Smart Water Management using IoT Technology

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***Abstract*— Water is one of the most prodigious factors of life. From providing nutrients to human body to its use in daily tasks, water plays a major role in life. Due to this, water needs to be saved and used wisely. In the present day and age, where Internet of Things (IoT) is playing a huge role in every sector, a Smart Water Management System is one of the best options to ensure efficiency and sustainable use of water. An IoT based system will provide transparency to the process in the system, will allow real-time monitoring and the ability to detect problems immediately. It will also automate the system which will reduce human errors. Using these factors to advantage, this paper describes the work carried out on a design of a Smart Water Management System which aims to provide facilities to monitor and manage water under one roof. It allows real-time monitoring of water usage, water purity and level of water in the tank. This information also allows one to detect any problems in the water supply like leakage in the pipes or impurities. The system was successfully implemented and the data was displayed on a user interface.**

Keywords—Internet of Things; sensor systems; wireless communication; smart living

I. INTRODUCTION

Water is one of the most prodigious factors of life. From providing nutrients to human body to its use in daily tasks, water plays a major role in life. Unfortunately, even in countries with adequate water resources, water scarcity is not uncommon. Although this may be due to a number of factors - collapsed infrastructure and distribution systems, contamination, conflict, or poor management of water resources [1]. Water needs to be saved and used wisely.

With increase in population, water needs have increased. So sustainable use of water is the need of the hour.[2] Local administration minister S. P. Velumani's statement in the Coimbatore assembly was that 50% of potable water supplied to the city was going waste presently. If not 50%, a conservative estimate by corporation officials puts the extent of water wastage at 30%. It accounts for a whopping 60 million liters (MLD) water daily on an average, out of the 200MLD water supplied to the 60 wards of core city a day [3]. 2.1 billion people, lack access to safe, readily available water at home, and 4.5 billion people, lack safely managed sanitation. Billions of people have gained access to basic drinking water and sanitation services since 2000, but these services do not necessarily provide safe water and sanitation. As a result, every year, 3,61,000 children under 5 years of age die due to diarrhea. Poor sanitation and contaminated water are also linked to transmission of diseases such as cholera, dysentery, hepatitis A, and typhoid [4].

Judging from the above statements, a lot of people who receive proper amount of water also face problems regarding their water supply. These problems include unclean water, wastage and huge costs. To provide justification for this statement, an online survey was conducted.

Fig. 1 refers to the data received from the online survey attempted by 41 households.

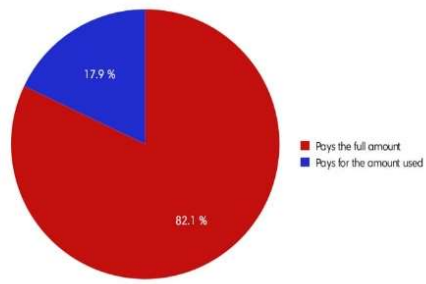

Fig. 1:Survey Result

According to the survey report, about 82.10% people are charged for the full amount of water that they receive which is way more than the amount that they actually use. High costs and no metering are some of the major concerns of the residents. People have also expressed their concern regarding other factors like wastage of water due to overflow and while performing other daily tasks, no metering, presence of impurities and hard water.

Hence, a Smart Water Management System was designed to monitor water usage, water quality and water level in real-time. This will also allow help in identifying problems such as leakages.

The rest of this paper is organized as follows. Section II describes the proposed system design and system architecture; Section III presents the experimental setup and results. In Section IV possibilities for future work are discussed and the paper is finally concluded.

II. PROPOSED SYSTEM DESIGN

The proposed system includes three main devices. These devices include - Water Meter, Water Quality Checker and Water Level Indicator which measure the usage, check the water quality and check the water level respectively. But the system is not limited to these functions only. The features of these devices are discussed individually, further in this report. All these devices will be communicating with an IoT server. Users will get timely information about their water supply, usage and also working of their system. The main system design is shown in Fig. 2.

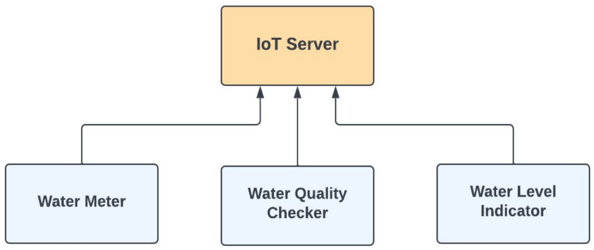

Fig. 2: Main System Block Diagram

A. Water Meter

Smart Water Meter is one of the devices included in the system. In the water meter, Esp32 microcontroller is used to operate the system along with the YFS201 Hall Effect Water Flow Sensor. Esp32 is selected since it is a cost-effective open source IoT platform which has embedded Wi-Fi module. The design of the water meter is shown in fig. 3.

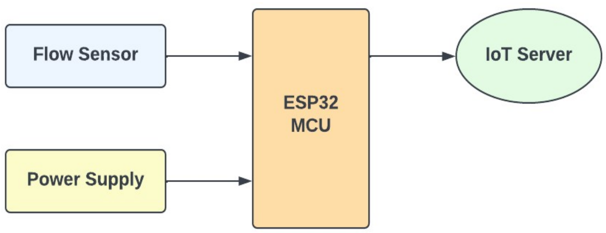

Fig. 3: Water Meter Block Diagram

The water flow rate is calculated by counting the pulses from the output of the sensor. Each pulse is approximately 2.25 millilitres. This sensor is cheaper and best but not the accurate one as flow rate/volume varies a bit depending on the flow rate, fluid pressure, and sensor orientation. To get better precision of more than 10%, a lot of calibration is required.

The pulse signal is a simple square wave, it is easily converted into litres per minute using the following formula:

Pulse frequency (Hz) / 7.5 = Flow Rate in L/min …. Eq.1

Flow rate is determined by a change in velocity of the water. The water velocity depends on the pressure that forces the water through pipelines. The cross-sectional area of the pipe is known and remains constant; thus, one can calculate the average velocity that indicates the flow rate. [5]

Let's consider Q is the flow rate/total flow of water through the pipe, V is the average velocity & A is the cross-sectional area of the pipe. In such a case the basic relationship for determining the rate of flow of liquid in such cases is,

$$Q = V \times A \quad \text{.... Eq. 2}$$

Sensor Frequency (Hz) = *7.5 * Q (litres/min)* …. Eq. 3
Litres = *Q * time elapsed (seconds) / 60 (seconds/minute)* …. Eq. 4
Litres = *(Frequency (Pulses/second) / 7.5) * time elapsed (seconds) / 60* …. Eq. 5
Litres = *Pulses / (7.5 * 60)* …. Eq. 6 [5], [6]

B. Water Quality Checker

Quality of water will determine its suitability for utilization. This is where the system will be measuring the pH level, detecting the presence of turbidity and salts, using sensors for the same. The Water Quality Checker is a device that uses multiple sensors to check the purity of water and this set of sensors is controlled by an Esp32 microcontroller as shown in Fig. 4. The sensors used in this system are pH, turbidity and conductivity sensors.

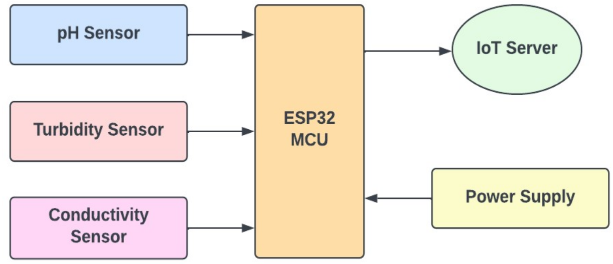

Fig. 4: Water Quality Checker Block Diagram

- *pH Sensor:* The sensor used for this system is a pH probe sensor with advanced sensor module. This sensor will measure the amount of alkalinity and acidity in water and other solutions. Water with a very low or high pH can be a sign of chemical or heavy metal pollution or contamination.

  The pH electrode is first calibrated and then the pH is calculated using the Nernst equation.

  The glass electrode response governed by the Nernst Equation can be given as:

  $$E = E0 - 2.3\,(RT/nF)\,\ln Q \quad \text{.... Eq. 7}$$

  Where,

  Q = Reaction coefficient

  E = mV output from the electrode

  $E0$ = Zero offset for the electrode

  R = Ideal gas constant= 8.314 J/mol-K

  T = Temperature in ºK

  F = Faraday constant = 95,484.56 C/mol

  N = Ionic Charge [7]

  Water with pH ranging from 6.5 to 8.5(may vary up to 9.5 depending on the different sources of supply) is considered safe for drinking [8]. Water with other pH readings indicates that the water is contaminated and thus is unfit for use. Therefore, having pH sensor in the system will help in keeping a check on the pH level of water that is supplied.

- *Turbidity Sensor:* The system consists of a Turbidity sensor module. The water that is received in houses, might contain some minute suspended solid particles. A turbidity sensor is thus provided in the system to detect the turbidity present in water. Fig. 4 shows the working of the turbidity sensor.

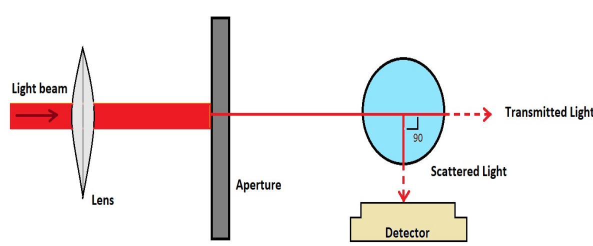

Fig. 5: Working of Turbidity Sensor

- *Conductivity Sensor:* Conductivity sensor is used to detect the presence of dissolved salts and other inorganic material in water. It gives the TDS value which stands for Total Dissolved Solids (TDS). It indicates the water quality. In general high TDS, the value indicates high dissolved solids in water and low quality. So TDS values define the cleanliness of the water. Low TDS values of 0-150 are safe for drinking [9], [10]. High TDS values are not recommended for consumption. The model used in the proposed system is known as TDS Water Conductivity Sensor Module.

C. *Water Level Indicator*

Since overflow is one of the major reasons of water wastage, a Water Level Indicator is included in the proposed system. To detect water level, an Ultrasonic sensor is used (shown in Fig. 6) which provides values in terms of percentage. Since the speed of sound is around 340m/s then the distance can be calculated using;

*Distance = (time/2)*speed of sound* …. Eq. 8

To determine the level of the water in the tank, the total length of the tank must be known. It is this value that will enable one to calibrate the tank. The water level is calculated using the following,

*Max water level = 0.9 * Tank Height (Considering 10% gap between max water level and sonar)* …. Eq. 9

Gap btw Sonar = Tank Height - Max water level …. Eq. 10

Temp = SonarReading – Gap btw Sonar …. Eq. 11

ActualReading = Max water level -Temp …. Eq. 12

*Percentage = (ActualReading / Max water level * 100)* …. Eq. 13

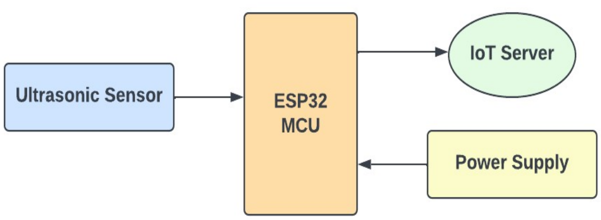

Fig. 6: Water Level Indicator Block Diagram

D. *IoT Server*

All the data from the other three devices will be sent to and displayed on an IoT Server. For the prototype of this system, ThingSpeak App has been used as the IoT Server. This is an analytics platform service and through this any authenticated person can check and analyse the system information easily.

III. Experimental Setup and Results

A prototype of the system was built and tested. In the system prototype, the three esp32s sent their data to one IoT server channel in ThingSpeak after every 15 seconds. All three circuits were connected to represent one water supply system.

A. *Water Meter*

On turning on the water supply, the water passes through the flow sensor which is used for measuring the water quantity. Water flow sensor consists of a plastic valve from which water can pass. A water rotor along with a hall effect sensor is present to measure the water flow.

When water flows through the valve it rotates the rotor. By this, the change can be observed in the speed of the motor. This change is calculated as output as a pulse signal by the hall effect sensor. Thus, the rate of flow of water can be measured. [11]

Shown in Fig. 7, the circuitry for the water meter.

Fig. 7: Circuit for Water Meter

The water flow rate graph and the quantity of water used is displayed on the IoT server created for this system. Fig. 8 shows the server display. Fig. 9 and 10 show the graphical representation of flow rate and water quantity in mL respectively.

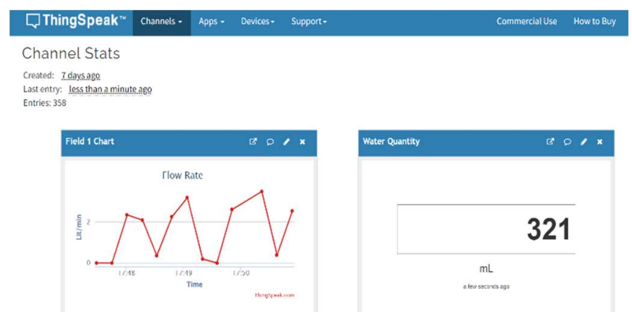

Fig. 8: Server Readings for Water Meter

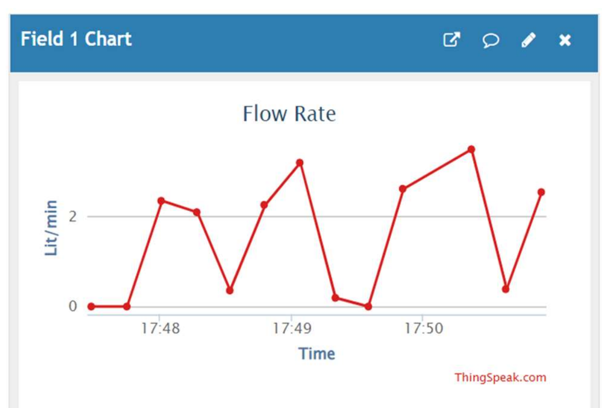

Fig. 9: Flow Rate

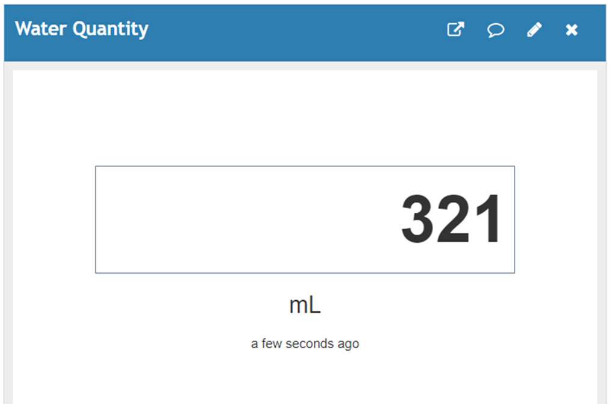

Fig. 10: Water Quantity

B. Water Quality Checker

The Water Quality Checker, consisting of pH, conductivity and turbidity sensors (Fig. 12) was tested with multiple solutions to ensure proper working. In the code, the sensor results are compared with the desired results for drinking water and using conditions, the solution is declared safe or unsafe for drinking. Fig. 11 shows the conditions applied for determining safe for drinking water.

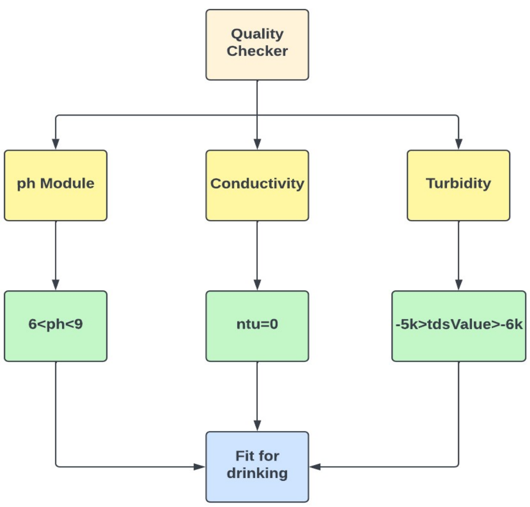

Fig. 11: Conditions for drinking water

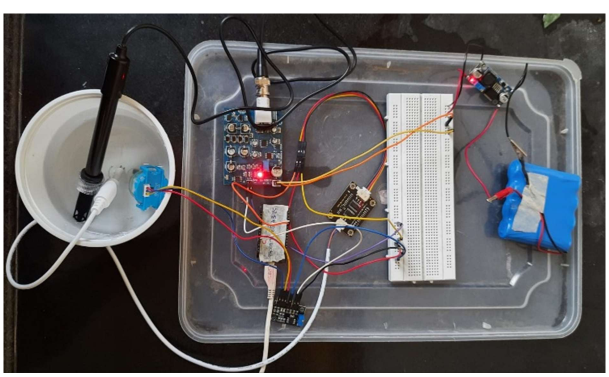

Fig. 12: Circuit for Water Quality Checker

Fig. 13 shows the test results in different types of solutions.

Sr. No.	Solution	pH Sensor Data	Conductivity Sensor Data	Turbidity Sensor Data	Fit for drinking	Not Fit for drinking
1.	Normal Water	6.02	0	-5000 to -6000	✓	
2.	Soap water	10.83	-10754	-6000 to -6500		✓
3.	Mud water	5.56	0.3	-5000 to -7000		✓

Fig. 13: Quality Test Table

The data from water quality checker is displayed on the server in the form of lamp indicators (Fig. 14).

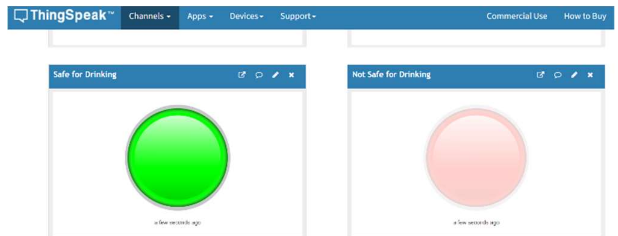

Fig. 14: Server Reading for Water Quality Checker

C. Water Level Indicator

For the prototype, the ultrasonic sensor is attached to the mouth of a jar (as shown in Fig. 15) which resembles a water tank. The sensor measures the distance till the level of water. The distance between the sonar and the maximum water level has been considered as 10% of the water tank. According to this, the water level is calculated in percentage. This percentage value is then displayed on the server (Fig. 16).

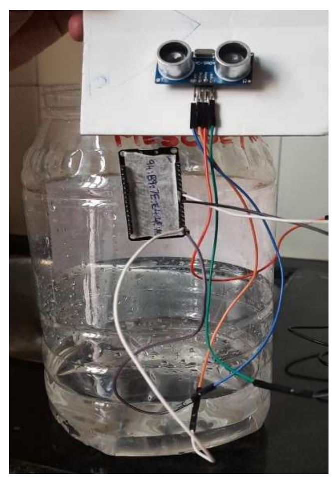

Fig. 15: Circuit for Water Level Indicator

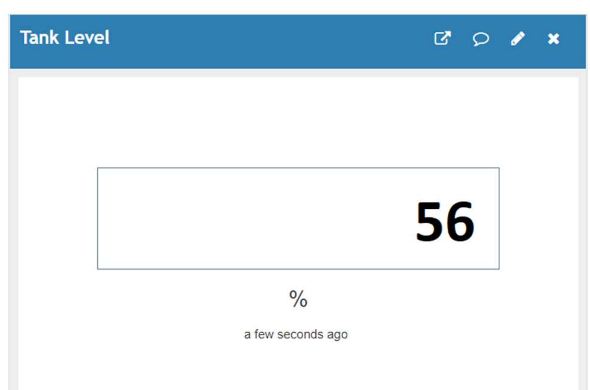

Fig. 16: Server Reading for Water Level Indicator

D. Final System

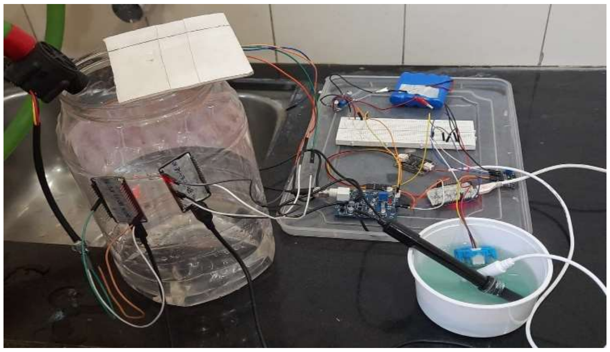

Fig. 17: System Setup

Fig. 17 shows the entire setup of the Smart Water Management System prototype.

ThingSpeak App allows one to download the csv file for the IoT data received by the server (Fig. 18).

	A	B	C	D	E	F
1	created_at	entry_id	field1	field2	field3	field4
2	2022-03-29 11:08:05 UTC	261	0	0	1	0
3	2022-03-29 11:12:25 UTC	262	2.34058	29	1	23
4	2022-03-29 11:12:40 UTC	263	2.08875	57	1	37
5	2022-03-29 11:12:56 UTC	264	0.35553	104	1	42
6	2022-03-29 11:13:12 UTC	265	2.2517	183	1	52
7	2022-03-29 11:13:28 UTC	266	3.18497	215	1	63
8	2022-03-29 11:14:14 UTC	267	0.91258	321	1	68
9	2022-03-29 11:14:33 UTC	268	0	321	1	71

Fig. 18: CSV File generated in ThingSpeak Server

IV. Conclusion and Future Work

The system was successfully implemented and the data from all the devices were transferred wirelessly. Real-time data transfer was achieved and stored. The system in all worked with 98.06% accuracy.

As a major part of the worldwide population receives piped water, it is essential to monitor such a supply system. There are several devices in order to manage and monitor water supply. But it is quite rare to see a system housing the devices that perform multiple functions, being affordable at the same time. Therefore, a system that can provide these facilities and will encourage sustainable use of water is a major step towards building a smart city.

Smart water metering technology offers more advantages to customers and to the service provider who will certainly drive their installations in various places. These meters help in identifying heavy usage along with leak detection techniques, the main aim being reducing water wastage and its sustainable use [12].

This not only expresses the importance of the proposed Smart Water Management System but also addresses a huge market for such a system.

A. Future Work

This is the era of smart technology and IoT. With the growth in technology, automation has made life easier. Under home automation, the proposed Smart Water Management System can be modified further to ensure sustainable use of water.

- All three devices can be connected to a Main Unit instead of communicating directly with the IoT server. This main unit will collect all the data from the three devices and transfer it to a phone application. This will establish a common communication unit between all the devices and the IoT server.
- To avoid unnecessary loss of water knowingly or unknowingly, a solenoid valve and valve control can be installed to control the flow of water. This feature is useful where one wants to limit their water wastage since a lot of water will be wasted during one-time use. Users can set the flow level in the app through their smart devices. Also, this is useful when in some cases the water flow needs to be stopped immediately.
- In cases where there are chances of the tank overflowing, the Water Level Indicator can send this data to the main unit which in turn can either send a signal to the water meter to reduce/stop flow of water or send an alert to the user so the water supply can be stopped.
- Though chances of leakage can be predicted from the total water supply and water usage, it is always advisable to be sure. A pressure sensor can be used to detect leakage in the pipelines.
- Excessive water usage alerts on smartphone.

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