schedule, smart lighting solutions gather and analyze data on illumination, vehicle and passenger movement, and historical and contextual information (such as public transportation schedules, special events, and the time of day and year). Consequently, a smart lighting system "tells" a streetlight how to change its brightness, dimming, turning on, or off depending on the outside environment.

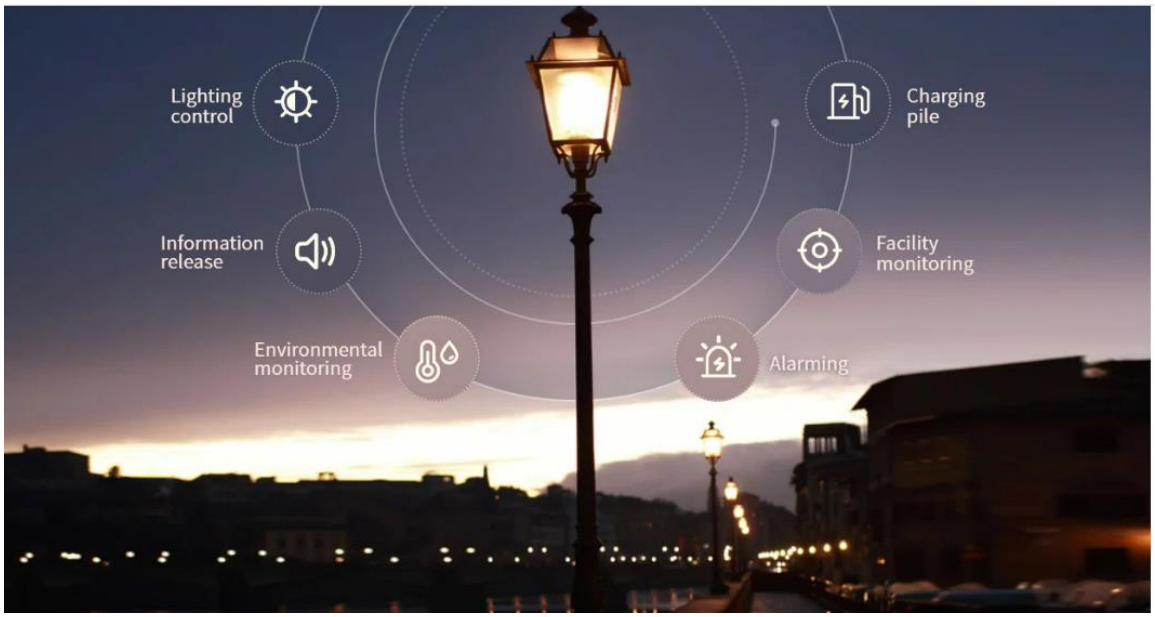

Fig. 13 – Street Light Monitoring System [20]

4.10 Smart Water Monitoring System

By 2050, almost half of the world's population will reside in water-stressed areas, according to research from MIT. This demonstrates the justification for implementing the solutions, which are centered on water management and have the potential to significantly lower annual water waste. Municipalities waste between 20–30% of their drinking water due to pipe leaks. Data collection and analysis from various water equipment, including pumps, valves, and complete water processes like irrigation, is now far cheaper because of wireless connectivity and Internet of Things sensors. In addition to monitoring fill levels and regulating water quality, IoT leak detection sensors can be installed in buildings or plants to help detect water leaks.

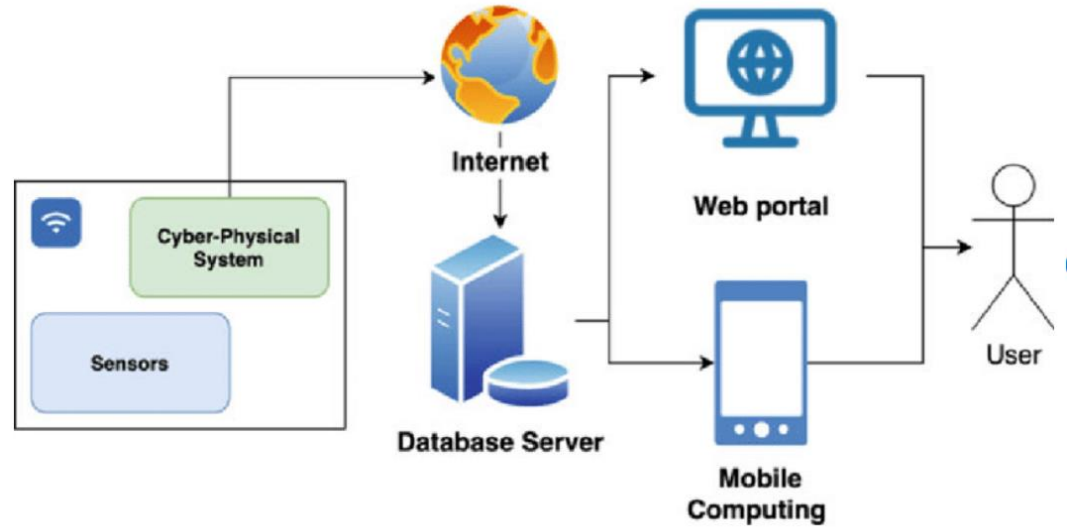

Fig. 14 – Smart Water Monitoring System [23]

4.11 Smart Water Management System

The water resources in rural communities vary greatly in terms of their quality, quantity, and consumption patterns. These communities have various water resources, each with a different water quality index. Consequently, one of the main challenges is to integrate these resources, prioritize their use based on factors like water recharging capacity, water quality index, and distance from source to destination. The water is used for a variety of purposes,

including daily household chores, irrigating agricultural land, bathing and drinking cattle, and other uses. This dynamic variability in the water resources' quality and consumption pattern calls for a special monitoring system and automatic decision models to effectively conserve the available water resources concerning these factors.

Fig. 15 – Smart Water Management System [18]

The management of groundwater resources is a critical issue in the Indian context since groundwater availability is highly variable and varies significantly throughout the nation. In this work, Preeja et al. proposed an Internet of Things (IoT)-based sustainable water management system that automates water distribution, storage, and waste regulation. A sustainable water management system based on the Internet of Things (IoT) was proposed here. It automates water distribution and storage as well as minimizes water waste. Using real-time data obtained from the field, the system, which is based on the Internet of Things, will optimize water usage in real-time and automate the water management process. By taking into account the socioeconomic status of the area, water supply, and patterns of water demand, this approach seeks to ensure water sustainability. The IoT architecture of the proposed system is shown in Figure 16.

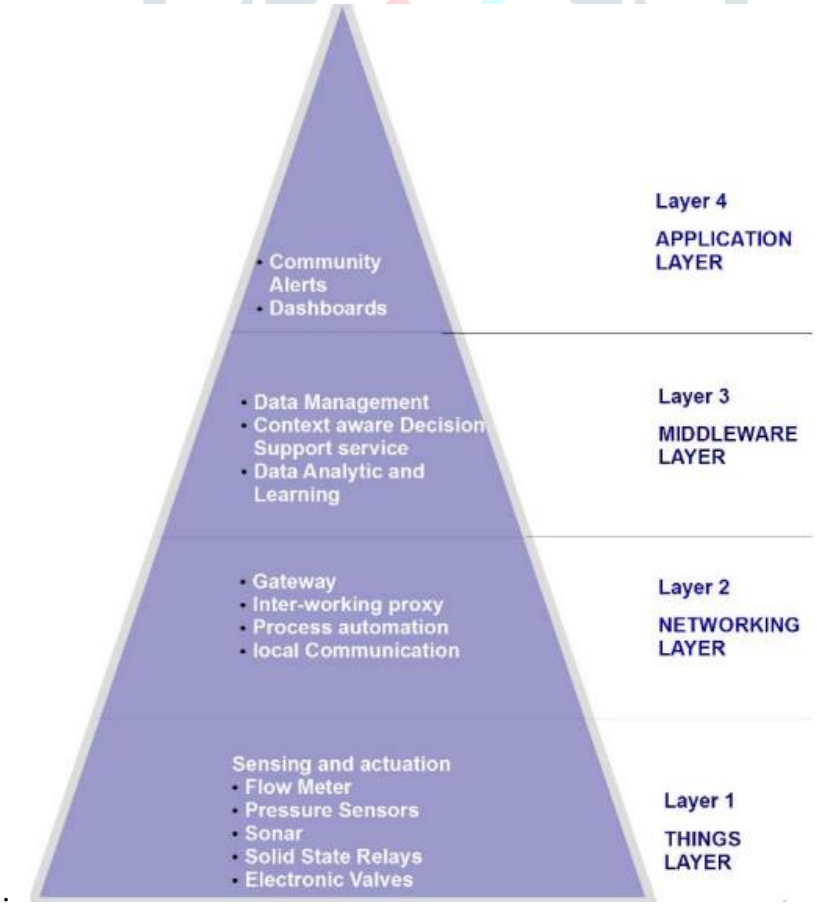

Fig. 16 - The IoT System Layered Architecture [4]

The proposed system consists of four layers.

4.11.1 Layer 1-Things Layer

This layer includes their hardware, interfaces with the digital world, and monitoring and administration components. Its components include ultrasonic rangefinders to measure the water level in the tank, flowmeters positioned between distribution networks to measure water flow through pipes, pressure sensors installed in borewells for the prototype, and actuators that control solenoid valves and motors automatically. These tools are employed with the understanding that the system's development expenses must be minimized without sacrificing the level of service that the system is meant to offer.

4.11.2 Layer 2- Networking layer

A microcontroller or microprocessor with a communication module is part of the networking layer, and it is responsible for gathering data produced by the lower layer. In the event of an unstable network, these microcontrollers perform as a gateway by offering local communication ports, acting as an interworking proxy, and managing water.

4.11.3 Layer 3- Middleware Layer

The middleware layer is responsible for a number of functions, including: data management to support sensor data generated and logging control actions. It also provides central control of managing and monitoring modules associated with resource, distribution, and storage. Finally, it identifies and processes context information that will have an impact on basic computation. This layer also oversees policy management, system diagnostics, and service orchestration.

4.11.4 Layer 4- Application Layer

An alarm system for the local community to get notifications about the availability and level of water is hosted by the application layer. Access to a web-based dashboard with real-time visualisations of system availability, usage, and health is available to both researchers and administrators.

4.12. Smart Irrigation Management System

The practice of conserving water during irrigation by science and technology is known as smart irrigation. It has several controls, soil sensors, and weather sensors. The controller decides when to open or close the water valve based on data from the sensor, which also tracks the real ground humidity and the current weather. Acquire irrigation that is automated. Scientific assessment of the necessity, timing, and volume of water. It works well for managing water usage in landscapes, farms, and lawns, among other places.

Fig.17 – Smart Irrigation System [17]

For many developing nations to experience sustainable development and reduce poverty, agriculture is essential. It's essential to the nation's economic management processes. It also provides a lot of job chances for individuals. The region's economy is better off when there is development in the agriculture sector. Using controlled drip irrigation powered by Renewable Energy Sources could be just one of many other green computing initiatives that seek to lower carbon emissions and promote innovative ways to utilize technological advancements without negatively affecting the environment. It is predicted that global warming will seriously impair food security and have a negative impact on agriculture.

Many articles describe how to use Internet of Things (IoT) devices to gather data from various sensors and then send it via a wireless protocol to a database server. Sangeetha et al. had suggested in paper [8] was useful for field data monitoring, agricultural activity regulation, and adaptability. The strategy utilized to establish an agricultural model for assessing the use of water to minimize pollutants and to construct a software framework that would assist farmers maintain soil quality and operate the irrigation system through a digital application of some type.

CONCLUSION

Technology is now an essential component of sustainable development because it can be used to manage natural resources in an efficient and well-planned manner, giving people access to cheap, clean energy, clean water, the ability to live in the least polluted environment possible, and efficient environmental governance management systems. Making the "right" decisions early in a technology's development process is the only way to see a sustainable world vision realized through research and invention. Traditional development can be considerably transformed into sustainable development by deployment of the IoT by using specifically designed products and services for a sustainable environment. The focus of implementation of IoT for sustainable development can only be fruitful when global, national, regional, and individual efforts are streamlined to collaborate and co-operate for the promotion of innovatively designing and implementing IoT devices. The study of the impact of the Sustainable Development Goals (SDGs) on sensor and Internet of Things (IoT) applications in human environments should be considered essential for the future of our territories. This paper gives an overview of IoT, sustainable development Goals and the role of IoT in sustainable development ,real-time applications and examples of IoT used for sustainable development. The way we live and how we consume is being significantly impacted by the Internet of Things (IoT). It is becoming a more important facilitator of sustainable growth from an industrial and consumer standpoint.

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