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Modeling of Smart Water Control Mechanism using IoT

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Abstract*: The unexpected water demand has become a serious concern in the last few years. The increasing demand for water supply has posed a significant challenge for many countries around the world. Various factors, such as population growth, urbanization, and climate changes, have further exhausted water resources. Therefore, water conservation and natural resource management have become crucial factors for human survival. The proposed study presents the modeling of smart water control system based on IoT technology. The implementation of the proposed water control model is carried out using an analytical approach with cost-effective, functional modules using sensors and wireless communication system. The proposed smart water control mechanism is mainly designed for water distribution and monitoring application.

Keywords*: Water management, Internet of Things, Cloud, Water level Sensor.

I. INTRODUCTION

Water is a precious substance found on the earth, and about 70% of the earth's surface is covered by water. However, only 10% of the water is available for human use-(drinking). Most of the water part is present in the ocean, which is difficult to consume due to its saline properties. In the last few years, unprecedented growth in water demand has become a serious concern [1]. The growing demand for water supplies has met a significant challenge facing many countries around the world. Various factors, such as increasing population, urbanization, and climate change, have further depleted water resources. Therefore, water conservation and resource management become crucial factors for human survival. However, due to the continuous increase in water usage, water management is currently a major challenge for both governments and private water companies [2]. This challenge also includes cost-effectively providing quality-aware water. The existing water distribution systems in developing countries like India are wrong and seem to be a significant problem in water management [3]. This is because the control of the water distribution line is carried out by human resources, which is not effective because opening and closing the valve is a time-consuming task.

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Another problem with the existing water distribution system is that it is not efficient to provide the required unit of water in each region, so some areas get rich water instead of other places.

Another critical issue in the direction of water management is water wastage, and water quality [4].People are not serious about the constraints of drinking water resources and are using water arbitrarily [5]. Appropriate methods need to be developed to support water management and resource maintenance in order to achieve cost-effective long-term benefits of quality-aware water. Recently, we have encountered an emerging technology called IOT- (Internet of Things), through which we can provide a significant contribution to water resource management [6]. However, ensuring the rational use of water is challenging, but the appropriate deployment of IoT technology in water management systems will facilitate human lives and conserve valuable natural resources. IoT has the potential to provide new solutions to enhance existing water distribution and its management systems to make the best use of water resources [7]. Optimal water management scheme and its implementation can reduce costs by up to more than 15 %, which has a real impact on various aspects of human life. IoT can connect individual smart devices with sensors, actuators, and wireless communication system to obtain real-time data and report about water consumption, quality, and losses [8]. The following are some of the practical benefits that can be gained using IoT technology; water leak detection, infrastructure maintenance, water quality maintenance, and safety monitoring, smart irrigation, wastewater management, and consumption transparency. It has also been seen that few researchers have already developed water management scheme based on some intelligent approaches using data analytics, Wireless Sensor Network, and IoT [9-10]. It has found that some approaches have designed to handle a particular type of issue and are suffering from computational complexity.

The proposed manuscript presents the modeling of a smart water control system using a novel concept of IoT technology. The proposed smart water control model uses the implementation of an analytical approach to design a cost-effective using sensors and wireless communication system. The remaining part of the paper is structured as follows. Section II discusses the background section for reviewing various existing IoT-based water management schemes and approaches. Section III illustrates Problem description, Section-IV and Section V discusses the design of the proposed system;

Section-VI briefly describes the implementation details and results. Finally, the conclusions and future work are discussed in Section VII.

II. REVIEW OF LITERATURE

Nowadays, many researchers are focusing on smart water management, water conservation technique using the internet of thing (IoT). The work done by Joseph et al. [11] focuses on IoT devices that assist in controlling and planning the utilization of the water. The work carried out by Myers et al. [12] presents the improvement of intelligent water management and information technique to build active decision while releasing the water for the fruit trees and grasses. This study demonstrates the SWAMP-project using IoT based water conservation method for the correctness irrigation into the agriculture by Kamienski et al. [13]. This study focuses on monitoring and managing the water resources using IoT based technique by Xiaocong et al. [14]. Suciu et al. [15] introduce a method of water management that familiarizes to build unique services in IoT and cloud computing. Machado et al. [16] present the water conservation technique by using micro-controller ZR16S08 while IoT solution for the losses avoidance and water allocation support. The outcome shows the efficiency of architecture for the sensor nodes, allow the application for water monitoring. The work done by Siddula et al. [17] introduces a unique design of gathering and distributing real-time information regarding water levels to allow the central command during field communication. This study also focuses on developing the information method based on existing techniques with the uses of IoT and several sensors. Another study introduces the various kinds of technology and platform, which is the need for the smart environment. The architecture design has been developed for smart water management, which presents the detail of water conservation method By Shahanas and Shivakumar [18]. The work done by Narendran et al. [19] shows the empirical water management technique based on IoT, which computerizes the water allocation, storage, and regulation of water waste. The work of Radhakrishnan and Wu [20] discusses the IoT technology for the smart water technique. The study also demonstrates design, applications for IoT using water management technique. The work done by Hadipour et al. [21] focuses on multi-intelligent control technique of water drain and drain station, which is designed and utilized for the agriculture field. The presented model is introduced to apply to a realistic case study that shows the efficiency of the given control technique. By Pule and Chuma [22] the WSNs is used to study the survey work which is used in monitoring the quality of the water. The many authors proposed the data security execution, power supply designs, potential application, and wireless communication to monitor the parameter. The work by Amatualla et al. [23] illustrates the IoT architecture for water monitoring, which sustains internet-based data gathering on the real-time scenario. The research study presented by Kamienski et al. [24] a smart water management policy (SWMP) design is introduced for agriculture using IoT-based correctness irrigation. The outcome shows the adequate performance for the SWMP pilots; however, it needs some good design configuration of some component to give maximum scalability by using minimum computational resources. The work of Yelamarthi et al. [25] introduces the IoT-based water management technique for monitoring the water in flat technique as well as different sectors. The work of Anuradha et al. [26], have presented a low-cost sensor-based water quality monitoring system, that used in the measurements of chemical and physical parameters like PH, turbidity, and TDS of the water. The experimental outcomes of this presented technique are achieved high mobility, low-powered, and high frequency during water quality monitoring. The similar kind of work can be seen in the study of Nikhil et al. [27], where they have presented a smart quality water monitoring system along with an IoT sensor device. The experimental result performed with five parameters of water, and these are turbidity, water level, PH value, the temperature of the water with high speed from a different sensor using thing speak. The work of Geetha et al. [28], where they have presented a simple and effective IoT-based technique for in-pipe water quality monitoring. The presented technique absorbed a sample of in-pipe water during testing and uploaded the tested data over the internet for analyzing. The main advantage of this presented technique is to provide an alarm for a remote user whenever any new water sample test is matched from a pre-defined set of standard value. The study of Arun et al. [29], have focused on the problem of water management in the agriculture field because 69% of freshwater required for agriculture land. To overcome the problem of more water utilization, the authors have IoT-based water irrigation and recycling system. The experimental shows that the presented technique is effectively performed in agriculture land and decrease the level of more water use through recycling and irrigation process. The work of Anjanas et al. [30] provides an IPv6 network-connected IoT framework for real-time water flow testing and monitoring. The presented technique is to address new challenges during monitoring, such as ease of billing and fair belling. The implementation result demonstrates that the used IPv6 is to make this system more useful and necessary. Suresh et al. [31] provide a smart metering technique to automated water-meter reading provides a consumption report in the commercial and domestic field. The simulation result illustrates that the presented technique decreases the meter handling manual problem and also decrease reading and belling issues. The work of Ashwini et al. [32] has discussed on the workability of the Iot-based smart irrigation function for the surveillance of crop-field. The irrigation system is more useful for which areas where there is more demand for water. The work presented by Manoharan et al. [33], provides a real-time water quality measuring technique at low cost based on IoT. The presented technique is to develop the quality of water and testability. By Spandana et al. [34], provides an IoT based real-time water quality management technique through testing of the water sample. The tested data is updated on the internet and gate accurate result. The work done by Kiruthiga et al. [35] provides a PIC-water-based monitoring technique for tank water level sensing and reduces the uncontrolled use of large apartment and office.

III. PROBLEM DESCRIPTION

After reviewing existing research works in the above section, it is found that some existing works are suffering from a significant problem as follows:

- Existing systems are time-consuming to collect data associated with water levels.
- Most of the prior art does not focus on the insights that can be obtained from the data
- Few studies lack effective method implementation, and this approach is providing real-time analysis.
- Some existing work is also seen to be suffering from computational complexity
- Very fewer studies have focused on computational complexity

The problem statement for the proposed study can be expressed as: *"It is a challenging task to design a cost-effective and precise smart system that can offer real-time data information for analysis and performing further needed action."*

IV. PROPOSED SYSTEM

The prime objective of the proposed study is to present a practical framework for implementing robust water management mechanisms for preserving water resource and ensuring effective utilization of water supply among humans. The contribution of the proposed system is also to ensure the construction of cost-efficient and less complicated implementation. The model is designed to provide adaptive and practical implementation approach in a real-time water management system.

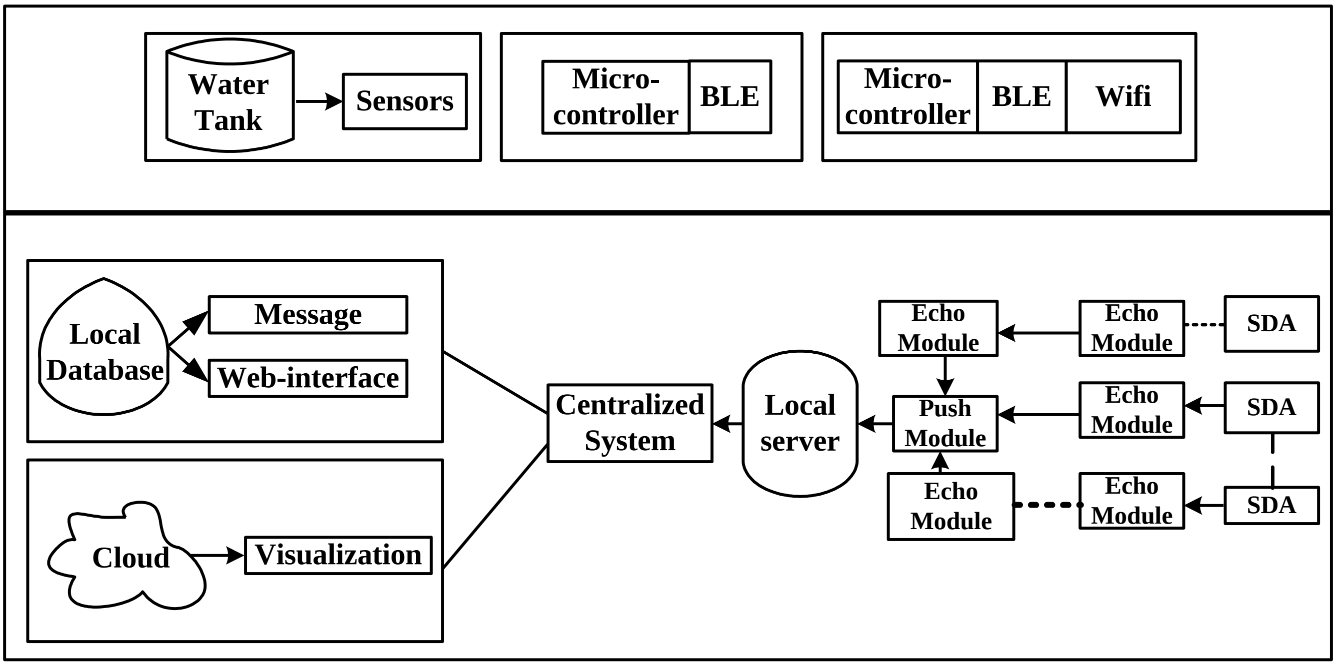


Fig. 1.proposed a system architecture

The proposed smart water control model is based on an analytical approach, considering the real-time scenario. The proposed system uses techniques of advance wireless communication system and sensors. The proposed strategy uses sensors devices to collect information about the water level from the tank and transmit it to the centralized server using a microcontroller and small computing device. For notifications and live updates, the proposed system implements a message and email alert system. Also, the proposed method uses cloud computing technology and a simple interface system to visualize data in real-time. The essential functional components of the proposed system are described as follows:

a. Basic Component

- Microcontroller → Aurdino
- The small computing device- Raspberry-Pi
- Water level Sensor
- BLE- Bluetooth Low Energy
- Wi-Fi Module
- ***Sensor Deployment Area (SDA):-*** SDA is the area where the sensor is deployed, where information about the water level will be collected. The proposed system considers two different types of SDA, such as pools and overhead tanks, of which 6 sensors are deployed at different levels of 10%, 25%, 35%, 50%, 70%, and 90%. If the water is at the appropriate level-(i.e., 70% to 100%), the sensor will indicate TRUE. Otherwise, it will indicate FALSE. A small computing device installed with Bluetooth Low Energy (BLE) module on each SDA for the data collection.
- ***Echo module:*** - This is the module in which a small computing system with BLE is used when SDA not found in the range of Wi-Fi.

This module can be considered a hop. The required amount of such hops depends on the length of space between the SDAS location and the Wi-Fi range.

- ***Push Module:*** - The push module is hop in the Wi-Fi range designed using a microcontroller with BLE. This microcontroller will push the data into a file in the local server.
- ***Centralized System Module:*** - This module contains a small computing system with Wi-Fi modules for data processing and integration processes. Data from the local server will be taken by the central system, which further goes under processing operation. A small computing system is implemented in such a way that data updates and real-time visualizations must be performed. In this case, the local database system and the Cloud are used to notify the event via messaging and email services. When the water level is below the defined cutoff range, the alarm will be triggered, showing real-time updates and past observations.

V. ALGORITHM

This section presents the algorithm of data processing and its analysis to perform further needed action. The significant steps are as follows:

Input: Sensed water level Data
Output: Updated data and Alarm Flagging
Start

1. Load data → W_d
2. Execute → W_d
i. Process: → $f_1(W_d)$
ii. for T_{cat} → O_T & S_T
Update → *Water Consumption & Excess usage*
Update → *water level*(T_{cat},T_{id})
Flag Alarm: for T_{cat}, T_{id}, T_{area} → *if* $T_{level} > C_v$
3. Update status: → *Current Consumption*
4. Update status: → *Current Excess usage*
5. Update: Water level → $T_{cat-Tid}$
End

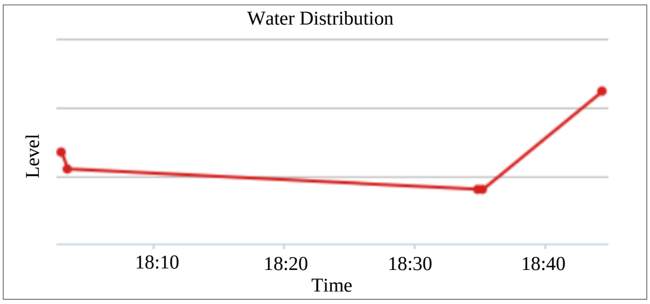
The above-presented computing steps are subjected to the process of data For data maintenance and flagging alert based on the water level and consumption observations. The first step of the algorithm is responsible for taking data from the sensors, which is further stored in the database Wd. The second step of the algorithm is subjected to execution and processing operation where the system uses function f1 over data Wd to perform analysis. In this the data is first is stored in a temp file and the then the main file is flushed out in server to carry further next information. After getting data, the system then identifies tank category and update the level of water such as consumption of total water, excess usage of water. Then after the system updates such information in the database with tank category and its id for the visualization purpose. If the consumption level and excess usage level is found below than the user-defined cutoff value, the system triggers an alarm or warning notification via messaging and email services (Step-2). The next step is responsible for updating the current status with water consumption and water level every 10 minutes. The whole procedure is updated in every 10 minutes and is sent to authorize members to further action- (Step-3 to Step-4).

VI. RESULT AND DISCUSSION

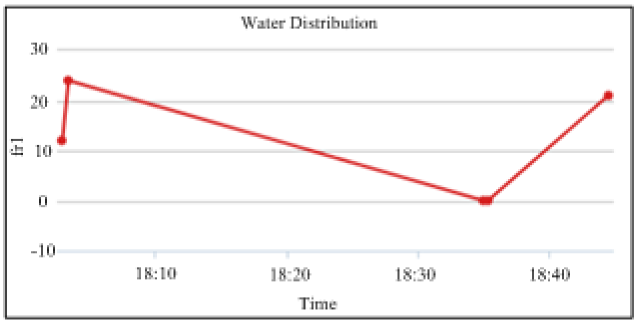
The implementation of the intelligent water management system is performed in two phases. The first phase is subjected to data from the SDA and maintains a database with the sensed events. The second phase of implementation is subjected to extraction of collected information from the observed events stored in the database and processes it for further visualization and notifications. The small computing device is implemented as a centralized system. The implementation of proposed modeling is carried on windows O/S system using XAMPP server for the web interface and MySQL database for information gathering. Simple script is constructed for reporting events (current observation and past observations) on a daily and monthly basis.

a. Data Processing

The sensor is deployed in the SDA. Each SDA contains 6 different levels of sensors. One small computing device is configured for each SDA which sensed event and collect data from the sensor and encode it as #<tankcategory> <tankId> _ <T / F> …n<T / F>. For low complexity computations, the system assumes water level at 50% water after which All SDAs will send the sensed information to the local centralized system that started processing.



(a)



(b)

Fig.2 (a) and (b) water distribution level analysis

The above figure 2 (a) and (b) shows water distribution level analysis outcome w.r.t date

b. Visualization and data alerts system

Event visualization and notification are implemented in web-based and alerts based using messaging service and email services. A simple web interface is developed that has multiple interfaces, for demonstrating water level, consumption, over-subscription, and fault. The Water Level interfaces automatically refresh in every 10 minutes and also shows the capacity of particular tanks. Also, this interface offers a summarized view of entire tank capacity, available and required quantity. The Consumption interface shows a description of the amount of water consumed, the amount of water required to refilling tank. The visualization will assist in water management, which will provide significant notification to the concerned authorities so that consumption can be optimized based on the past observation and usage pattern in the coming days.

C. Data alerts system

This the second method of visualization, which is performed based on Cloud. The service includes an alarming system that triggers warning or notification in the form of SMS, email when the sensor value reaches to the user-defined -cutoff value. In this, each user is assigned with one API key to access the information securely. Furthermore, the alert system is configured according to suitable conditions, when the water level in the respective tank goes below a user-defined cutoff range, the SMS will be sent to associated members and tank refilling person.

VII. CONCLUSION

The tremendous growth of population has led to a massive demand for water. In recent year the water distribution system concentrated focuses on various aspects such as proper water supply, over-consumption alarms, and quality-aware water. These factors can be effectively monitored through the use of smart sensors and advanced technologies such as the Internet of Things. The proposed study presented a smart water control management strategy using IoT technology. The design of the proposed system is fully analytical and is configured with low complexity module. However, in current work, the implementation is done for a small number of tanks. In the future, it can be extended to a wide-area water management system for further analysis, such as leak detection, water required for future saving and also it can be extended to the smart irrigation system.

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