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Implementation of Sustainable Technologies for Smart Water Resource Management: A Review

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Abstract: *Water is an essential human requirement in all economic activities. Agriculture, renewable energy, manufacturing, and mining are all vital economic sectors. Water resources are experiencing significant pressure as population growth escalates the demand for water from competing economic sectors. Groundwater resources are being exhausted in numerous regions, jeopardizing the current and future generation's ability to safeguard against escalating climatic variability. Consequently, information technology approaches and internet communication technologies are essential in managing water resources to mitigate the excessive wastage of freshwater and to regulate and monitor water contamination. This paper reviews research utilizing the Internet of Things as a communication platform to manage water conservation and prevent waste by homeowners and farmers. Recent advancements in information and communication technology and the Internet of Things have created new possibilities for the real-time monitoring and management of urban buildings, infrastructures, and services. This review paper seeks to offer a contemporary and insightful perspective for academics, consumers, and stakeholders about the implementation of smart and sustainable technologies in water resource management.*
Keywords: *IOT , ICT , AI , WMS , DL Models etc*

INTRODUCTION

Today, humanity confronts numerous critical challenges, with water scarcity being one of the most alarming. The Earth's resources are finite and may prove inadequate for a continually growing population. The United Nations and the World Bank project that nearly 40% of the global population is impacted by water scarcity, and by 2030, an estimated 700 million individuals may be displaced owing to drought. Numerous major cities, including Sao Paulo, Bangalore, Mexico City, Cairo, Beijing, Jakarta, Moscow, Istanbul, London, and Tokyo, are anticipated to experience drought in the near future. The ever-increasing population, restricted groundwater resources, limitations on rains, intermittent drought conditions, and substantial water demands for agriculture, industry, and daily domestic activities have rendered water the most invaluable resource. Global urban water scarcity is projected to become a critical issue by 2050, with approximately 50% of the urban population residing in water-scarce locations.[1]

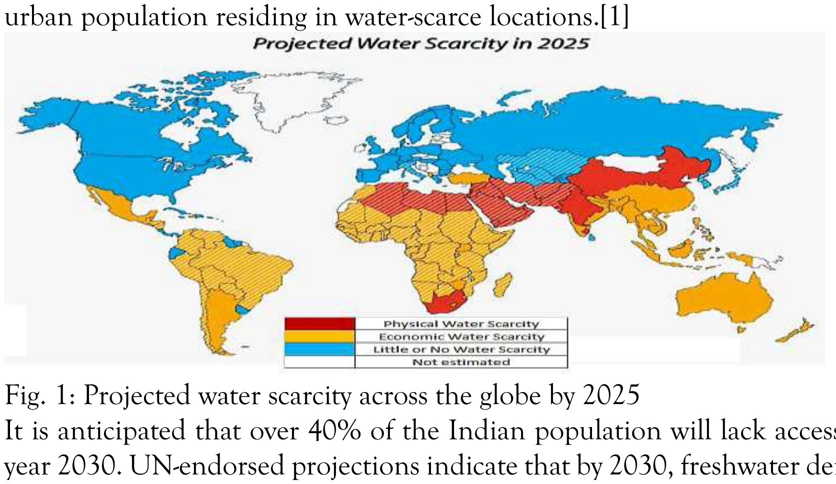

Fig. 1: Projected water scarcity across the globe by 2025

It is anticipated that over 40% of the Indian population will lack access to sufficient drinking water by the year 2030. UN-endorsed projections indicate that by 2030, freshwater demand will exceed availability by 40% as a result of climate change, population growth, and human activities. It is evident that our natural water sources and groundwater are limited, and our water supply and distribution infrastructure is inefficient.

Unfortunately, there is no singular solution to tackle the issues of the water crisis [2]. The Internet of Things (IoT) is progressing swiftly due to recent advancements in wireless technology and embedded devices, particularly the development of low-power microcontrollers that are ideal for remotely distributed IoT systems, allowing them to connect and function for prolonged durations without maintenance. Transforming IoT into a necessity rather than a luxury requires data aggregation for military systems. The number of IoT devices rose from 8.4 billion in 2017 to an expected 30 billion by 2020 [3]. Wireless mechatronic devices for support and personal care are poised to gain popularity in residential environments, offering significant advantages in assistive healthcare, particularly for the elderly and disabled populations [4,5]. A water monitoring and control system leveraging Wireless Sensor Networks (WSN) was created for environmental protection, employing ZigBee, GSM, Xbee, mote WiFi, and TCP/IP for data transmission [6]. This review study analyzes several components and approaches for water management and quality system regulation through IoT, encompassing sensors, controllers, and IoT platforms. There is no consensus on the criteria that should be employed to evaluate different characteristics of water.

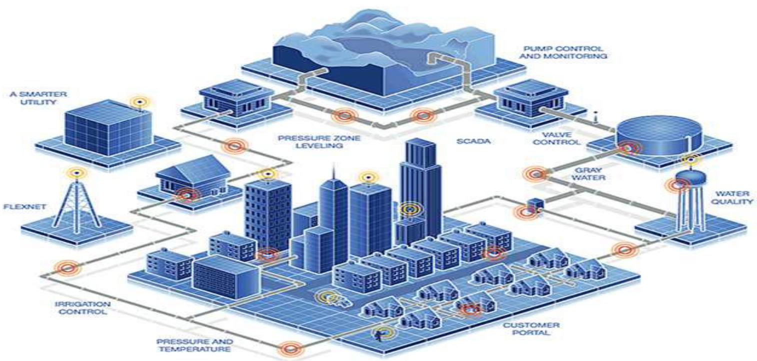

Fig. 2: Smart Water Management System (SWMS)

SMART WATER MANAGEMENT SYSTEM

The primary purpose of the Smart Water Management System is to deliver adequate water to consumers at a fair cost while maintaining water quality standards. Water distribution and management is a challenging issue due to constrained water resources. The Smart Water Management System aims to ensure the rational and sustainable utilization of water resources by adhering to certain overarching objectives. Avoiding or limiting water wastage entails the conservation of water resources. This is particularly crucial during periods of elevated water use for agricultural and industrial operations, as the potential for water wastage increases if not well regulated and monitored. Techniques such as precision agriculture, intelligent irrigation, agricultural water management, and automated water meter reading are prevalent for controlling and reducing water wastage. allocation of water throughout communities, municipalities, structures, and industrial facilities according to demand and established standards can provide enough water supply for all users. Water pressure regulators and intelligent sensors are employed in several regions to guarantee effective water delivery. This ensures effective and optimal water distribution. Effective water leakage management: Water leakage in piping systems results in the wastage of millions of gallons annually. Controlling water leakage is essential to minimize water wastage and prevent unexpected calamities. Automated water meter readings and water leakage detection systems are employed to mitigate and manage water leakage. [7]

FEATURES OF THE SMART WATER MANAGEMENT SYSTEM:

The Smart Water Management System has demonstrated its significance by facilitating the efficient management and distribution of existing water resources. Its capabilities extend beyond mere water supply distribution and control. The typical Smart Water Management System encompasses the following functionalities:

- Intelligent regulation of water accumulation, storage, distribution, purification, and recycling
- Control of water motors to manage supply
- Monitoring of water supply
- Activation and deactivation of water supply
- Regulation and control of water pressure
- Quantification of water through automatic metering
- Support for the Smart Irrigation System in meeting the water requirements of green areas
- Alerts and notifications for warnings, alarms, and disaster scenarios
- Real-time water data analysis encompassing information regarding

SMART WATER MANAGEMENT AND SERVICES

The diversity of drinking water sources and their variations are determined by regional features [8]. Some rely on rivers, while others depend on the extraction of groundwater and alternative sources. ICT methodologies are employed to acquire surface water sources, such as rivers, and to ascertain their depths and areas [9,10]. Remote sensing technologies and geographic information systems (GIS) software can enhance the exploration process by utilizing satellite and aircraft imagery. Constructing spatial databases and performing requisite analyses to achieve practical outcomes with reductions in effort, time, and cost relative to conventional technical methodologies of research and exploration [11]. Additionally, several approaches are employed for groundwater investigation, including remote sensing and geographic information systems.

INTELLIGENT IRRIGATION SYSTEM

The intelligent irrigation system is an automated irrigation program that takes into account environmental circumstances to guarantee that plants and crops receive the optimal amount of water [12]. Convection depletes soil moisture, whereas irrigation and rainfall augment water content. It facilitates the design of automated irrigation by recognizing conditions particular to each root zone [13]. Figure below illustrates an intelligent watering system which consists of 10 principal components and additional sensors for the proposed device. Two Arduino Mega 2560, two relay shields, three moisture sensors, and two 220V components mini water pumps, and SIM900 GSM Shield. These components are also equipped with two water pumps. For analog input, the first humidity sensors are attached to the Arduino A0 pin to obtain the moisture content of the soil. The Vcc pin (+) is connected to the 5V Arduino pin. The second humidity sensor, which is attached with A1, is connected simultaneously to the bottom of the tank. The third humidity sensor is connected with A2 to get the critically high value when the tank is filled with water. A3 port attaches with an analog pin to the Rain Drop Sensor. It attaches to relay models and connects with two water pumps, D2 and D3 are classified as digital pins. The D18 and D19 bind to GSM Shield so that the homeowner receives SMS. [14].

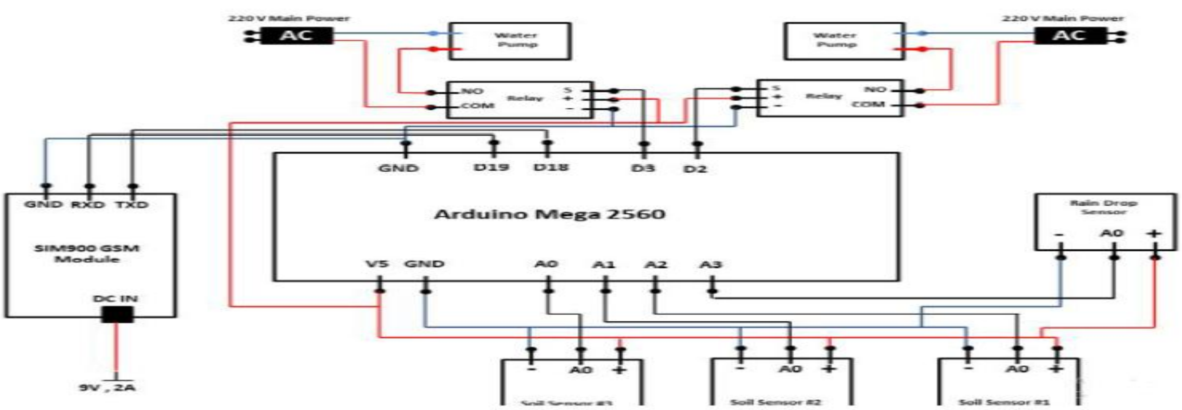

Fig. 3: Irrigation System Architecture

INTERNET OF THINGS (IOT)

The development of the Internet of Things (IoT) facilitates connecting devices equipment through the internet, which would be very useful in the automation of the distribution of water and malfunctions or leakage monitoring [15,16]. The principal architecture for IoT comprises three layers: the physical layer, the network layer, and the application layer [17]. At the physical layer, sensors collect data from the outside environment, turn that data into usable information. Well, time-sensitive data should be processed the moment they are collected [18]. Otherwise, the data has to be stored in the cloud to avoid network congestion. The data is collected at the network level and converted into digital streams for data processing [19]. The user-facing layer is responsible for delivering specific services to the user. [20].

SENSORS

A variety of sensors for water monitoring are accessible in electronic retail outlets. Examples of such sensors include constructed sensors, capacitive sensors, turbidity sensors, and soil moisture sensors, among others [21].The constructed sensor is of the float type. The sensor comprises an energy panel and a transmission module, including a solar cell and a lithium-ion battery [38]. The output of this sensor module will be directly connected to the microcontroller without the need for extra signal processing circuitry [22].All published works include fabricated usability sensors. The parameter control sensor was utilized. [23].The capacitive sensor is employed for water level measurement. This sensor has advantages such as low power consumption, linearity, affordability, ease of installation, and suitability for harsh situations [24].The turbidity sensor assesses water quality by monitoring sedimentation or opacity [25]. It is utilized to assess water quality in rivers and streams, monitor wastewater and effluent, control settling ponds, and conduct laboratory research. This liquid sensor offers both analog and digital signaling types [26].The soil moisture sensor is a basic breakout device designed to monitor humidity in soil and analogous materials [27]. The soil moisture sensor is relatively user-friendly. The two sizable exposed pads function as sensor samples, collectively operating as a variable resistor [28].

WIRELESS COMMUNICATION TECHNOLOGY

Wireless technology is used from the controller to the cloud for communicating between the sensor and the controller. Different technologies have been used in any collaboration situation. For the sharing of information, wireless networking technology is also used. Sensors are remotely connected to the microcontroller by either the Zigbee protocol or URAT protocol in the sensors-controller communication. ZigBee is a technology for wireless transfer. It is intended for control systems with multiple channels. Also, alarm and lighting control and has low energy consumption. ZigBee builds on the physical layer of access control and media defined for low-rate WPANs under IEEE standard. Zigbee Protocol is applied in smart water systems when the sensors are located remotely from the control system to communicate between the sensor nodes and the controller. Controller-centralized data storage communications are carried out in long-range communication standards such as 3G and the internet. Some of the earlier work is intended to alert the user to water quality in SMS. The proposed systems necessitate using an additional SIM card for the GPRS module attached to the controller. The disadvantages of these schemes are the additional costs for SIM card operation. Furthermore, the user location is incapable of storing or retrieving vast quantities of data [29,30].Numerous studies examined have employed Arduino boards as control units, including the Arduino Uno [31], Arduino Pro [32], Arduino Mega2560 [33], and Arduino Ethernet SHIELD [34]. According to [35], the Arduino Uno, utilizing the ATmega328 microcontroller, and the Arduino Pro, which may employ either the ATmega168 or ATmega32, are categorized as Entry Level Boards. In contrast, the Arduino Mega 2560, based on the ATmega2560, is classified as an enhanced features board. Entry-level boards are the simplest to utilize and program, but advanced feature boards are intended for intricate project development and offer superior functionality and performance compared to entry-level boards. The Arduino Ethernet Shield facilitates communication to the Arduino board for Internet of Things (IoT) applications. Arduino Shields are specifically engineered for novices to simplify the connection of components and to augment hardware resources. Arduino is prevalent mainly owing to its characteristics: an autonomous platform, affordability relative to other microcontrollers, open-source hardware and software, and user-friendly programming using the Arduino IDE. Zigbee facilitates communication among various nodes (sensor, base station, and hub). The software facilitates real-time data management and visualization on a network server utilizing web-based Java toolkits. The wireless monitoring of field irrigation systems enables remote oversight and management through applications. The emergence of cloud computing presents a feasible solution for the substantial data created by smart sensor networks. The device is modeled both manually and automatically. Real-time sensed data are processed on the cloud server for decision-making and behavior monitoring. The user can oversee the farm's regulatory actions and manage irrigation using the farmers' mobile phones via the Android application. The system comprises a Mamdani fuzzy controller that gathers environmental variables, including soil and temperature sensors, and subsequently employs fuzzy rules to regulate the water flow from the pump, ensuring timely and suitable irrigation. This may be developed and coded via MATLAB. A strategy to provide an educated irrigation solution for water conservation and enhanced irrigation management in regions experiencing high water stress was characterized by fuzzy logic and IoT technology. The proposed fuzzy controller utilizes trapezoidal and triangular component functions based on Mamdani fuzzification to effectively ascertain the irrigation duration and timing for a specific crop. The fumigation control application-maintained soil moisture above a specified threshold, ensuring gradual fluctuations that prevent frequent device fatigue while conserving water and electricity. A substantial ZigBee wireless network was employed to monitor the device in real-time. [36,37,38,39,40]Currently, the preservation of clean water supplies is more challenging globally. Utilizing a smart water meter to regulate water resources, Singaporeans can preserve water for future generations. Sensors will facilitate the monitoring of hydraulic data, as well as automatic control and alert notifications utilizing Cloud technology. A thorough assessment of this study will enable one to undertake significant action. Consequently, they advocate for an advanced water metering system to be utilized by citizens in Pakistan and globally. This system will decrease water wastage. We advocate for serverless architecture because to its potential for rapid adoption and large-scale implementation. In conclusion, based on all of this discussion, an in-depth analysis of the investigated articles supports the readers in identifying the main challenges, relevant recommendations, and future directions for IoT applications for smart water management. utilization of real-time input data from IoT devices and Android phone was utilized to remotely oversee and regulate the drips from the smart farm irrigation system. [41,42]

CONCLUSIONS

Intelligent water management is a technique intended to gather significant and actionable data regarding a city's water supply, pressure, and distribution. The primary objective is to ensure the proper management of facilities and electricity utilized for water transportation. Economic expansion, climatic change, and population growth impact the accessibility of water supplies. Information and communication technology play a pivotal part in this matter through various technologies that enhance water conservation, regulate water quality, and facilitate water management. Contemporary SWMS are sophisticated and highly automated systems in comparison to conventional water management systems. The SWMS extends beyond mere water management. It offers critical insights on water consumption, water waste, water recycling, and future water needs. SWMS solutions contribute to the protection of environmental and public health, enhance water management and security, and mitigate unnecessary water wastage. In addition, SWMS, with other tools like GIS, continuously seeks to track water movement across geographical areas, thereby identifying new water sources. It plays a crucial role in rainfall collecting, water recycling, and the proper disposal of wastewater. Numerous intelligent technologies exist for water services, encompassing exploration, technical methodologies, filtration, and processing, among others. This review research study intended to examine proactive strategies for the development of Smart Water Applications. In addressing water shortage and its associated challenges, the Smart Water Management System has transitioned from a desirable feature to a fundamental service for Smart Cities.

Declaration of Competing Interest: The authors declare that they have no any conflict of interest.

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