**An IoT-Based Water Management**

**System**

Phase 2 Document Submission

Project Title: Smart Water Management

**Abstract** Water conservation is one of the prime concerns in the current scenario where environmental conditions are deteriorating at an alarming rate. Smart cities, unlike the conventional system of living, are in the frontline of innovation in terms of both connectivity and technological advancement. The main idea is to use the available technology to make life easy with lesser harm to the environment. An Internet of Things (IoT) and data analytics (DA) based water management system will be a basic ground for implementation and future research on how data and IoT can be used to make this happen. This paper proposes an Internet of Things (IoT) anddataanalytics(DA)based waterdistribution cum management systemthat would help in optimal distribution of water based on user consumption at the plot holding level. The proposed system would not only save water misuse but also help in storing usage data for analysis and town planning at a macro-level.

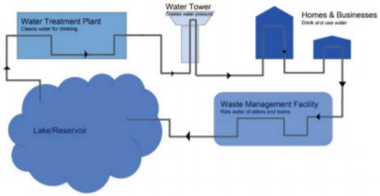
**Keywords** Water management · Data analytics · Internet of Things · Smart city

**1 Introduction**

Smart cities combine technology and innovation in day-to-day living. The idea behind every smart city is that the application of IoT and intelligent techniques in regular everyday activities can increase the ease of living and efficiently perform these activities with less effort. In a smart city, the basic idea of IoT is implemented, which is “anything that can be automated will be automated.” One very important task in a smart city or any city, for that matter, is water distribution and conservation. In traditional cities and housing communities, water is distributed manually with the use of traditional pipe and motor systems. This being very inefficient in terms of availability and also conservative management of this valuable resource, planned and efficient water management is required. A water management system with the implementation of IoT and data analytics is expected to decrease water wastage and also be more efficient in terms of water availability and conservation. This paper presents a plot-holding level plan for smart water management, applicable in upcoming smart cities. This IoT- and DA-based system uses user consumption behavior to optimize water distribution. Using smart sensors, the proposed system also presents a plan to harvest rainwater at the plot level. The following sections of the paper will give a detailed explanation of the basic terminologies used in this paper, provide specifications of the sensors and their usage, describe the architecture of the water supply block, outline the structure of the water tank and how its structure facilitates rainwater harvesting, and explain the distribution of water in the smart city and how it is optimized with the use of data analytics. In the end, the conclusions and future works summarize the paper and the methodologies proposed and present possible research and advancement in the proposed methodology

**2 Existing Distribution Method**

Urban water distribution methods, or the conventional method of water distribution which is being followed in cities all around the world, work but are inefﬁcient and have a lot of opportunities for development. It has a one-way cycle, consisting of the reservoir/any water body, treatment plants, water storage, homes/consumers, ﬁnally to the waste management/treatment facility and send back to nature as groundwater or natural water(Fig. 1). This methodof waterdistribution can have certaindownfalls like inefﬁcient water supply or unavailabilityoftheresource attimesdueto unwanted



**Fig. 1** Conventional water distribution architecture

usage or an architectural failure in the system. This paper has been targeted to over- come some of these basic failures that might occur in the conventional method of water distribution.

The aim of this paper is to optimize the distribution method, to achieve better, faster distribution and also better use of technology to conserve water, which is the need of the hour.

**3 Basic Terminology**

This section presents in brief the terminologies and technologies used in this paper. This includes IoT, data science, the different sensors and its purpose.

**3.1 Internet of Things (IoT)**

Advancements in computing power, component miniaturization, and improved bandwidth for faster communication have fueled the evolution of Internet technologies. Initially conceived as a digital mailing system, it has now blossomed into the expansive World Wide Web. Leveraging these technologies, a fascinating domain has emerged, granting unparalleled control over geographically dispersed devices, enabling data collection for analysis and intelligent control—termed as the Internet of Things (IoT). It involves systematic interconnection of devices across various machines, objects, and even humans, each assigned a unique identifier, all interlinked through the Internet [5]. The fundamental objectives of IoT encompass automation, human-computer interaction, and comprehensive data gathering and analysis. Fundamental concepts such as embedded systems, automation, wireless sensor networks, and control systems significantly contribute to the realization of the Internet of Things.

IoT has witnessed extensive applications in domains such as home automation, security systems, elder and child care, personal healthcare, telemedicine, transportation, traffic control, livestock tracking, farming management, wildlife conservation, and defense, among others. The scope of applications is continuously expanding, limited solely by creativity and sensor availability. An illustrative application focusing on water management is presented below.

**3.2 Smart City**

A smart city is an urban area where sensor-based Internet of Things is used to aid in management of resources and civil life. The sensors are used to collect data from various sources to be analyzed and used for better utilization of assets and services. This data may include citizen count,trafﬁc data, electricity usage data, rainfall data,

etc. which can later be used in analytical models to draw inferences to signiﬁcantly change the quality of life for the citizens. “Smart city” or a “digital city” is the use of modernized techniques in communication, sensing, analysis and integration to run everyday living conditions [6].

Smart implementation of technology can give intelligent and prompt responses to different needs including but not limited to commute and trafﬁc management, public safety, resource distribution and management and commercial trade and activities. In layman terms, a smart city is a way of living with and aided by technology and data. Unlike conventional cities, smart cities integrate technology with governance and that is what makes smart cities different. Automation is made from the smallest entities such as a simple trafﬁc light to more complex infrastructure such as water supply, energy transfer, governance and emergency situationhandling.A smartcityis therefore portrayed as being better equipped to face growth-related changes through a simple transnational relationship of governance with citizenry and resource usage patterns.

**3.3 Data Analytics (DA)**

The growing environmental consciousness and a need for efficient productivity are driving governments towards constructing smart cities, emphasizing connectivity via sensors and utilizing data analytics. Data analytics involves analyzing data patterns to extract actionable insights, employing machine learning techniques like regression, classification, and boosting methods such as XGBoost and AdaBoost. Implementing analytical approaches in IoT and smart city applications enhances their performance, aiding decisions like traffic flow regulation and energy-saving initiatives. Integration of data analytics with IoT, often leveraging cloud technologies, facilitates safe data storage and accessibility, showcasing potential in various areas like traffic and weather analysis, carbon emission reduction, and water management for sustainable urban development.

**3.4 Sensors and Transmitters**

The data for the analysis obtained from the water supply mechanism and the water reservoir and tanks present in the city is collected continuously using sensors and transmitted to the cloud. This following section has the basic description of the technology used. This project uses the Arduino UNO is an open-source microcon- troller to connect and coordinate the different sensors. Arduino UNO is an open- source microcontroller developed by the Arduino group. This board has 14 I/O pins to connect different sensor and transmitter to collect the data and transmit the data to the cloud. It is programmed using the Arduino IDE and a simple USB cable. This board is powered by a 9volt power supply. Different sensors are used to measure the water conditions and levels for data collection. The microcontroller, sensors and transmitters used are:

• Arduino UNO

• SRF-05 sensor (ultrasonic sensor)

• YF-S201 Hall effect sensor (Water ﬂow sensor)

• LM393 chip-based sensor (Rain sensor)

• ESP-8266 Wi-Fi transmitter

• Stepper motor

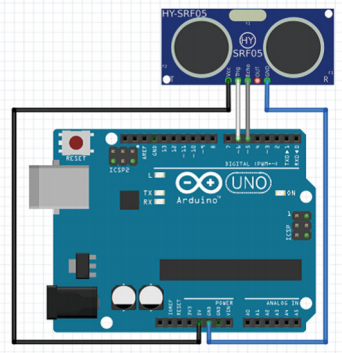
1. RF-05 sensor (ultrasonic sensor): The SRF-05 ultrasonic sensor (Fig. 2) is a wide range distance sensor which uses the SONAR technology. The SRF-05 sensor has a range of 4 min total.

It is used in the top of the water tank in this project to measure the amount of water present in the tank. Let x be the height measured from the top of the tank to the surface of water level and h,r be the height and radius respectively of the cylindrical tank. So, the volume of water in the tank can be calculated using the following formula.

πr2 (h − r) (1)

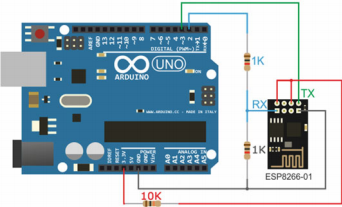
2. YF-S201 Hall effect sensor: Accurate ﬂow measurement is an essential step in terms of both qualitative and economic points of view. Flow meters have proven excellent devices for measuring water ﬂow, and now it is very easy to build a water management system using the renowned water ﬂow sensor YF-S201. This sensor sits in line with the waterline and contains a pinwheel sensor to measure how much water has moved through it. There is an integrated magnetic Hall effect sensor that outputs an electrical pulse with every revolution.

3. LM393 chip-based rain sensor: The LM393 chip-based rain sensor is a sensor used to sense whether there is rain or not. This sensor uses the principle of resistance. It is basically connected to the Arduino board to sense the presence of moisture on the rain board. If there is moisture, then a signal is sent back to the microcontroller.



**Fig. 2** SRF-05 ultrasonic sensor with Arduino UNO

4. ESP-82866 Wi-Fi transmitter: The ESP-8266 (Fig. 3) Wi-Fi transmitter is the low-cost wireless microchip with a fully integrated TCP/IP stack ready for deploymentwith any microcontroller such as Arduinofor experimentalpurposes.



**Fig. 3** ESP-8266 Wi-Fi transmitter connected to Arduino

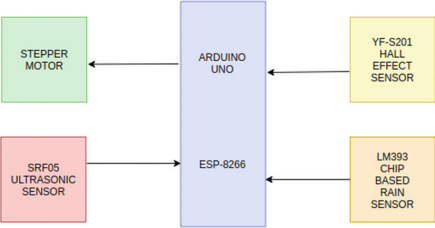
The ESP8285is an ESP8266with1MiB ofbuilt-inﬂash,allowingfor single-chip devices capable of connecting to Wi-Fi.

**4 Blocks of Water Supply Architecture**

This section gives a brief overview of the architecture of the smart city and how the basic blocks of the city are laid out for the water transmission.

**4.1 Block Structure of Smart City**

The water management system in the smart city is solely based on thefactthatthe city is divided into several blocks, and each block consists of several houses to which the water is supplied. The paper assumes this block structure to ease the explanation. The entire city is seen as a collection of blocks which are again recursively organized as sub-blocks. The recursion can go up to a suitable level as would be required for efﬁ- cient and effective management. Individual houses would be the atomic constituents of such blocks. As shown in Fig. 4, initially the water is stored in the reservoir, from where the water for the smart city is obtained. From the reservoir, it is directly sent to the water treatment plant as it is treated to make it ready for use. Every outlet in the water supply architecture is monitored using motorized valve for ease of activation.



**Fig. 4** Microcontroller setup

**4.2 Server and Data Control Room**

One of the main components of this architecture is the server and data control room where the data from every sensor in the block is collected and sent to the cloud and also a main hub for the maintenance of the valve and sensor mechanisms. The sent data is then used in the cloud to perform different extrapolation and feature modeling methods to ﬁnd the water consumption and usage rate and predict the values for the future use.

**4.3 Underwater Storage Facility**

Water from the treatment plant is taken to the underwater storage facility [1]. This facility is present near every block of the city, and the water in this storage unit is used for immediate consumption on demand [ 11]. The water from this facility is sent to different blocks and houses using the sensors and the motor-controlled valve and smart water pumping systems.

**4.4 Water Tanks and Pressure Control Systems**

The water from the underwater facility is sent to every house in a block using pumps and sensors [5]. The specially designed water tanks are used to measure parameters like current water level and amount of water used to make the water supply more efﬁcient [ 13], and conservation and management of the resource become easier. The structure and organization of the tank are explained in the further section.

**5 Structure of the Water Tank**

The water tank present in every house is of a speciﬁc structure. Firstly, the water tank is fully customized to suit our requirements of the smart city [ 14]. It mainly takes care of three functions:

1. Senses the shortage of water to release water into the tank.

2. Records the amount of water used by the person/house on a daily basis.

3. Uses a rainwater harvesting method to smartly open the valve to capture falling rainwater.

**5.1 Build of the Water Tank**

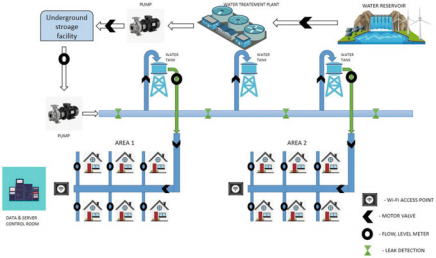
As mentioned above, the water is stored and supplied to each house through a smart water tank ﬁtted on top of each house [6]. The smart water tank has several features as mentioned below.

**5.1.1 Microcontroller Setup**

The water tank is ﬁtted with the Arduino UNO microcontroller, and it is powered with a battery which is recharged with a solar panel. The board is kept in a waterproof container to keep it from moisture which might cause short-circuiting. This micro- controller will control all the sensors connected in and around the tank. The UNO is connected with an ESP-8266 Wi-Fi transmitter which is used to connect with the nearest access point which in turn is connected to the server room to transmit data [9].

The basic architecture is mentioned in Fig. 5. The second sensor is the SRF-05 ultrasonic sensor. This sensor is used to measure the amount of water in the tank. The sensor is ﬁtted, face down inside the tank. The sensor emits ultra-sonic waves and sends it in the tank. The waves are reﬂected back to the sensor, and it senses the height h meters. Assuming that the radius of the base of the cylindrical tank is r meters, the volume of water in the tank volume would be:

vol = πr2 h (2)



**Fig. 5** Smart city water distribution architecture

This measure would help ﬁnd the amount of water in the tank. If the measured amount is lesser than the minimum threshold, the automated motorized valve opens ﬁlling the tank with water. This also helps in supplying the house with the required amount of water. If the tank is having enough water for the home’s usage, the valve is kept closed until required later. The amount of water used by the house (data) is collected using theYF-S201 Hall effect sensor. The tank has the outlet into the house on its base. The Hall effect sensor is placed on the outlet. The amount of water used up from the tank is calculated using Eq. (2), using the ﬂow rate, average velocity of the water and the cross-sectional area of the pipe. This gives the essential data to analyze the data to identify and ﬁnd out the rate of usage of water with the historic data.

**5.1.2 Rainwater Collection**

The water tank is crafted for efficient water distribution and rainwater collection, featuring a funnel-like structure with a flip-open door and a base water filter atop the tank's opening. A stepper motor operates the door, preventing unnecessary evaporation by keeping the funnel closed when not needed. At the tank's top, an LM393 chip-based rain sensor, linked to an Arduino board, detects rain and triggers the stepper motor to open the funnel door, directing rainwater through the filter into the tank. After the rain stops and the sensor dries, the Arduino signals the stepper motor to close the funnel door. This innovative design optimizes water conservation and usability.

**6 Water Distribution**

The water distribution is also fully monitored and controlled with the help of sensors and fully connected valve systems. The water from the reservoir is sent to the treat- ment plant from which it reaches the underwater storage. From the underwater storage, the water is sent to each block in a speciﬁc manner. All the monitoring from when the valve opens, to how much water is sent, everything is controlled from the server and data control center. The underwater storage facility sends the required amount of water to separate distribution tanks in each block.

From the analysis of the data received and the predicted amounts of water, the water is sent through pipelines with motorized valves to each house. The water sent to each house depends on two things:

1. The signal from the sensors of the tank.

2. The requirement calculated from the data.

**6.1 Signal from Sensors**

As mentioned in section IV, the water tank placed on top of every house is ﬁtted with different sensors. These sensors keep sending the data to the control center. This data is used to determine when the water should be supplied and when not. When signals are received from the sensor that the water level is low, the motorized valve at the outlet of the pipe is opened and water is sent in. In case the sensor shows that enough water is present in the tank adequate for the consumption of the household (obtained from the historic data collected), then the water is not sent to the house. This helps to divert that water to another area or block where it is actually required. Following this method will reduce the wastage or unwanted supply of water to the houses in the city.

**6.2 Supply on Demand**

The water supply to houses, as mentioned previously, also hinges on another factor—supply based on demand. Essentially, water is provided to households based on their specific needs, determined by analyzing historical data. By extrapolating usage patterns using the YF-S201 Hall effect sensor, future water requirements can be predicted. This approach ensures precise water supply to each household, minimizing waste. In cases of excess demand, arrangements for individual household delivery can be made upon special request. Comparing obtained and actual values helps fine-tune the predictive model by utilizing errors. Storing this data and excess supply information for households aids in refining predictive models and analyzing error margins. This data can also be utilized to levy taxes on individuals exceeding set usage limits. This data-driven approach distinguishes it from conventional distribution methods, allowing for continuous model tuning to optimize distribution. Moreover, the model can account for seasonal usage variations and assist in making administrative decisions during water scarcity due to insufficient rainfall.

**7 Conclusion**

The water distribution can be optimized, and the water can be conserved better by the application of the above method in a real-life scenario. The proposed method- ology can be improved with the application of better sensors and industry grade materials which would make it efﬁcient. Motorized valves can be replaced with a better alternative and the Arduino with the ESP-8266 upgraded with a NodeMCU or even better ones. This can make the working faster and better. Improvements in the analytics can be done by using advanced ML algorithms with neural networks or similar techniques for a better outcome.

In the current paper, as already mentioned, simplifying assumptions have been made about the layout and plan of the city where it can be implemented. This has been done purely for ease of identiﬁcation of the individual households, as analysis of the data gathered plays a pivotal role in the proposed model. It becomes essential therefore to pinpoint every holding and regulate the supply accordingly. The scala- bility of the proposed model in its current form is limited only by the organization of the cities household. The same may however be implemented on any scale, small or big, provided a proper distinction can be made between individual houses to enable the analysis to be based on that identity.

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