International Journal of Advances in
Soft Computing and Intelligent Systems (IJASCIS)
2022, Vol 01, No 01, 53-64

Original Paper

DESIGN OF SMART WATER METERING, FLOW CONTROL AND QUALITY MEASUREMENT USING IOT COMMUNICATION

Sk Ibrar Ahmed[1], Quazi Mohmmad Alfred[2]

[1,2]-Dept. of Electronics and Communication Engineering, Aliah University

ABSTRACT

India can face a shortage of potable and fresh water in the near future. Coherent, efficient, and low-cost methods to monitor water usage are crucial to prevent this alarming issue. Measurement of water usage accompanied with monitoring the purity of water can result in saving of water. In this paper an IoT based complete water flow monitoring system with some added features (Internet of Things) is proposed here. The entire setup is developed using Wi-Fi enabled microcontroller which consists of various sensors and actuators e.g. hall effect sensor, pH sensor, TDS sensor, solenoid valve, etc. Hall effect sensor is mainly used to measure the water flow whereas pH and the TDS sensors are used to measure the purity of water. The solenoid valve is used to control the water supply. To meet the need for fresh and drinkable water a novel solution is proposed in this paper which is based upon cloud based IoT (Internet of Things) network.

KEYWORDS

Water flow control, IoT, water purity, TDS sensor

1. INTRODUCTION

As per 2011 census report, India is a country of 1.2 billion people with a diverse population pattern. India shares around 16 percent of world population but the country reserves only 4 percent of freshwater resources.

Adding to this, water statistics are very alarming for such a huge and populous country. According to National Sample Survey Office's(NSSO) 76th round, only 21.4 per cent households has piped drinking water connection in India [1]. Still, many people are deprived from drinkable fresh water due to limited resources, unavailability of low cost technology and also due to poverty. Every year in India, many people die due to diseases caused from drinking of unhealthy water.

In global scenario, according to International Water Management Institute, one third of the total population of the entire world, will going to suffer from severe shortage of fresh water by 2025[2]. Hence, providing safe and drinkable water is one of the Sustainable Development Goals(SDGs-6)has been set by United Nations(UN) which includes improvement of water quality and efficient use of water resources.

As per reports , culture of unnecessarily wastage of water is one of the main reason of scarcity in India.

In this line of problem statement, we necessarily need to resort some technology to control and monitor the efficient water usage of each individual households and also limiting the wastage to certain extend.

In this communication, we would like to introduces IoT and cloud based smart water metering system which will measure, control the flow of water supply in the households. It will also effectively reduce the wastage in distribution as well as in the household usage. This system also features online monitoring of water quality e.g. TDS of supplied water. In this paper, with the help of sensors and actuators we can able to monitor the flow of water in the pipeline and calculate the volume of water usage for each residence or block. In addition, we can able to set a limitation to the water usage with the help of actuator. In this way, we can create a consciousness among the people to use the water judiciously. Data can be wirelessly send to the internet-cloud using IoT network for visualization of water usage and hence can be monitored from our smartphone or even from mobile smart phone.

2. HARDWARE REQUIRED

2.1 IoT and ESP8266

IoT or Internet of Things can be referred to millions of devices connected globally to the Internet, all are collecting and sharing data. According to a survey there are approximately 7.4 billion people on the planet, out of which 30 billion – devices connected to the internet. Modern digital networks like IoT makes all possible. The world is quickly being covered with a huge Umbrella made up of networks that allows digital devices to interconnect and transmit. Due to the advent of economic computer chips and the pervasion of wireless networks, now it's possible to connect anything as small as a pill or something like as big as any ship, into a part of the IoT. Due to the advent of modern technology and embracing of these digital devices by the society we can see the digital transformation. As a result of digital transformation we can also notice that economic benefits of digitation continue to grow.

NodeMCU ESP8266 is a development board with Wi-Fi module (ESP-12E) enabled with it containing ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. It operates at 3.3V and its input voltage is 7-12V. It's basic pin structure is shown in the below diagram. It contains Control Pins (EN, RST), Analog Pin (A0), GPIO Pins (GPIO1 to GPIO16), SPI Pins (SD1, CMD, SD0, CLK), UART Pins (TXD0, RXD0, TXD2, RXD2), 12C Pins. ESP8266 has a Flash Memory: 4MB and SRAM: 64KB. It has a Clock speed of 80MHz. It's a plug and play USB-TTL, CP2102 based development board which is a perfect kit for IoT projects. NodeMCU can be powered with Micro USB jack or VIN pin (External Supply Pin). It supports UART, SPI and I2C interface.

NodeMCU board can be easily programmed with Arduino IDE. All we need is the Arduino IDE, a USB cable and the NodeMCU ESP8266 board itself. After writing the code in the Arduino IDE we can compile it and then we can update the code to the board after successful compilation of the program. One thing we must be aware that we need to select the exact Arduino board in the Arduino IDE before updating the program in to the NodeMCU board.

2.2 Sensor

According to Oxford Dictionary: A device, which detects or measures a physical property and records, indicator or otherwise responds to it is termed to be known as Sensor. There are various kinds of sensors available in the market, thus it is a very tough choice to select a sensor for any system design. Sensors play a completely important function in these days' computerized systems. Being a small, low cost and dependable device, sensors are smooth to embed with large electronics. Today we will find numerous styles of sensors inside the marketplace. With the advance in technology, sensors are also advanced of their functioning and size. From the early size of cm devices, size of sensors has shrunk to the size of nm. Sensors have additionally solved many demanding situations of electronic and electrical engineering, which include locating the depth of ambient light, determining the temperature within the furnace, calculating humidity of surrounding, and so forth.

In this paper we generally used two sensors i) Flow sensor, ii) TDS sensor.

2.2.1. Flow Sensor

Flow sensors are generally established on the water source or pipes to measure the rate of flow of water and calculate the amount of water flowed via the pipe. Rate of flow of water is measured as litters per minute or cubic meters.

The water flow sensor actually works on the principal of Hall Effect and it is generally used for volume and water flow rate measurement in compatible with Arduino. [9] The flow sensor contains a pinwheel/propeller-shaped rotor, which is placed in the path of the liquid flowing and it is used to measure how much liquid moved through it. The liquid moving through the sensor against the rotor causing it to rotate and the integrated magnetic Hall Effect sensor measures every revolution and gives an electric pulse as output with every revolution and by counting the pulses; we can easily calculate the water flow. The following formula can be used in order to calculate the flow rate in litter per minute: Pulse Frequency (Hz) /7.5= flow rate (L/min). The sensor contains three wires one is for power (5v -18v DC) maybe red in colour, another is for the ground may be comes with black colour and the last one is data (PWM) output which may come in yellow colour. The Product colour may vary as per shipment.

Following are the features of the flow sensor used in this paper:

Model: YF-S201, Sensor Type: Hall Effect, Max current Draw: 15mA@ 5v, O/P type: 5v TTL, Working Temperature range: -25 to +80^{o}c, working Humidity range: 35%- 80% RH, Working flow Rate: 1 to 30 L/min, Durability: minimum 300,000 cycles.

Figure 1. Flow sensor

2.2.2.TDS Sensor

TDS stands for Total Dissolved Solids, which indicates that what number of milligram of soluble solids dissolved in one litre of solution, usually water. The working of TDS sensor is very interesting. The electric conductivity of the water can be measured using this sensor. Before knowing about the TDS sensor in details it’s important to understand what TDS actually is? Generally, we know that after the rain, the rainwater gets collected underground naturally, due to this phenomenon, the rainwater dissolves minerals present in the rocks and soil and the minerals remains in the water at varying levels of concentration. This natural process result in tasty water, which in turn slightly rises the pH value of the water. Magnesium, Calcium and Sodium are the most common minerals found in the water. If the dissolved minerals are higher in the water, then the water becomes “hard”. Different places have different levels of these dissolved minerals. Thus, if the TDS level goes under 200 mg/L (or ppm) then the water is considered as good water which is drinkable, and 100mg/L is considered as excellent drinking water. Bur, if the TDS level of water is above 400mg/L, then it is considered as non-portable (or not fit for drinking). Thus, TDS sensor is an important sensor for the measurement of water purity, so that we can have a clear data about drinking water and not fit for drinking water.

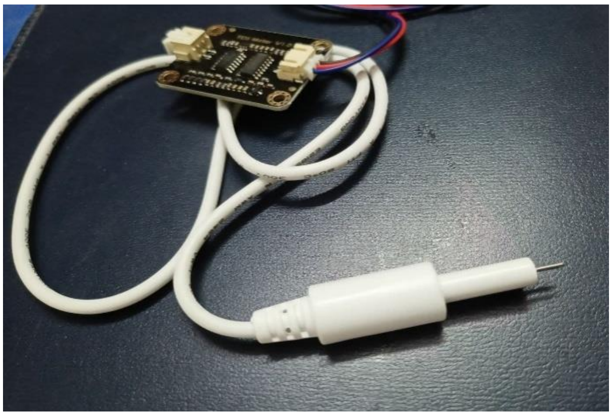

Figure 2. TDS meter

2.3. Actuator

The cause of the movement or control of a system though a component of a machine or a system is termed to be known as actuator. Basically, a source of energy and a control system is required for an actuator.

The Actuator actually responds when a control signal is received and then it converts the energy into mechanical motion. The entire control system of the Actuator can be software based (e.g. - robot control system), a human or any other input.

In this paper, we generally used a Solenoid Valve as an actuator for the water flow control.

2.3.1. Solenoid Valve

It is an electromechanical device, which is used to control the flow of liquid or gas with the help of an electrical device. The solenoid Valve may have two functions: (NO) normally open solenoid valve and (NC) normally closed solenoid valve. The body of the solenoid valve is generally made up of Brass. In this paper DC solenoid is generally used with resistors and RC- network in parallel to avoid voltage surges (inductive peaks). The smooth switching of the DC Solenoid is due to its constant current consumption and this is one of the main advantage of DC Solenoid.

Current is passed through the coil located on the solenoid valve with the help of the electric device. The displacement of the metal actuator takes place as the magnetic field produced due to the current flow. Inside the solenoid valve, the mechanical valve is mechanically linked with the actuator. [14]

Due to the changes in the state of the valve either closing or opening happens which allow a gas or liquid to either flow to either flow through or be blocked by the solenoid valve. When the current flow is removed, the valve comes back to its resting position with the help of a spring. This is how the solenoid valve mainly works.

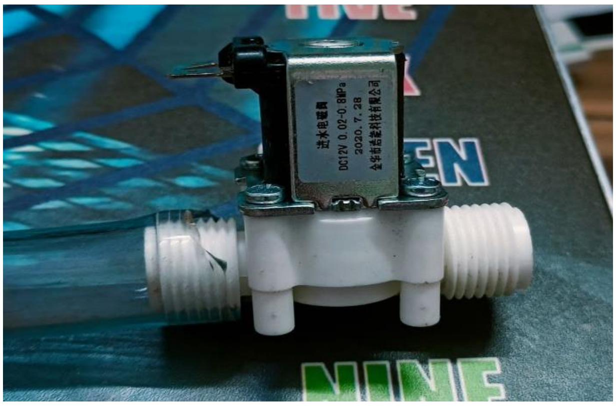

Figure 3 Solenoid Valve

3.METHODOLOGY

The entire system is designed in such a way so that the water flow and quality can be measured and limited water distribution can be established.

Both the sensors and the actuators with relay is connected with NodeMCU and an external 12v power supply required for the interfacing of the solenoid valve with NodeMCU. After all, the data was then processed through the microcontroller. Then the flow rate data collected from the flow sensor was converted into rate of water consumption in Litre. At the same time the TDS sensor calculates the TDS value in PPM (parts per million) and then the task of actuator comes into action. A certain limit was codded in the microcontroller and according to that it resists the flow of water through the solenoid valve. While calculating the flow rate and rate of water consumption we considered the Calibration factor of 4.5 for the flow sensor. For the TDS sensor we considered the room temperature for the calculation of ppm (parts per million).

The entire calculations are made with the help of code in the Arduino IDE and the data received in each and every step was published in the MQTT web server. Instead of using mobile based Application we used the SMS system in compatible with Cloud which is much faster and user-friendly. Various GUI widgets are used in the web server so that user can easily analyse the water usage and flow rate and the water quality. For example, we used both GUI based analogy and digital meter for showing the rate of water flow and we used GUI based Tank to show the water usage etc. After a certain usage of water, the user will receive a SMS in his/her smartphone where he/she can track the quality of water and water usage. The user will also receive couple of warning SMS before the water flow was ceased. In this way the entire system works automatically using IoT and the user receives SMS time to time regarding water quality and water consumption.

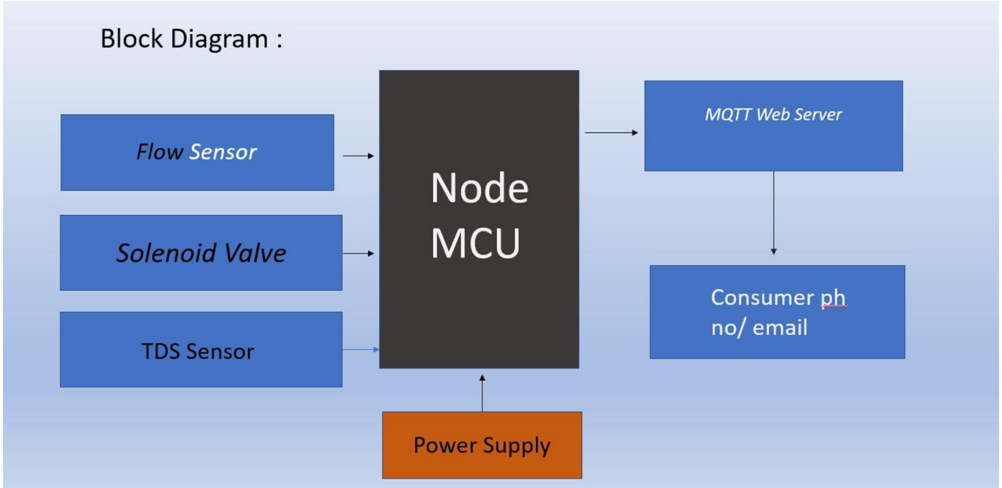

Figure 4. Block Diagram

3.1. System architecture

Figure-1 depicts the system architecture for the proposed solution. It comprised of Embedded microcontroller as processing unit, sensors and actuators at the pipelines for data acquisition of water flow and quality measurement. In real time, data is acquired from the sensors and sent to the My Devices Cayenne cloud through Internet of Things(IoT) network. Internet of Things (IoT) can be referred to millions of such heterogeneous devices connected globally to the Internet, all are collecting and sharing data. Modern digital networks like IoT and cloud services makes it all possible [3]. Due to the advent of modern 5G technology and embracing of such kind of digital service s by the society can be seen as digital transformation. [4]. Water usage data will be continuously updated in the cloud server which is available in mobile smartphone. Data stored in the cloud can also be shared to analytics for machine learning. The predictive results will be shared to user as well as government for decision and policy implementation.

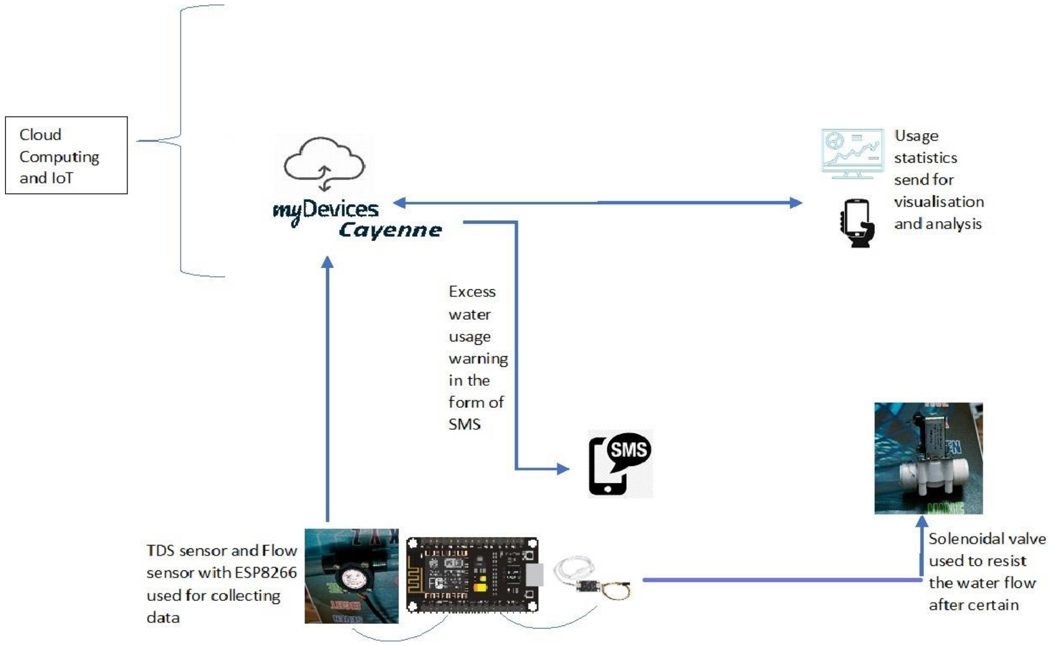

Figure5. System architecture of the solution

3.2. Design Components:

The entire design is subdivided into three main modules: Sensors data acquisition, Networking& Cloud Computing, Actuators. The sensing part senses the required parameters and sends it to the microcontroller while the network part carry the information/instruction/ command data obtained from the sensors. These data will be stored in the cloud and also be visualized through mobile network, Further, analysing the collected data, command to the actuator can be sent as per requirement in the system as depicted in flow diagram of Figure-2.

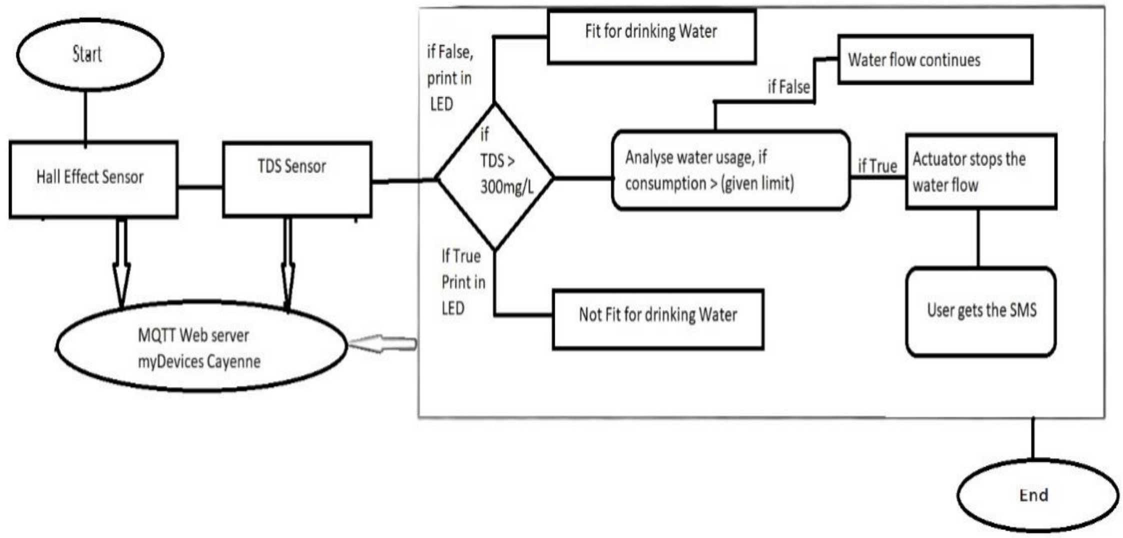

Figure 6. Flow diagram of the solution

The microcontroller used here is NodeMCU development board with Wi-Fi module (ESP-12E) enabled with it containing ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. It operates at 3.3V and its input voltage is 7-12V.It acquires both analog and digital data. NodeMCU can be powered with Micro USB jack or VIN pin (External Supply Pin). It supports UART, SPI and I2C interface. [5] NodeMCU board can programmed with Arduino IDE. [6]

With the advancement of sensor technology, various kind of sensors are available which have been. able to cater many demanding situations of electronic and electrical engineering, for example, l determining the temperature within the furnace, measuring humidity of surrounding, and so forth [7].

In this work we have primarily used two sensors i) Flow sensor, ii) TDS sensor.

Flow sensors are generally established on the water source or pipes to measure the rate of flow of water and calculate the amount of water flowed via the pipe. Rate of flow of water is measured as litters per minute or cubic meters [8]. The water flow sensor actually works on the principal of Hall Effect and it is generally used for volume and water flow rate measurement in compatible with NodeMCU. [9] The flow sensor contains a pinwheel/propeller-shaped rotor, which is placed in the path of the liquid flowing and it is used to measure how much liquid moved through it. The liquid moving through the sensor against the rotor causing it to rotate and the integrated magnetic Hall Effect sensor measures every revolution and gives an electric pulse as output with every revolution and by counting the pulses; we can easily calculate the water flow. The following formula can be used in order to calculate the flow rate in litter per minute: Pulse Frequency (Hz) /7.5= flow rate (L/min). The sensor contains three wires one is for power (5v -18v DC) maybe red in colour, another is for the ground may be comes with black colour and the last one is data (PWM) output which may come in yellow colour. The Product colour may vary as per shipment. [10] [11]

Following flow sensor used in this work:

Model: YF-S201, Sensor Type: Hall Effect, Max current Draw: 15mA@ 5v, O/P type: 5v TTL, Working Temperature range: -25 to +80^{o}c, working Humidity range: 35%- 80% RH, working flow Rate: 1 to 30 L/min, Durability: minimum 300,000 cyclists stands for Total Dissolved Solids, which indicates that what number of milligram of soluble solids dissolved in one litre of solution, usually water. The working of TDS sensor depends on electrical conductivity of the water can be measured using this sensor. Normally, magnesium, calcium and sodium are the most common minerals found in the water. If the dissolved minerals are higher in the water, then the water becomes “hard”. Different places have different levels of these dissolved minerals. Thus, if the TDS level goes under 200 mg/L (or ppm) then the water is considered as good water which is drinkable, and 100mg/L is considered as excellent drinking water. But, if the TDS level of water is above 400mg/L, then it is considered as non-portable (or not fit for drinking). Thus, TDS sensor plays an important role for the measurement of water quality, so that we can have a clear data whether the supplied water is fit for drinking. [12] [13]

Actuator: actuators actually respond when a control signal is received and then it converts the energy into mechanical motion. Here, control signals are digitally generated and through the IoT network in this paper, a solenoid valve is used as an actuator for the water flow control.

Solenoid Valve is an electromechanical device, which is used to control the flow of liquid or gas The Solenoid Valve may have two functions: (NO) normally open solenoid valve and (NC) normally closed solenoid valve. Current is passed through the coil located on the solenoid valve with the help of the electric device. The displacement of the metal actuator takes place as the magnetic field produced due to the current flow. Inside the solenoid valve, a mechanical valve is connected with the actuator. [14]

Due to the changes in the state of the valve either closing or opening happens which allow a gas or liquid to either flow to either flow through or be blocked by the solenoid valve. When the current flow is removed, the valve comes back to its resting position with the help of a spring. This is how the solenoid valve mainly works.

3.2.1. Networking (IoT)Protocol

In IoT, there are many M2M data communication protocols available but in this paper, we mainly used MQTT protocol. MQTT stands for Message Queue Telemetry Transport. Its basic structure is based on publish-subscribe model. It's a lightweight-based messaging protocol used in conjunction with the TCP/IP protocol. Actually, MQTT was introduced by IBM in 1999 and standardised by OASIS in 2014.

MQTT components include:

Publishers: Lightweight Sensors, Subscribers: Applications involved inn sensor data, Brokers: It connects Publishers and Subscribers and classify Sensor data into topics.

Moreover, the publish-subscribe messaging pattern was controlled or hosted by a message broker. The message published by any individual client to the broker, includes a topic into the message. The routing information for the broker is the topic. If the client wants to receive any message, then it subscribes to certain topic and the broker delivers the entire message with the matching topic to the client. MQTT works within the following methods: Connect Disconnect, Subscribe, Unsubscribe and Publish.

4. RESULTS

4.1. Data acquisition

We used the flow-sensor to collect the flow rate of supplied water through pipes. Then the water consumption can be obtained from the received flow-sensor data using the following formula.

$$FlowRate = ((1000.0/(millis-previousMillis))*pulse1Sec)/calibrationFactor$$

Here 'Millis' is a function that was used in the code for which returns the no of millisecond that has passed since the code was uploaded in the microcontroller. This function is mainly used for calculating the water flow rate with the help of flow sensor.

To determine how many litres we have, we need to divide the flowrate (litres/minute) by 60

In order to convert to millilitres we need to multiply by 1000.

$$FlowMilliLitres = (flowRate/60) * 1000$$

$$FlowLitres = (flowRate/60)$$

The principle reason of calibration factor is to calculate the amount of water and flow rate. We set the standard value of 4.5 as the Calibration factoring the code section. Actually, the meaning of calibration factor-4.5 means for each litre of water passed through the sensor per minute, 4.5-pulses are generated every second.

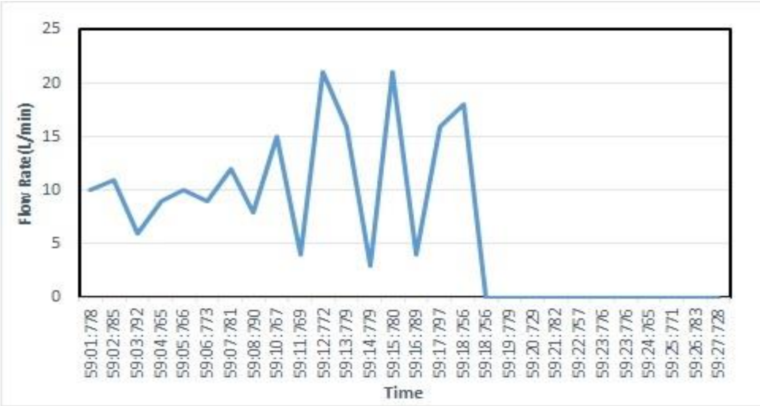

Figure 7. Flow Rate sample

4.2. Display

When the user wants to access the real-time data of the water usage or water quality on the smartphone or PC then the following internal process takes place:

According to MQTT protocol when the client (here smartphone/ PC) is trying to access any data for visualization, then the client tries to subscribe to the exact topic to the MQTT broker then, the broker delivers the information with the matching topic and publish the data to the client. In this way, we can able to visualize the real time data on the screen of any smartphone or PC as shown in Figure-4.

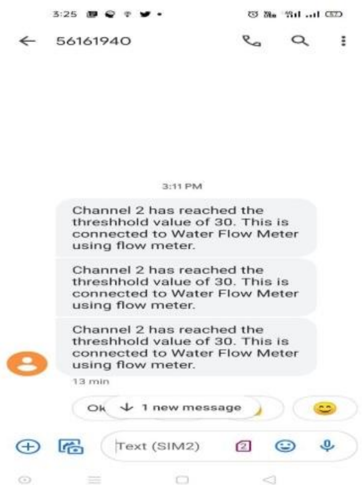

Figure8.SMS received from my Devices Cayenne Web Server

Also, the quality of supplied water from the TDS sensor as shown in Table-1 and Table-2.

Sample No	TDS sensor value(PPM)	Remarks
i	270	Fit for Drinking
ii	255	Fit for Drinking
iii	286	Fit for Drinking
iv	365	Not Acceptable
v	472	Not Acceptable

TDS value measured

Table 1.

Sample no.	Source	TDS Value	Remarks
1	Village tap water	798-826(ppm)	Not Drinkable water
2	Treated water after RO(Reverse Osmosis)	21-16(ppm)	Demineralised water
3	Packed drinking water	260-280(ppm)	Fit for Drinking water
4	Water from Gov. Treatment plant	211- 232(ppm)	Fit for Drinking water

Table 2.

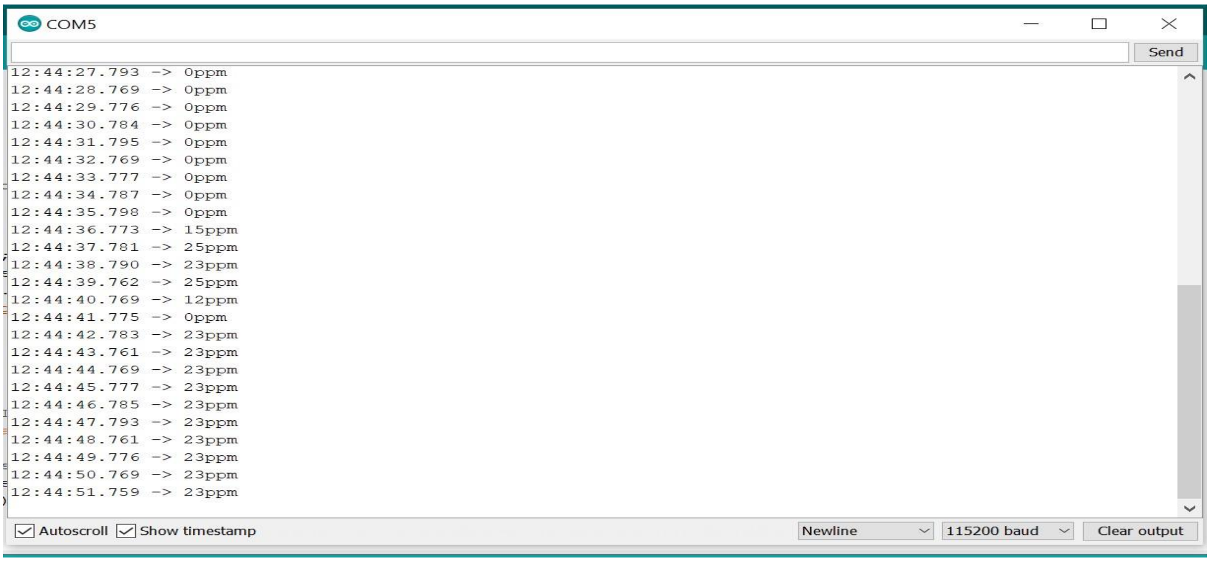

Figure 9. Recorded data of TDS value

Analysing the sensed data, a limit can be set to the water usage.by the action of an actuator, i.e. mechanical water valve. When the data from the sensors are received, then immediately it was published to the LCD as well as to the MQTT server. So that whenever the client tries to subscribe the data then the broker can able to publish it. Additionally, from the received data with the help of IoT -cloud tools, can able to create an event so, that after certain water usage the water flow will be stopped and then a short message will be send to the user's phone with the help of my Devices Cayenne cloud services.

4.2.1. The entire system

In this IoT system, we have used Arduino IDE as a developing tool where we can write the code for the ESP8266 microcontroller. Using that code only we can able to connect to the IoT web server my Devices Cayenne. As a result, we can able to visualize the real time data and can create events conditions, like sending SMS to user's phone for certain data/information transfer.

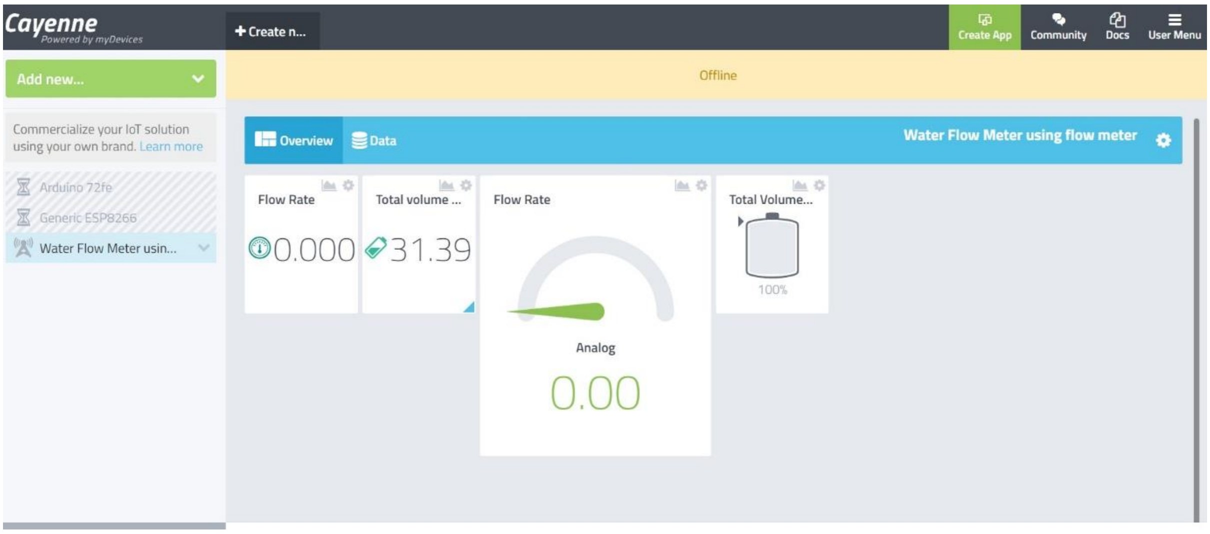

Figure 10. Dashboard of web server with GUI widgets

5. Conclusion

This paper is all about the design and implementation of intelligent water meter, flow control and purity check using IoT. The flow sensor or Hall Effect sensor was used to get the flow rate and water usage as well then according to the code written in the Arduino IDE the ESP8266 Microcontroller sends the data to MQTT web server and displays it to the LCD attached in the circuit designed. Then, according to the given criteria by the user, the microcontroller sends a signal to the actuator so that the solenoid valve cease the water flow. After that MQTT web server sends a final message to the user that "the daily water limit has been exhausted". For the water, Purity check TDS sensor was used in the design so that the user can aware of the quality of water provided. We used My Devices Cayenne as IoT cloud platform instead of Thing Speak as My Devices Cayenne provides more flexible Widgets and faster data transfer rate. In future work, the design can be modified with more sensors and actuators attached to the design so that we can measure and analyse more parameters like turbidity, temperature etc. We can also design and attach a low form factor Temperature control device in this system in future work. This system can be implemented in water distribution system, smart farming techniques and for domestic use as well.

Acknowledgements

Authors would like to convey acknowledgement towards the Department of Electronics and Communication Engineering, Aliah University, Kolkata.

6. REFERENCES

[1] Article, DownToEarth, India's water crisis: The seen and unseen. [Online].Available: https://www.downtoearth.org.in/blog/water/india-s-water-crisis-the-seen-and-unseen-76049, March, Friday 19, 2021.

[2] Andrew Keller, R. Sakthivadivel, David Seckler, "Water Scarcity and the Role of Storage in Development", International Water Management Institute, Colombo, Sri Lanka, 2000.

[3] E. Fleisch, What is the Internet of Things: An Economics Perspective, Auto ID Labs White Paper,WP-BIZAPP-053, Jan. 2010.

[4] Pushkar Singh, SanghamitraSaikia, "Arduino-Based Smart Irrigation Using Water Flow Sensor, Soil Moisture Sensor, Temperature Sensor and ESP8266 WiFi Module", IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Agra, India, 2016.

[5] Darshana Thomas, et al., “Optimizing power consumption of Wi-Fi for IoT devices: An MSP430 processor and an ESP-03 chip provide a power-efficient solution”, IEEE Consumer Electronics Magazine, pp. 97-100, 22 September 2016.

[6] Rosley, Samad. Z, Shaari M.F., Rosley, M.A., “Feasibility studies of Arduino microcontroller usage for IPMC actuator control,” in IEEE International Conference on Control System, Computing and Engineering (ICCSCE), 2014, pp.101-106,28-30 Nov. 2014.

[7] R. Ramlee, M. Othman, M. Leong, M. Ismail and S. Ranjit, “Smart home system using android application,” in International Conference of Information andCommunication Technology (ICoICT) 2013, March 2013, pp. 277-280.

[8] Miller and Richard W., "Flow measurement engineering handbook", 3rd ed., New York : McGraw-Hill, 1996, pp. 6.16–6.18.

[9] Islam, M.A.; Islam T.; Syrus, M.A.; Ahmed, N.,“Implementation of flash flood monitoring system based on wireless sensor network in Bngladesh,” in International Conference on Informatics, Electronics & Vision(ICIEV), 2014, pp.1-16, 23-24 May 2014.

[10] Deepak Awasthi, Syed Azeemuddin, Suresh Purini, Annesha.M, "Flow Sensor Iot Node for Wi-Fi equipped Apartments and gated Communities", IEEE Sensors, New Delhi, India, 2018.

[11]Li gang, Li qiao-zhen and Zhang hai-peng, “Study of the application of the Turbine flow meter", International Conference on Electronics and Optoelectronics, 2011, pp. 445-447.

[12] Brinda Das, P.C. Jain, "Real-Time Water Quality Monitoring System using",International Conference on Computer, Communications and Electronics (Comptelix),Jaipur, 2017.

[13] Steven Silva, Hoang N Ghia Nguyen, Valentina, Tiporlini, Kamal, "Web based Water Quality Monitoring with Sensor Network", 36th IEEE Conf. on Local Computer Networks, 2011.
[14] R.I.Rashid, S.M.Rafid, and A.Azad, "An Automated Fire Suppression Mechanism Controlled using an Arduino", IEEE Distributed Computing, VLSI, Electrical Circuits and Robotics (DISCOVER), Mangalore, India,2018.

AUTHORSHIP

SK IBRAR AHMED received his B.Tech degree in Electronics and communication Engineering of rom Aliah University, Govt. of West Bengal, India. His areas of interest include IoT, ML, Cloud and Embedded systems.	
QUAZI MOHMMAD ALFRED Associate Professor in the Department of Electronics and Communication Engineering, Aliah University, Kolkata, India. Received PhD degree in 2014 from Jadavpur University. Kolkata He has authored good number of research articles in national and international journals and conferences. His research interest includes array antennas, communication, signal and image processing, Internet of Things, Bioinformatics and computational Biology etc. Listed in *Marquis Who’s Who in the World* Member of academic societies like IEEE, IAENG, IRED etc.