IoT, Cloud and AI Enable Sensor Based Water Monitoring to Handle Water Crisis in Indian Cities

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Abstract

The internet is the greatest innovation of this era. The innovation of the internet has revolutionized the planet entirely by bringing the people and machines closer to each other than ever. The recent development in computing and networking technologies brings the next generation of internet which is called as Internet of Things (IoT). As the industrialization and the population are increasing the movement of people towards urbanization is also increasing. Therefore, cities are converting up into smart cities that can be accomplished with the service of the IoT. Water is one of the crucial resources for the existence of human life, so efficient supervision of water systems plays a significant role in smart cities. This paper uses three different modules of smart water management in context to smart cities. In this work three different sensors such as water flow sensor, water temperature sensor, and ultrasonic sensors are used to monitor water consumption. These sensors are interfaced with microcontrollers such as Raspberry Pi and NodeMCU. The sensors data can be observed on the Thing speak cloud server. This system helps in monitoring the leakage of water as well as to control the unnecessary use of water. Also, this module provides data in real-time for each user and that data can be used for monthly billing of water usage. Hence, the consumer will have to pay for the amount of water he/she can use only. Therefore, this model will allow the users to manage the water consumption efficiently.

Keywords: IoT, NodeMCU, Raspberry Pi, Smart City, Sensors, Thingspeak, Water Monitoring, Water Management

1. Introduction

The term "Smart" is becoming more prominent as a consequence of the use of recent technology (particularly ICT - Information and Communication Technology) has evolved. And, the demand of new innovative of IoT services has increased a new competition in acquainting new and pioneer products for smart applications. Therefore, Smart Home, Smart City, Smart Grid, Smart Water Monitoring, and Smart Maintenance are increasingly being discussed [1] and [2]. The water sector is facing new issues in the sustainable management of water systems. There are several external aspects, including effects of climate transformation triggered by the volatility of weather patterns, rapid population burst around the world, vast urbanization and industrialization in metropolitan centers, which enhance responsibilities for adopting more sustainable organization of water sector [3]. Water is a vital commodity that links direct sociopolitical and economic consequences to any aspect of the daily functioning of cities and communities [4]. Over the past few decades, many cities of the globe have witnessed the problems of severe water stress, and the risk of water pollution. It is assumed that by the year of 2025, more than 70% of the world population will be living in cities and they might face the problem of crisis of fresh water. The existing piped infrastructure that water supply relies will be inadequate. According to the studies of International Benchmarking Network for Water and Sanitation Services (IBNET), approx. 35% of water is vanished in supply and management [5]. Therefore, there must be a proper and smart management of water supply and piped infrastructure.

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The management of water is basically revolving around fulfilling the three main objectives such as: elimination of water losses, ensuring proper quality of water, and ensuring proper supply of water between water bodies and the consumers.

The Internet of Things (IoT) coined out as the significant technology and solution to resolve water conservation and management problems, to resolve water insecurity and to achieve the 2030 resolution of United Nations Sustainable Development Goal (SDG 6) on Clean and Fresh Water by digitization and creating intelligence in the water management system [6].The consumption of fresh water in rural as well as urban areas in illustrated in Figure 1 and the supply and demand of water from the year of 2015 to 2025 is described in Figure 2 [7] and [8]. In this work, we have mainly focused on the water problems and smart monitoring of water supplies for of two major countries of the globe which are United States of America (USA); the world’s largest economy and India; the country with over burst population and variety of culture based on geographical and linguistics conditions.

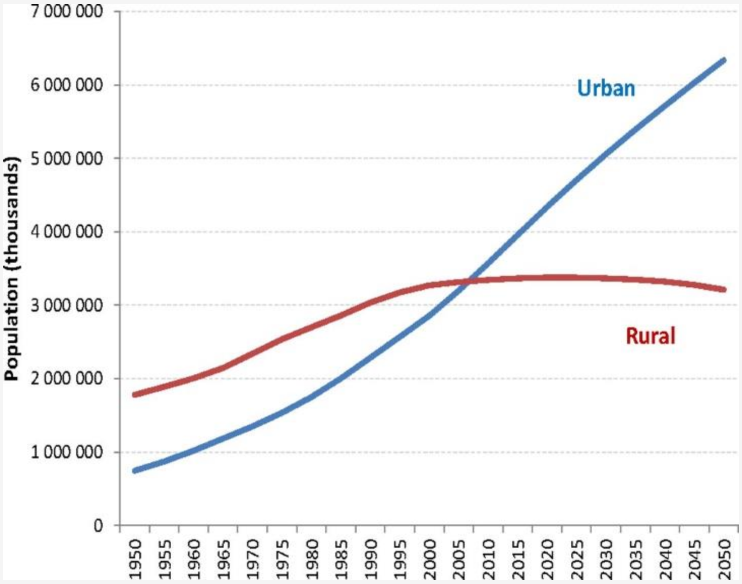

Figure 1: Water consumption in rural and urban from 1950-2050 [4]

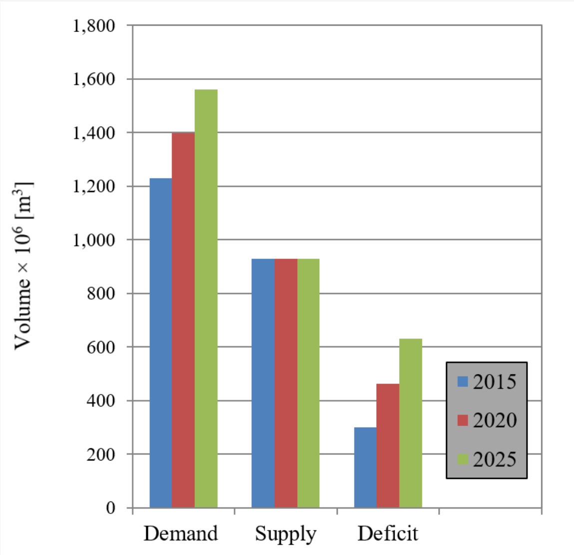

Figure 2: Supply and demand of water from 2015-2025 [5]

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According to census survey of 2011, in India about 63% of country's Gross Development Product (GDP) relies on urban population, and about 31% of country's population lives in this urban society. People from rural locality have started moving to urban environment for better ways of living. By the year of 2030, it is expected that about 40% of country's population will be living in the urban area ad they will add about 75% of GDP. To accommodate this urbanisation, growth in terms of infrastructure is needed [9]. To make the city smarter, smart solution are needed to make the infrastructure efficient and smarter. For the concept of smart city energy and water management are the fundamental area which needs to be focused upon. Power/Energy-Efficient devices, smart power meters, monitoring of water quality and its leakage etc. are some challenging solutions in Indian consequence. Day by day water consumption is increasing in Indian states therefore management of water is a big challenge of both local bodies and government. Therefore, the main challenge is the water management and distribution at reasonable cost [10]. Hence the overall annual usage of water in various Indian states is described in Figure 3 (Unit of water use is billion cubic metre), and the crisis of water in different Indian states is depicted in Figure 4 [11] and [12].

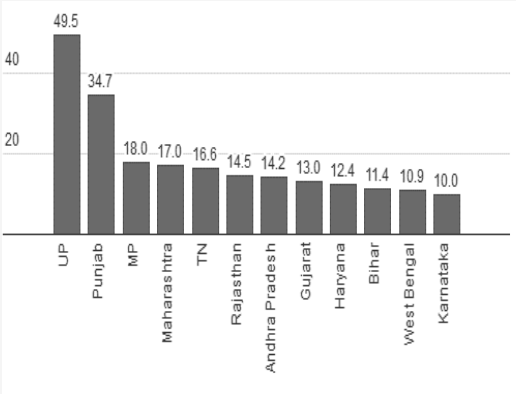

Figure 3: Overall annual usage of water in various Indian States (Unit of water use is billion cubic metre) [8]

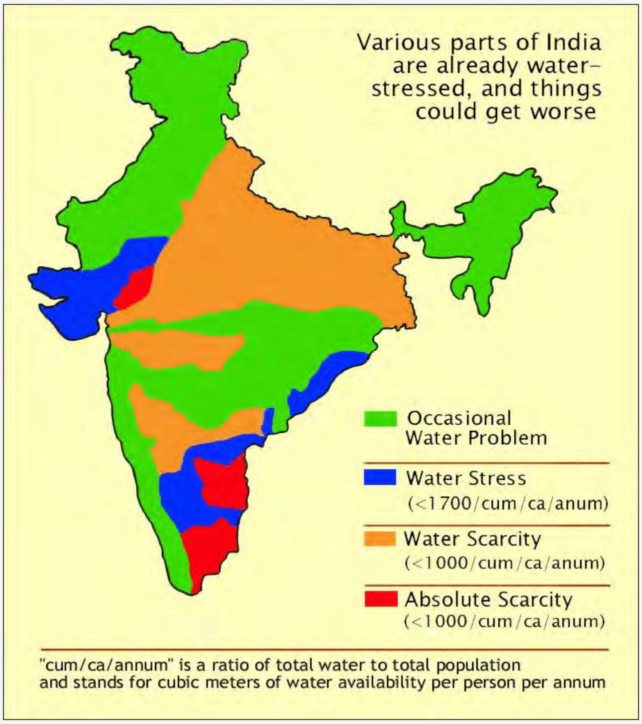

Figure 4: Crisis of water in different Indian States [9]

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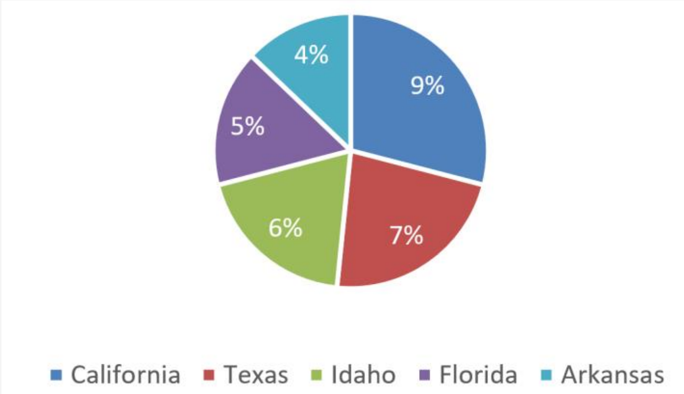

Figure 5: Water consumption by top five US states [13] and [14]

According to the reports of US government, the daily water consumption in the USA was 322 billion gallons per day (BGal/day) in the year of 2015. The water consumption has reduced in USA by 9% as compared to the year of 2010. According to the reports more than 50 % of water consumption is witnessed in only 12 states among the 50 states of USA. California, Texas, Idaho, Florida, and Arkansas are the top five water consumer US states [13][14] and [15] These states count 9 %, 7 %, 6 %, 5 %, and 4 % respectively of the total consumption in the USA, as shown in figure 5. In the USA the consumption of water mainly relies on mentioned sectors such as: Public Supply, Irrigation, Domestic Thermoelectric Power, Livestock, Mining, Industrial, and Aquaculture. The consumption of water in different US states in various sectors is depicted in Figure 5. In US the major sources of water are surface water, saline water, ground water. In all the three sources surface water counts for 61.5 % of the total consumption, while saline and ground water count for 13 % and 25.5 % respectively.

1.1 Sustainable Development via Water Management

Development that satisfies people's fundamental needs of today without compromising their capacity to fulfil future needs via environmental, unified economic, and community activities is regarded as Sustainable development. Sustainable development has been recognized and endorsed since the 1990s, and is based on the concept of requirements that need to be satisfied by taking environmental and technological capacities into consideration [16] and [17]. The environment is the foundation of the sustainable development, while the skill and technology are the tools and society's well-being are an aim respectively. Basic human requirements are linked to providing healthy living circumstances requiring quality food, fresh air and enough clean drinking water. Thus, sustainable development is mainly accomplished by decreasing the consumption of renewable resources, especially water, by removing harmful and toxic compounds from economic processes and by minimizing pollutant emissions into the atmosphere. The goal is to provide individuals a feeling of security and prosperity that is understandable as creating the circumstances that are beneficial to their physical, mental and social well [18]. Therefore, in the countries like USA and India, sustainable development with water management is very much required because of the following measures such as:

- USA is the world's largest economy and in recent years India is also becoming a global hub for a lot of organizations.
- Water management is need because of the vast population of India. As far as USA is concerned the population is also increasing here and visitors from across the globe is also increasing rapidly.
- Industrialization in both countries.
- Some parts of both countries like California (USA), Mumbai (India) etc. are facing water problems.

The rest of the paper is organized as follows: Section 2 is Existing Works. Section 3 is proposed method and Models. Section 4 is design consideration. Section 5 is the implementation with NodeMCU and Thing speak Server and implementation with Raspberry Pi and Thing speak Server. Section 6 is conclusion.

2. Literature Review

The cloud Internet of things is popular in designing the smart monitoring system. With the help of Cloud Computing (CC) and Internet of Things (IoT), researchers have designed a smart method of water distribution [19].

In this work authors used Wireless Senor Networks (WNS) IoT and CC to measure water distribution. In [20] authors have designed a framework for water managing system in perspective to smart cities in India. In this framework authors have used Arduino and Raspberry pi microcontroller, cloud platform to visualize the data. With the incorporation of Raspberry pi, water flow sensor, and IoT authors have proposed a smart architecture for water management [21]. Freshwater supply is getting much affected these days; therefore, to reduce these authors have implemented a design of smart management of fresh water with the help of IoT platform [22]. This fresh water can be used for drinking as well as for cultivation of crops since for agriculture purpose supply of fresh water is getting limited.

By using (FIWARE) technology and IoT researchers have proposed a method of efficient supervision of water for agriculture purpose [23]. In [24] with the use of blockchain technology and IoT researchers have proposed a system of intelligent management of water, since water is getting very precious commodity day by day. Every now and then every city is on the track of being smart and supply of fresh water is getting limited, therefore to conserve fresh water researchers have designed a project of monitoring the quality of water in smart cities [25]. A sustainable water management system is developed ay authors for housing societies. To monitor the water management IoT platform is used with Raspberry pi module [26]. An intelligent approach for usage of water for residential purpose is represented in [27] with the help of IoT frame work. A smart approach of managing waste water is represented by authors using Supervisory Control and Data Acquisition (SCADA) and IoT technologies [28]. A design for measuring the water level of reservoirs and rivers is proposed by authors [29]. In this design deep learning method is applied of analyzing the level of water, with the help of UAV. The results are observed on web portal [30]. With the use of technologies of ICT smart management of water resources is needed to avoid over exploiting of water for society [31]. Water management therefore provides amongst other major performance advantages to reducing leakage, ensuring water quality, improving customers' experience and optimizing operation [32] and [33].

A smart city may be pronounced as endorsing the use, as a facilitator of sustainable economy development, by stimulating investment in human and social wealth and by so enhancing the eminence of life of customers and so enabling better management of energy and water resources [34]. In [35], authors studied about the approaches towards water management in urban world for sustainable development. With the advancements in ICT, authors have proposed a framework for smart monitoring of water in urban localities [36]. In [37], idea of smart sensors and pipes have been introduced by researchers to promote the smart methods of water management. Efficient water measurement with smart water meter to measure the level and flow of water has been installed with the help of sensors and actuators [38]. SCADA and cloud-based framework has been adopted by researchers to endorse the efficient management of water [39]. From the existing work, it is observed that a lot of initiatives have been taken in account of managing and monitoring the fresh water for the domestic and industrial use. But a very few steps have been taken in account to do the same for the concept of smart city in Indian and American society, in the context of IoT, cloud, sensors, and microcontrollers. Hence this work is about proposing a designing a module with the help of IoT, cloud, sensors, and microcontrollers, which can be helpful in monitoring and managing the quality of water in smart cities of USA and India.

3. Proposed Methods

This section will discuss about the steps and the methods used in designing the module for efficient and smart ways of water monitoring system in smart cities of USA and India. The flowchart of the proposed methodology is presented in Figure 6. In Figure 6, first the data is taken from the sensor, if the sensor senses the input signal, then it will process the incoming signal and if it does not sense the signal, it will send signal back to sensor to send the input again [40] and [41]. After processing of the signal, the data is sent to the cloud server, at the cloud server first the data is updated then from the cloud server the incoming signals from the sensor can be accessed from any wide location from that server [42].

4. Design Consideration

In this design two IoT based microcontroller such as Raspberry Pi4 and NodeMCU are used with sensors such as water flow sensor; which is used to analyze the water flow, water temperature sensor; used to notify the temperature of water stored for the uses and to measure the temperature of water flowing through various water bodies, and ultrasonic sensor; used to identify the level of water in any storage container [43].

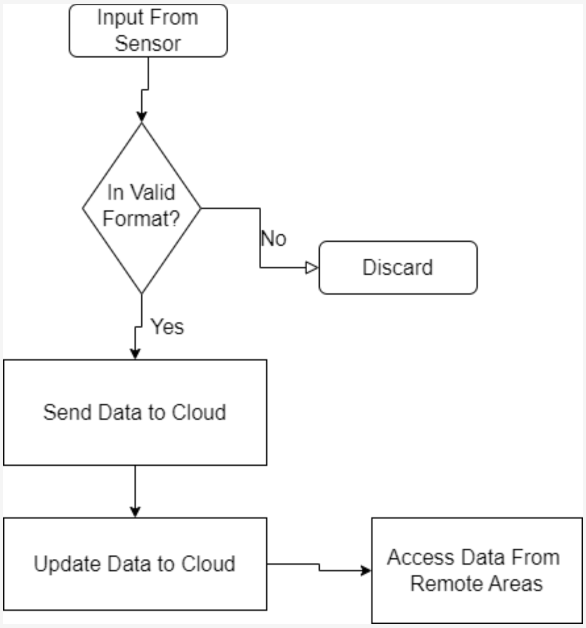

Figure 6: Flowchart of the proposed model

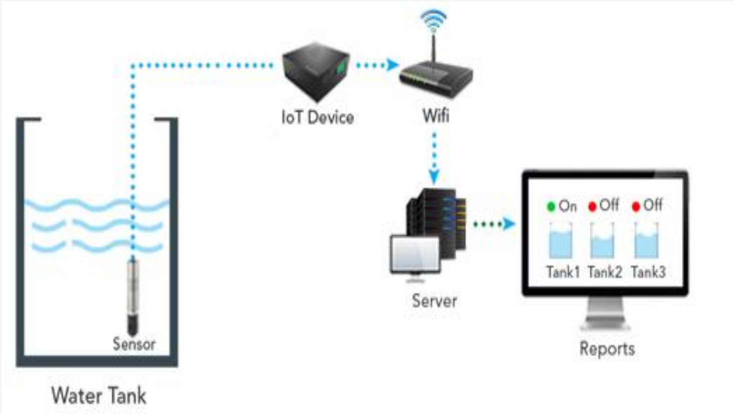

Figure 7: Overview of Water Monitoring Structure [44]

The results of these sensors are measured with the help of microcontroller devices and sent over the cloud platform which can be accessed from any remote location with the help of internet. Our monitoring system will have the three important features these are such as follows:

i. Water level monitoring
ii. Water flow measurements
iii. Water temperature calculation

The overview of the water monitoring infrastructure for the smart cities in USA and India as well as urban localities is represented in Figure 7.

In Figure 7, we used sensors which were connected with IoT devices through internet. Sensors were used to observe the data such as water flow rate, temperature, and water level [44]. The data were transmitted with the help of IoT devices such as NodeMCU and Raspberry Pi via internet. The data were stored on the server and could be seen on websites or phones or laptops [47]. The proposed module uses three sensors for water management which are such as water flow sensor (YF-S201), water temperature sensor (DS18B20), and ultrasonic sensor (HS-SR04) [45] and [46]. These are connected with the microcontroller, which is the main processing module, and with the aid of the Wi-Fi module, data transmission is achieved. The block diagram of the proposed system is represented in Figure 8. The design components used and its specifications are described in Table 1.

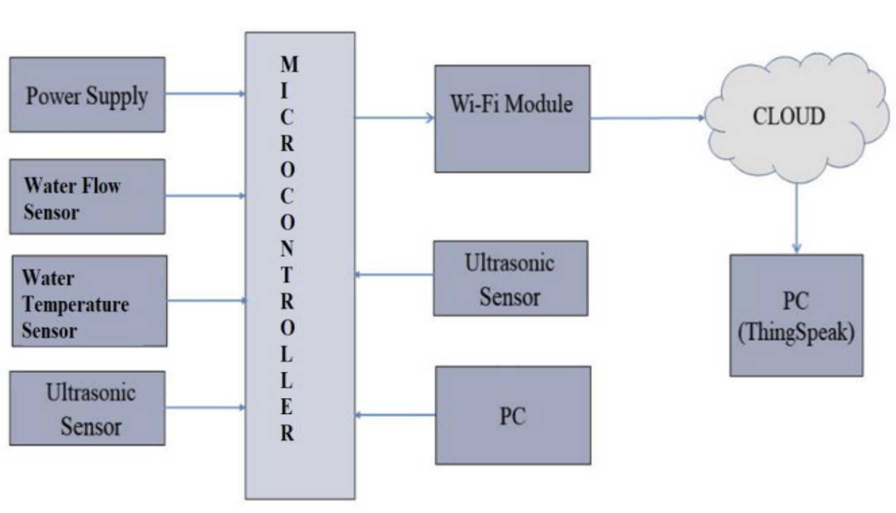

Figure 8: Block diagram of proposed system

Table 1: Design components specifications for the proposed system

Device	Description
NodeMCU	NodeMCU is an Open-Source IoT framework. It consists of the ESP8266 Wi-Fi Chip (SoC) on-chip and ESP-12 modulus-based hardware Device [40]. The NodeMCU Development Board was implemented with Wi-Fi, digital pins, analog pins and serial communication protocols. This is low-cost devices are used to monitoring infrastructure in real time [44].
Raspberry Pi	The Raspberry Pi is like a mini computer's CPU developed by the Raspberry Pi Foundation in the United Kingdom. It has both digital and analog pins along with HDMI ports, USB ports, and UART protocol [42]. This device is used for robotics prototyping and simulating sensors and monitoring in real time [43].
Water Flow Sensor	It is a Hall Effect sensor which is used for measuring the flow of water. It measures 1-30 liter of water per minute of time. This sensor is very hand to use and it is very cost effective [45].
Water Temperature Sensor	This sensor is used to measure the temperature of water in tank or any storage container. It can measure temperature in the range of -50C to +500C. It has three pins, one pin is connected to ground of microcontroller, and the other two are data pin and +5V (VCC) pins respectively [46].
Ultrasonic Sensor	This sensor is used to measure the level of water stored in any container with the help of ultrasonic waves [48].

5. Result and Discussion

5.1 Sending Water Flow Sensor Data to Things Speak Cloud with Nodemcu

In this section we will discuss the interfacing of water flow senor with NodeMCU and sending its data to thing speak cloud server. The interfacing of water flow sensor with NodeMCU is described in the following text. The data pin of water flow sensor is connected to D4 pin of the device and the rest two pins which are ground and power respectively are connected to ground pin and +3V pin of the NodeMCU respectively. The sensors reading are sent over cloud servers which can be accessed from a remote location in Thingspeak. The water flow sensor used here to measure the flow works on the phenomenon of hall effect, often called as hall effect sensor. The sensor has the diameter of 20 mm, and flow rate is approx. 30 L/m. Water flow can be measured by the use of kinetic energy of change in the value of velocity. The average velocity specifies the flow rate, since the cross-sectional area of the tube remains constant. The mathematical equation used to measure the flow is stated as:

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$$Q = VA$$

Equation 1

Here, Q is the rate of water flow i.e., flow rate, V is the average velocity, and A is the cross-section area. The reading of the sensor data can be accessed from any remote place through thing speak cloud server. It also ensures the effective flow of water and water consumption by a particular place on a single day.

5.2 Sending Water Temperature Sensor Data to Things Speak Cloud with NodeMCU

In this section reading of water temperature (DS18B20) sensor is observed on the thing speak cloud platform. Water temperature (DS18B20) is a 1 wire sensor which reads the temperature ranging from 9-bits to 12 bits. This sensor can read the temperature ranging between -55^{0}C to +125^{0}C. This sensor receives signal in an inactive state of low power. Within the sensor's 2-byte register, the generated temperature data is recorded, after which this sensor again gets back to inactive state. The master circuit may offer read-time slots adjacent to the Convert T command if the sensor is powered from an external power source.

The implementation of DS18B20 is done with the help of NodeMCU device is shown in Figure 9, and the readings of sensor sent to cloud.

5.3 Sending Ultrasonic Sensor Data to Things Speak Cloud with NodeMCU

In this section, we have measured the level of water in the tank. Here the ultrasonic sensor is used for measuring the water level of the tank, and the sensor data is recorded over the thing speaks cloud. The working of the ultrasonic sensor is described in Figure 10. The ultrasonic waves sent from the sensor measures the water level, first the incident rays strike the water level and reflects the signal to the sensor to measure the water level. The mathematical equation for calculating the water level is stated as:

$$H = \frac{1}{2}TC$$

Equation 2

where H is water level, C is the speed of sound i.e., 343 m/s, and T is the time taken by ultrasonic sensor to receive the signal.

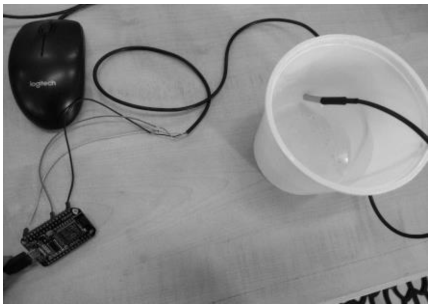

Figure 9: Implementation of DS18B20 is done with the help of NodeMCU

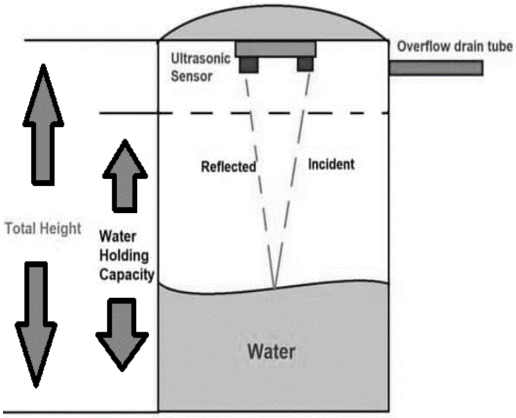

Figure 10: Working of ultrasonic sensor

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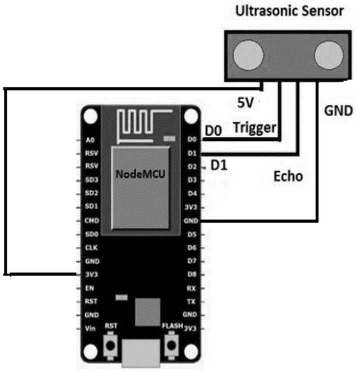

Figure 11: Interfacing of the ultrasonic sensor [47]

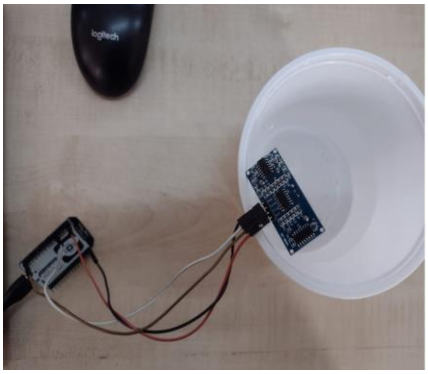

Figure 12: Water level measurement with ultrasonic sensor

The interfacing of the ultrasonic sensor is shown in Figure 11. In Figure 11, the trigger pin of the sensor is connected to D0 of the NodeMCU and the echo pin is connected to D1 of the NodeMCU and the rest pin are connected to ground pin and +5V pin respectively. The water level measurement with ultrasonic sensor and NodeMCU is described in Figure 12. The readings of the sensor are observed on the thing speak server is shown in Figure 13.

5.4 Sending Water Flow Sensor Data to Things Speak Cloud with Raspberry Pi

Here the water flow sensor is connected with the Raspberry Pi device to measure and control the flow of water. The code for interfacing the sensor with the Raspberry Pi device is written in python language. The water flow sensor used here to measure the flow works on the phenomenon of hall effect, often called as hall effect sensor. The sensor has the diameter of 20 mm, and flow rate is approx. 30 L/m.

The data pin of the senor is connected to GPIO pin 3, ground pin is connected to pin 6, and +5V pin is connected to pin 4 of the device. The electrical system outline and the server data of the water flow sensor is show in Figure 14 and Figure 15 respectively.

5.5 Sending Water Temperature Sensor Data to Things Speak Cloud with Raspberry Pi

For interfacing the water temperature senor with Raspberry Pi device, the data pin of the sensor is connected to GPIO pin 4, ground and +5V pin are connected to pin 4 and pin 6 respectively. The code for interfacing is written in python language. The interfacing with Raspberry Pi is described in Figure 16.

5.6 Sending Ultrasonic Sensor Data to Things Speak Cloud with Raspberry Pi

To measure the level of water in the tank, ultrasonic senor is used with the Raspberry pi device. The echo pin of the sensor is connected to GPIO pin 3 and the trigger pin is connected to GPIO pin 5 of the Raspberry Pi, and the other pin are connected to ground and +5V pin respectively. The interfacing is shown in Figure 17. The data of the sensor of water level measurement over thing speak cloud in shown in Figure 18.

Figure 13: Ultrasonic sensor reading on thing speak server

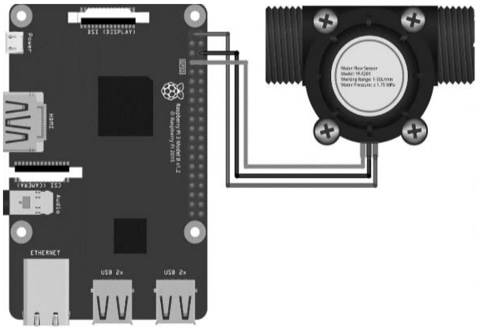

Figure 14: Electrical system outline with Raspberry Pi [44]

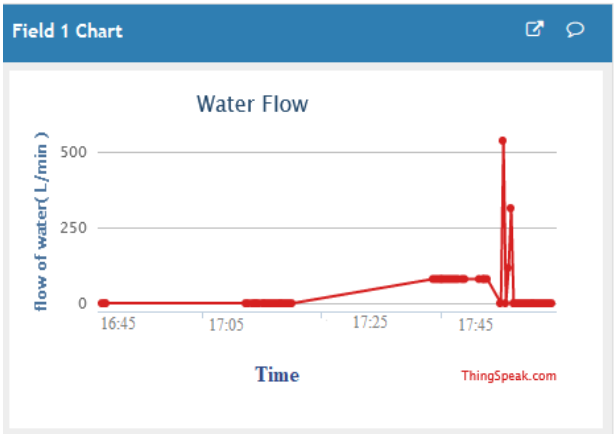

Figure 15: Water flow sensor data to cloud with Raspberry Pi

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Figure 16: Interfacing with Raspberry Pi

Figure 17: Ultrasonic sensor with Raspberry Pi

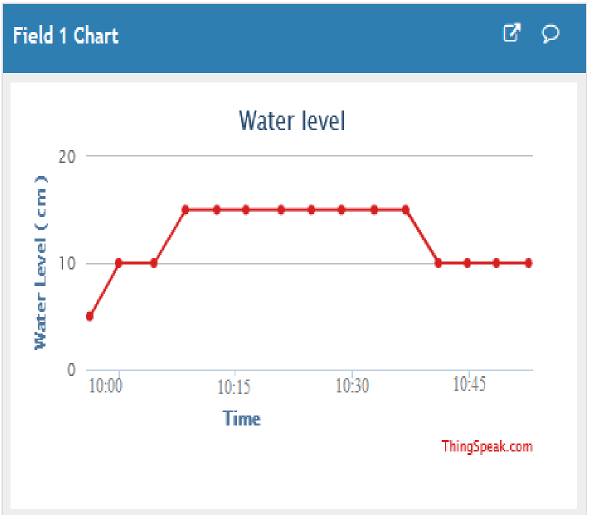

Figure 18: Ultrasonic sensor data to cloud

6. Conclusion

This work signifies the water management prototype system in the perspective of smart cities. To design the system two microcontrollers' i.e., NodeMCU and Raspberry Pi has been used and the data of the sensors are observed over thing speak cloud server. This work signifies a clear view of efficient water management for smart cities, since water vital part of our day-to-day life. In this work we can check the flow of water with the help of water flow sensor, also we can measure the water level of the tank and its temperature with the help of ultrasonic sensor and water temperature sensor respectively. This module provides data in real-time for each user's water use. Also, the data can be used for monthly billing of water usage. So, the consumer will have to pay for the amount of water he/she can use. This method alerts the user about the leakage in the pipeline; therefore, we can reduce water loss due to leakage by turning off the supply. Consumers will receive details of the daily consumption of water. This will allow them to manage water consumption if there is an unnecessary amount of water consumption.

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