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Online measurement of water quality and reporting system using prominent rule controller based on aqua care-IOT

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Abstract Nowadays, internet of things (IoT) became a leading beginning process of technology in advances of information and communication. The technology of it provides the system welfare and convenes in the water quality of the present monitoring. In order to watch the level of water quality various techniques were implemented in the areas of water in various localities like monitoring of drinking water quality, management of water quality and irrigation water, lakes, treatment, and ponds. In this technology, the development of it for system monitoring of water quality processes as a core technology by the wireless sensor network (WSN). However, the networking process is to monitor the water quality using a sensor nodes lightweight and tiny-powered gathering. Nevertheless, in the application environment the development process of technology is proceeding without security consideration, which creates a confidentiality susceptibility of the system. In this research process, the major contribution is to develop a secure process of a modern monitoring system of water quality based on wireless sensor network. Successively, the embedded system depends on secure IoT is planned using WSN, which can resource fully realize those necessities.

Keywords IoT · Aqua · Rectifier · Sensor · Water quality · Real-time application

1 Introduction

The quality evaluation of water is the substantial influence of several application environments like surveillance, human health, monitoring of ocean and habitat. Urban water quality is usually monitored by highly reliable networks of fixed locations as nodes. A fixed monitoring station can accurately measure a broad range of pollutants.However, permanent monitoring

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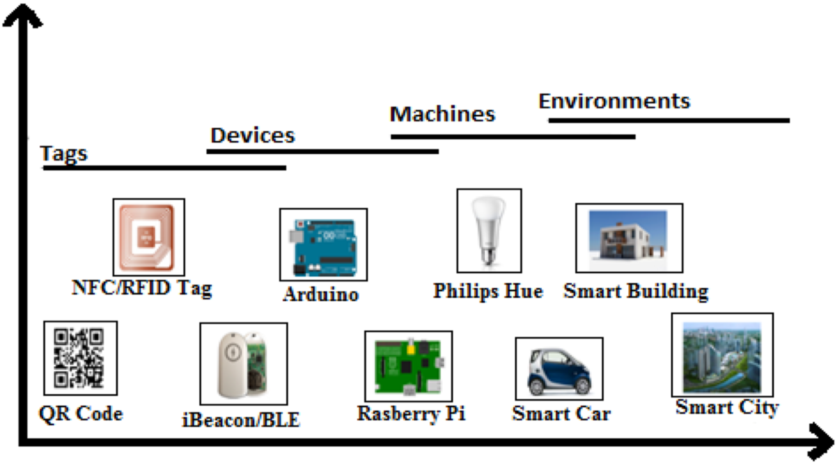

Fig. 1 Landscape of IoT (internet of things)

stations are frequently placed so as to measure ambient background concentrations or at potential hotspot locations and they are usually several kilometers apart. The importance of maintaining good water quality highlights the increasing need for advanced technologies to help monitor water and manage water quality. In particular, the IoT based implementation poses new challenges for supervisors who have traditionally observed water quality by taking samples and examining them in the test center. Figure 1 shows the landscape of internet of things.

The thing of network is IoT, which are associated in approximate form of network. As per the RFID tag in the box is concerning to the whole thing, to a clever city and in numerical form of objects enlarged of things. In the 21th century, the maximum communication and powerful standards is the Internet of Things (IoT).

In this environment, the daily process of objects becomes a network part because of the capabilities of communication and computing, which containing the digital process of transceivers communication and microcontrollers. It covers the network model with high persistent and it permits the unified collaborations between various device types like cameras monitoring, sensor environmental sensor and applications in medical and various fields.

Due to this intention, the IoT has developed additional creative in different locations such as environmental pollution monitoring systems and aqua quality of system management. It includes several inexpensive sensor categories in the environment and embedded, which will support the public by the services of modern quality monitoring and for the report without burden at anytime and wherever. Moreover, it is besides the progresses expressively as life quality of human's.

The primary objective of this work is to implement a low-cost IoT for monitoring several water pollutants namely Temperature, Conductivity, PH and Turbidity use integrated sensors. The specific objectives include:

1. Hardware implementation is by using WSN module and sensors.
2. Use of Arduino Uno software is to analyze, collect and filter raw data of water quality parameters readings using sensors.

The IoT based water quality monitoring and reporting system will provide information to the community about the risks of the continuous degradation of water quality in different areas such as nodes. Accessibility to such information is critical. A community without access to information compared to a well-informed community will not act in their personal way to help in environmental protection.

2 Literature survey

The advancement of IOT in water quality measurement applications has made reporting more feasible. Recently, several WSN environmental pollution kinds of research and procedures have been suggested, which determine the endless watching of water quality in different areas, Health care systems, and open management of the atmosphere (e.g. monitoring of athlete condition). This segment refers to insufficient projects of outmoded investigation about the systematic evaluation of a water feature by using it based sensor networks.

Wang et al. [1] connected pack detecting hypothesis to keep away from excess information in WSN's and IoT. Communication structure serves to information compacted testing [2], dynamic the transmission [3], precisely restoring information to lessen energy necessity [4], expanding system lifetime, and information repetition.

Pai et al. [5] discussed an Alarm-network is describing the various abuse state of privacy like the vulnerable detail is in confrontational secrecy occurrences that are specially developed for monitoring the health of the patient in the atmosphere of the house and help out corporeal. The networks of sensor have the Alarm-net [6] and environmentally friendly networks of sensor help network and data security for physiological, environmental, behavioral parameters.

Ying et al. [7] have predictable a style of watching groundwater. This will determine the gathered information to take-off and the feedback design of the system is landing negative by a monitor of water level. Here, the single-chip of 89C51 and a comparator IC are considered. The devices recording randomly and associate with the combined code of dynamic have realizedactual and interrupted groundwater with suitable observation [8].

Mo et al. [9] deliberate programmed menstruation and coverage of quality level of water in the system has been implemented. After that, the data square measurement of loud refers to the midpoint fulfillment within the SMS smartness by using the network of GSM. If there is excellent quality of the water, then the details is transferred to the center observance and mobile controlling's at a parallel time within the similar scheme. It's suitable for corresponding essential measures managing process of time period and determines the remote control process of water quality.

Odey et al. [10] planned is constantly monitoring of parameters process in aqua-environmental and provide an early alert or warning to the end user of the system. It exceeds the evaluation of thresholds bound of the square. The details made through the scheme to have provincially on the entry or transfer to the target of server on distant net. The data are associated with the server of remote net or info is retrieved with sufficient personal desktop or mobile phones.

Web-based frameworks on a cloud stage are presented by Nikolopoulos et al. [11] for the examination of vitality utilization and conduct designs, with the end goal of controlling the request reaction, and for anticipating of future application utilizing machine learning (ML) models which has been prepared with a massive dataset. Furthermore, this work proposes an electronic system operates on a cloud stage for the investigation and comprehension of vitality utilization, future request prediction, and remote control of machines in a college grounds. In any case, it is at the advancement stage.

Feng et al. [12] have a feasible process of network preparation in the wireless device and irrigation of technology with the scheme of the random control process. The crucial network examination of web reinforced of farmland in the application of agricultural plants with the system irrigation of water-saving integrated scheme. The customer uses the technology of daily use of mobile phone or controllers of wireless will be humbly observe the content of soil wetness through on-line and appreciate the computerization development of management.

The reconfigurable keen interface gadget to peruse information parallel progressively with fast on various detecting components. It diminishes perfect issues for any recently added detecting component to interface device by embracing standard convention shrewd transducer interface (STIM). STIM interface standard IEEE1451 empowers sensors to find and organize Consequently given arrangement of particular provided by interface gadget and perform attachment and play operation on every sensor [13].

IoT has been ended up being useful for water administration by expanding proficiency and profitability, mechanizing the data accumulation, and overseeing and organizing various subsystems. Verma et al. [14] exhibit a client driven keen water management framework that screen the utilization as entire, and break down gathered information to speak to data in visual charts to improve the lucidness. Such framework can be actualized in keen grounds to give clients data about water utilization.

Zhuet et al. [15] planned the evaluation of quality of water is frequently unlisted within the controlling of lake or pool. The poor quality will reported as issues such as unnecessary blooms of protoctist, vesicant smells or lifeless, plants advance development and fish dying. So, to overcome the issues, a simple water chemistry understanding and substitute constraints of physical is life-threatening.

Matos et al. [16] gave dynamic power administration IOT changing mode Convention to increase the lifetime in current observing structures. It expands a system life time viably by changing the hub to a rest mode (only 1 ms) when it transmits the information parcel. The framework with IOT convention takes full points of interest by transferring 33% of a larger number of bundles that the context without losses.

The assessment of nature of water is every now and again unlisted inside the controlling of lake or pool. The low quality will reveal as issues, for example, superfluous blossoms of protoctist, vesicant scents or dead, plants propel improvement and fish biting the dust. In this way, to beat the issues, a straightforward water science understanding and substitute imperatives of physical is life-debilitating [17].

The above research papers studied so far, demonstrate the practical use of sensor networks for water monitoring and contamination detection [18].

In [19], authors investigated 21 water-quality parameters of 18 selected African countries, to assess if they are significantly different across countries and compare them to those of WHO, EU, US and China. There were significant statistical differences among twenty of the twenty-one studied parameters. The mean quality standards of Africa were generally higher (weaker) than those of WHO, EU and China but compared well with those of US.

In [20], authors conducted cross-sectional study in 24 randomly selected upazilas, arsenic was measured in drinking water in the field using an arsenic testing kit and a sub-sample was validated in the laboratory. Water samples were collected to test water pH in the laboratory as well as a sub-sample of collected drinking water was tested for water pH using a portable pH meter. For laboratory testing of other chemical parameters, iron, manganese, and salinity, drinking water samples were collected from 12 out of 24 upazilas.

However, most of the papers have proposed various schemes to make this system effective and efficient, but some of these schemes are costly due to the high cost of sensors and some of the sensors used have the short lifetime. Papers where field deployment is done that is not

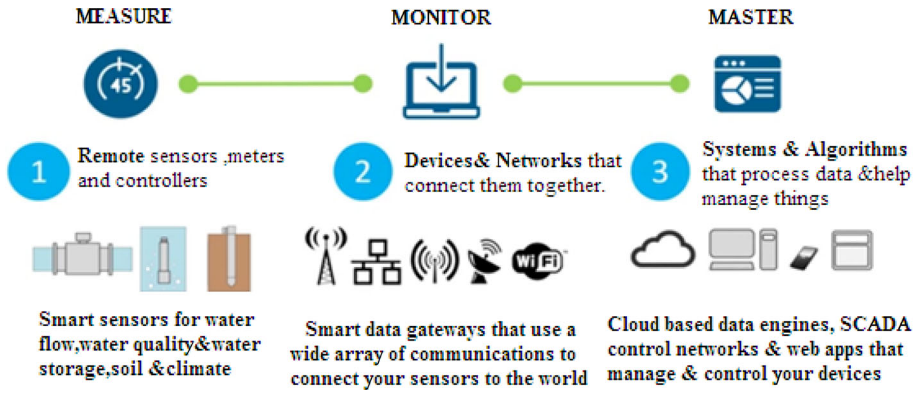

Fig. 2 Basic system service (cited from http://aquamonix.com.au/)

suitable for some of the important parameters of water quality. So it is necessary to design and implement a system by taking the requirement of multiple parameters of water quality using small cost sensor and system design.

3 Proposed work

This section provides the IoT system architecture, system requirements and its detailed description of hardware-software implementation with the basic structure and flow diagrams. Figure 2 shows the basic service of the proposed system and Fig. 3 shows the aqua care-IoT service design, which calm the nodes of sensors capable of being implanted. Every node is combined with the corresponding parameters of sensors like Temperature, PH, Turbidity and conductivity sensor, etc. These sensors collect the water quality parameters and forward them to a coordinator called data Processing Server Unit.

The proposed work reduces human intervention by using the aqua care-IoT, and it is consists Arduino Uno controller, temperature, PH, Turbidity and conductivity sensor arrangement and Wi-Fi transceiver module. The Arduino microcontroller is connected to the data concentrator using USB cable. The Arduino microcontroller sends the water quality parameter's data which is read from the sensors to the cloud node server through Wi-Fi transceiver module.

The data server mechanism is as a router among the nodes and the essential server is proceeding by using the medium transformation of wireless process like the networks of mobile mode 3G/CDMA/GPRS. Also, at what time of detecting the server of any irregularities is processed and offers an immediate alert to the Tamilnadu Water Supply And Drainage Board (TWAD) team in the particular area. The architecture of IoT consists of data acquisition sensor nodes with Different nodes (N1, N2, and N3), Data server and cloud sensor network with smart city environment. The aqua care-IoT data acquisition interface composed of sensors and various data collection terminals.

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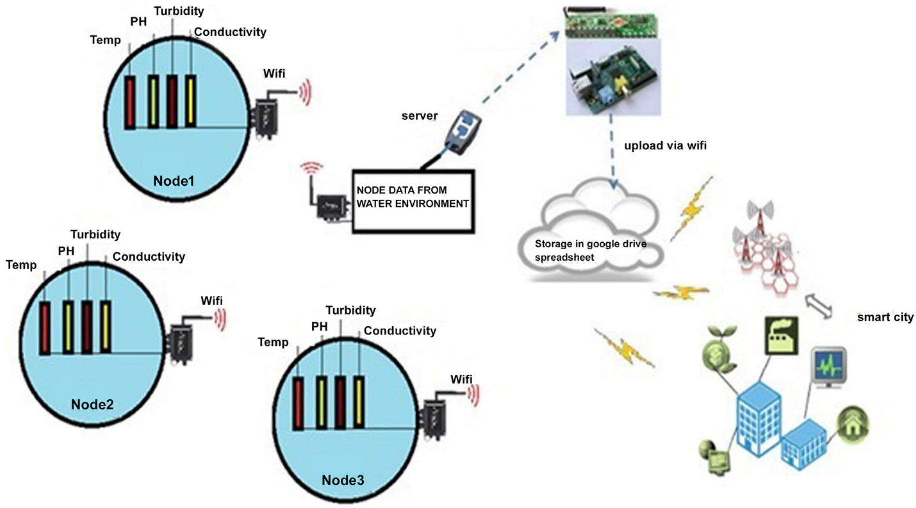

Fig. 3 Water quality environment with aqua care-IoT service architecture

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Also, describe the requirements of aqua-care IoT based water quality monitoring sensor network. The proposed system of aqua care-IoT needs of sensor (Calibration/Resolution/ Sample rate) are Temperature, PH, Turbidity and conductivity sensors at each location. Temperature Sensor cares temperature level of the water at different nodes produces the proportional output voltage in Celsius (Centigrade) temperature. Figure 4 shows the monitoring area and connection with a network.

Turbidity Sensor based optical techniques are used to measure the dirt, food or other particles floating in the water solution. The level of water turbidity is denoted as WTL.

$$WTL = \frac{Scattered\ light\ signal}{Total\ transmitted\ light\ signal} \tag{1}$$

A pH measurement consists of sense the- hydrogen ion employed in the water environment, which produces the corresponding potential voltage difference between the electrodes. The ph communicate the values to the absorption of hydrogen ion, which ordinarily ranges are between 0 and 14. A pure water solution has a pH of approximately 7. On the high concentration of hydrogen ions shows a very acidic solution has a low pH value such as 0, 1, or 2 then the High ph values like 12, 13, 14 described as a less acidic solution.

4 Hardware and software implementation

In the Hardware implementation, the sensor LM35 minds the sample water tank temperature and transfer the value to the microcontroller of the present temperature. Likewise, the sensors conductivity, Turbidity and pH performances are obtained and communicated with

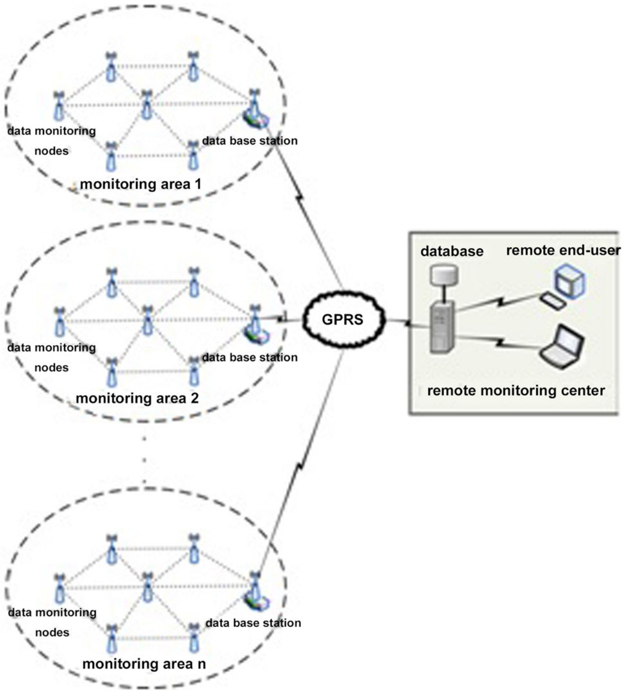

Fig. 4 Sample-area monitoring in cloud environment

Table 1 Various conductivity set points

0.042 µS/cm	Ultrapure water (20 °C)
0.5–5 µS/cm	Deionized water
100–300 µS/cm	Soft ground water
45,000–55,000 µS/cm	Sea water

the controller of the Arduino Uno controller through the transceiver of Wi-Fi. The hardware implementation of aqua care-IoT module controller was shown in Fig. 5 and the sensor circuit of the LM35 temperature is shown in Fig. 6.

As a Sample, the sensitivity of the sensor in tank observes the present temperature and transfer to the microcontroller.It operates the process in the range of temperature between −55 and +150 °C and process between the volts of 4–30. It pullsthe supply of 60 µA and has less self-heating of below 0.1 °C in the motionless air. As a result, the IC provides 10 mv/degree centigrade.

In Electrical Conductivity, the key facilities are for passing the electric current and have common electrical resistance (ohms). Hence, it evaluates water conductivity or entire ion absorption and considered entire strategy of dissolved in aqueous clarification. Siemens is the conductivity unit and the probe is shown in Fig. 7. Also, its various value of set point is illustrated in Table 1.

Similarly, Turbidity is the liquid fuzziness produced by various particles individually, which are physically not viewable to the naked eye and smoke in the air. Its unit is Formaz in Turbidity Unit (FTU) and it is suggested by ISO. Its voltage is rated to 5V DC, maximum

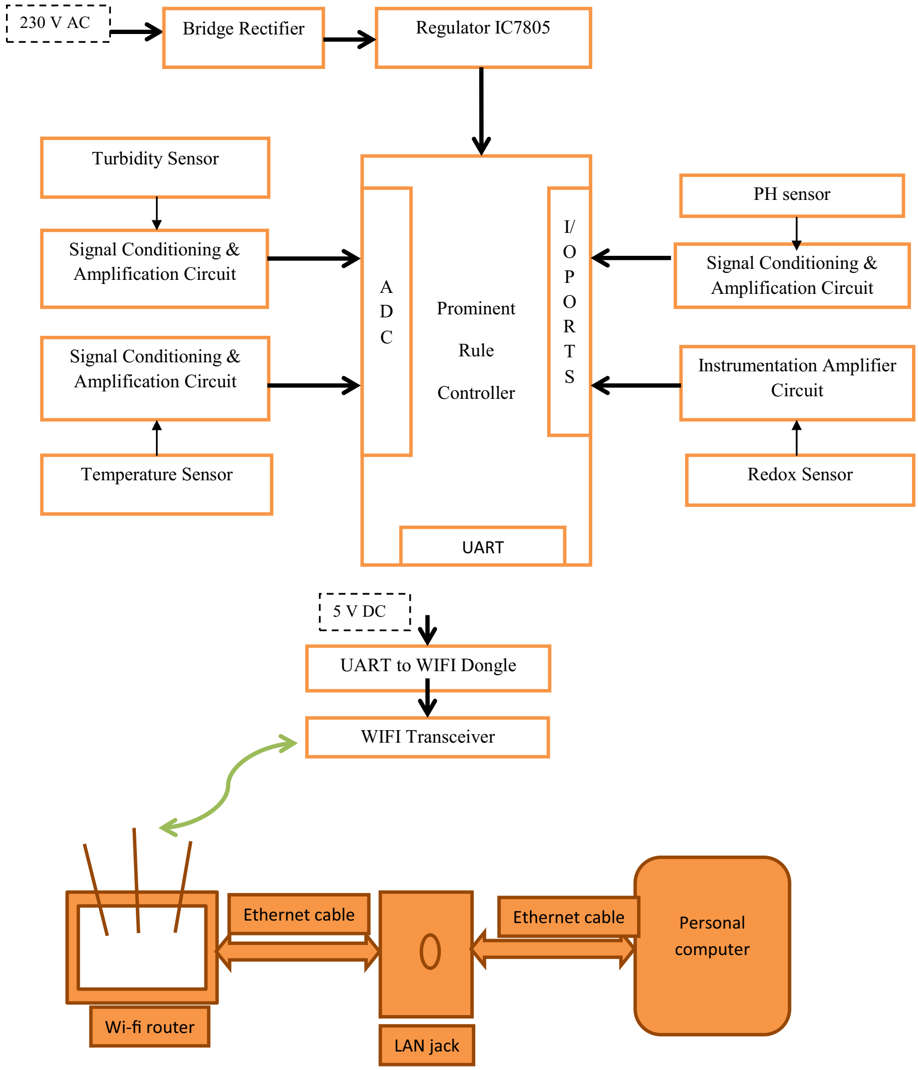

Fig. 5 Block diagram of the transceiver module

current 30 mA and the range of temperature to operate is between −10 deg Centigrade and 90 deg Centigrade. Figure 8 shows the sensor circuit of PH and Fig. 9 shows the turbidity sensor.

Every detail of the sensor is observed in the local system and reported to the cloud server. The information of the sensor can be uninterruptedly examined via network with an isolated address of IP by using the service of cloud computing. Figure 10 shows the system flow based on IoT.

For access of all sensor terminals the embedded c program was written to observe the value of sensors threshold randomly at specific intervals of the period. The Arduino Uno originates prepared for interfacing with a drivers range. Then the controller sends the data to the aqua care-IoT module sends the data to the google drive using cloud computing and also

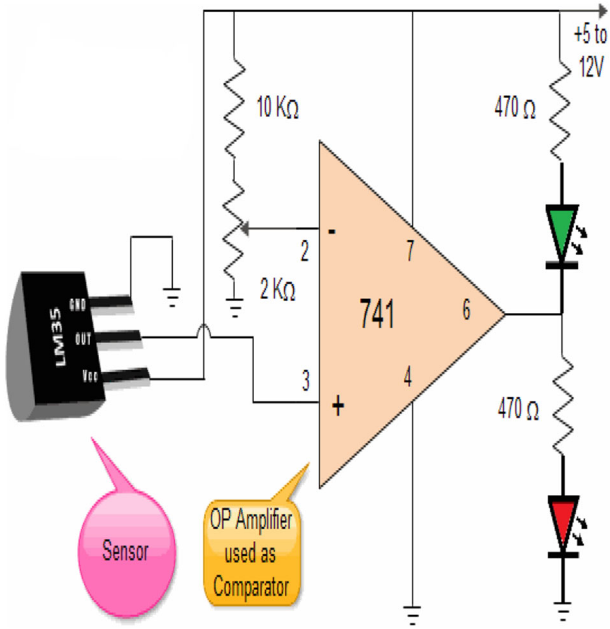

Fig. 6 LM35 temperature sensor circuit

Fig. 7 Conductivity probe

to WIFI for accessing network devices. The data passing and reporting via wireless sensor network is shown in Figs. 11 and 12 shows the system power supply.

Similarly, the implementation of Software included the transmitting and receiving of data reporting system based on master and slave process. The function of the control includes data processing and transmission. The primary role of the slave is data collection and then sending the data to the host control center and reporting the TWAD according to commands sending from the host control center. The master's host is Arduino controller and the slave's host CPU is Wi-Fi chips. The procedure of embedded system control of all sensors monitoring is given below.

Prominent rule control algorithm

The water quality measurement and control implemented by using the proposed Prominent Rule control Algorithm with diverse groupings. The Prominent Rule controls the water quality measurement error along with the threshold value. From the controlled Prominent rules from the Ardiuno controller selects the predicted logic of error. The Prominent rule set algorithm is presented as below.

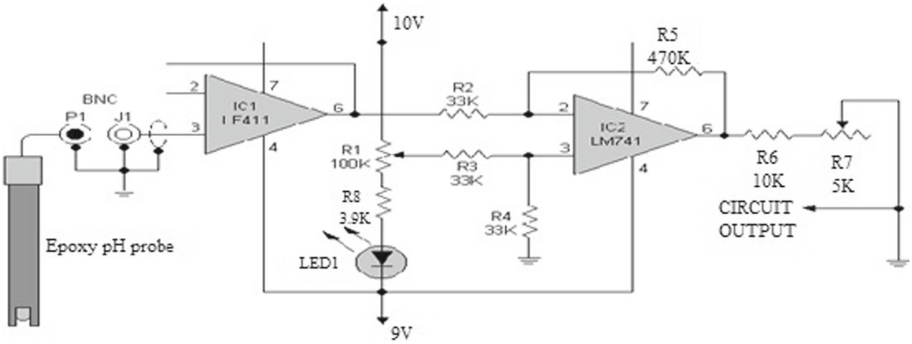

Fig. 8 pH sensor circuit

Fig. 9 TST 10 Turbidity sensor

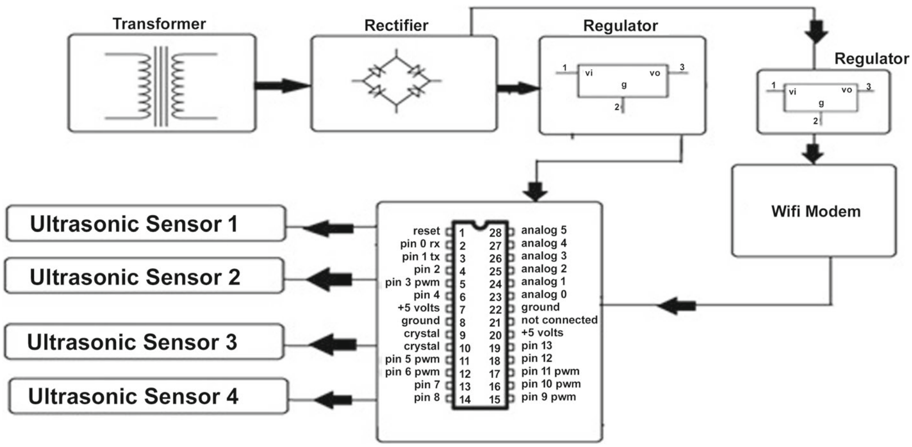

Fig. 10 Block diagram of IoT based system

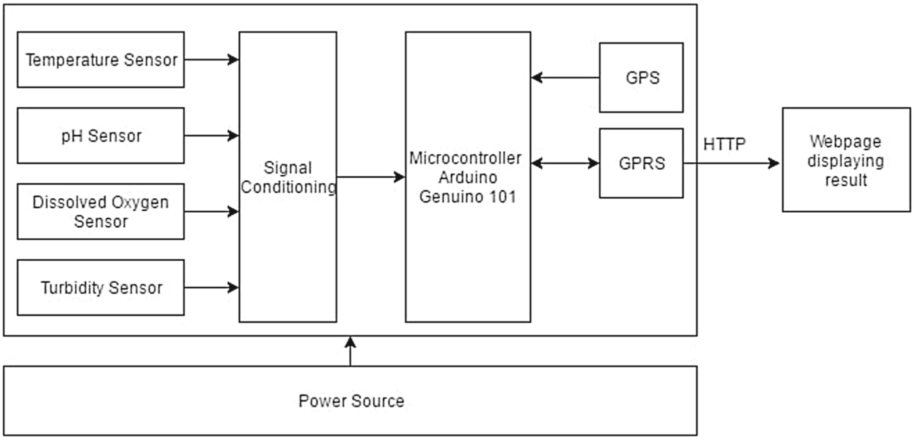

Fig. 11 Block diagram of data reporting through WSN

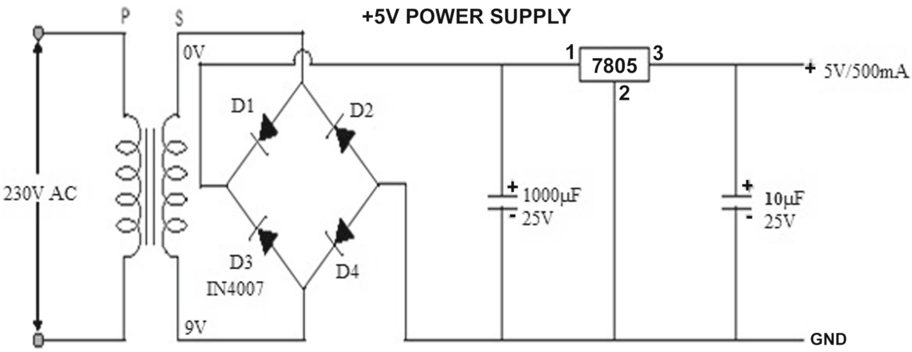

Fig. 12 Block diagram of power supply of the system

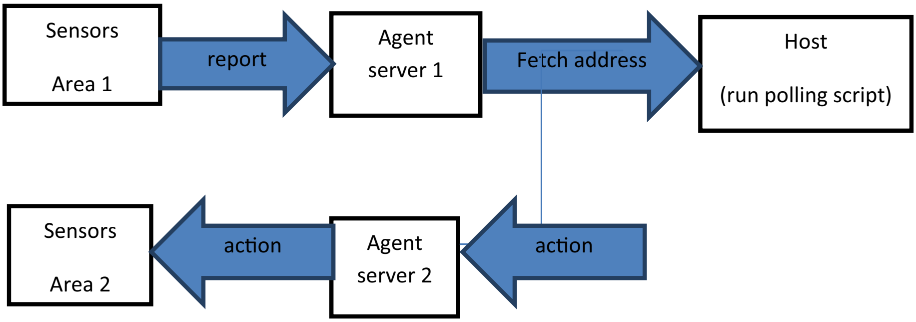

Fig. 13 Aqua care-IoT services

Procedure: Prominent Rule control based water quality Monitoring system

```
Input: Port values
Output: digital values of Sensors (T - Temperature,PH - pH sensor,Turb - Turbidity,Cond - Conductivity)
  Start begin
    while(1)
        Read the values of sensors at t= 10 sec
        Load D=sensors.
        Case 1:
          if (T > threshold value) then
            TX=A, // Transfer T value to system
          end if
        Case 2:
          if (PH > threshold value) then
            TX=B,(send PH value to the system
          end if
        Case 3:
          if (Turb> threshold value) then
            TX=C // Transfer Turb value to system
          end if
        Case 4:
          if (Cond> threshold value) then
              TX=D // Transfer Cond value to system
          end if
        else
         TX=NULL // Values not transferred
        end case
    end while
  end
```

The different sensor (e.g., temperature, PH, Turbidity) senses the water quality parameters and sends the data to the cloud-enabled system using Arduino. The microcontrollers on the board are programmed using Arduino programming language based on wiring and the Arduino development based on the processing. In the frame work script of aqua care-IoT, the services are composed in different parts like Sensor Devices, Agent Servers, Agent Clients and Hosts as applications, which is shown in the architecture of the service as presented in Fig. 13.

The Hosts can use the Agent Clients to access directly the Agent Servers or use the script to define all interactive behaviors of the entire group for smart applications completely. The Hosts can communicate with the Agent Servers through the Agent Clients to receive feedback from devices or to drive devices to take pre-determined actions and responses.

The Agent Server also provides another interface that was connected to the Agent Client interface accessed by the host.The application program on the Host is in the form of the script, and the Agent Client must use as an API to access the Agent Server to compose the text. When the Host is not directly connected to the device, it relies on a survey of the Agent Client to determine all statuses in the group.

The Host can register with the Agent Service to cause it to execute particular scripts upon receiving particular <Key, Value> that are reported by devices. The Agent Client must also be installed in the Agent Server hardware to operate as the API to execute Scripts on the Agent Server. The procedure of reporting system of aqua care-IoT is given below.

Procedure: Reporting - AQUA CARE – IoT

Input:AQUA CARE-IoT (UserId Uid, UserLocation Uloc)

Output: selected cloud service CS.

Begin

Step1: read user id Uid.

Step2: read user location Uloc.

Step3: read service details SD, Service History Sh.

Step4: select available services according to the location Uloc.

$$Ss = \int_{i=1}^{N} \mathrm{Mx}\ \ \mathrm{sh}\ \times\ \mathrm{Sd}\ \ \mathrm{Uloc} \tag{2}$$

Where,

N- Number of available services,

Mx- Minimum frequency of service,

Sh – service history

Step5: return Ss.

End

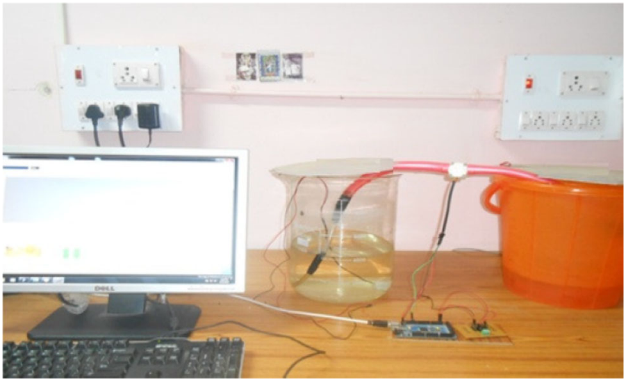

Fig. 14 Prototype of the system design

5 Results and performance analysis

In this section, the simulation process of the proposed system design and implementation is carried out using Embedded C Programming. Figure 14 shows the prototype of water quality monitoring setup for aqua care-IoT applications. As per combination of the hardware module, the system gains little computational cost with a reduced number of CPU cycles, less execution time, least consumption of power, volume reduction and additional features.

The analysis with the previous system of monitoring the water quality using huge apparatus the proposed system provides further suitable and flexible process than the existing. It is relatively appropriate for the monitoring scheme. The control process of the multimode can be recognized via the module of WSN. As per the planned idea the expenditure reduction is obtained and ensures the information gathered from the various nodes at entire atmosphere.

The proposed solution has been implemented based on the cloud computing platform integrated with the proposed solution to evaluate the aqua care IoT methodology. The three different clouds were formed each one is running on different locations and three service providers who are running at N-Number of locations.

The proposed solution has been hardwired with the proposed controller design and enabled Wi-Fi wireless communication to access the cloud service. The overall system performance of the proposed solution requires the following parameters are measured, namely T, PH, Turb, Cond Value and Overall Performance Ratio. Figure 15 shows the proposed system performance on the webpage (Fig. 16).

Table 2 shows the comparison values of different controllers namely PID, Fuzzy and Prominent rule controller based performance metrics. The different characteristics of Rise time (RT), Settling time (ST), Controlled Esteem (CE) are Presented in Table 2. Based on the observed characteristics the performance of prominent control algorithm is the best from remaining algorithms. Further parameters are needed to evaluate to make a comparison that to improve the standards of the water quality monitoring system.

Figure 17 shows the values of Rise time varies from 22(s) for PID, 26(s) for Fuzzy and 19(s) for proposed controllers for water area sample 1. Hence the prominent rule controller reduces the Rising time as small within a tolerable limit. Benefits of RT is used improve the performance.

Figure 18 shows the values of settling time varies for 35(s) for PID, 28(s) for Fuzzy and 19(s) for proposed controllers for water area sample 1. Hence the prominent rule controller

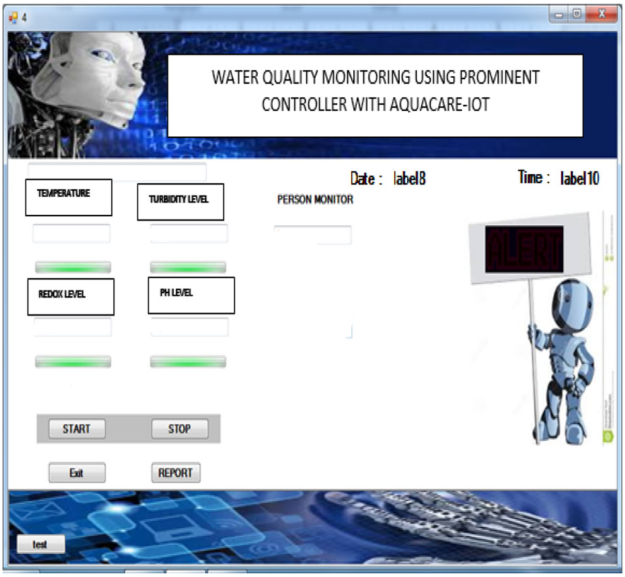

Fig. 15 Aqua care-IoT on webpage

Fig. 16 Prominent rule controller implementing Water quality measurement

Table 2 Comparison values of PID, fuzzy and proposed prominent rule controller

Water sample area	PID			Fuzzy			Prominent rule control		
	CE (L)	RT (s)	ST (s)	CE (L)	RT (s)	ST (s)	CE (L)	RT (s)	ST (s)
1	0.058	22	35	0.041	26	28	0.029	19	21
2	0.056	41	64	0.047	53	47	0.025	28	25
3	0.048	52	73	0.039	64	58	0.019	47	46
4	0.054	73	92	0.042	85	89	0.023	62	60
5	0.053	91	111	0.033	104	108	0.013	87	79
6	0.041	112	135	0.022	125	120	0.011	108	110
7	0.058	121	144	0.038	124	137	0.028	117	118
8	0.059	140	163	0.039	145	158	0.019	136	137
9	0.057	161	182	0.047	164	173	0.017	157	156
10	0.055	206	221	0.045	218	219	0.015	190	189

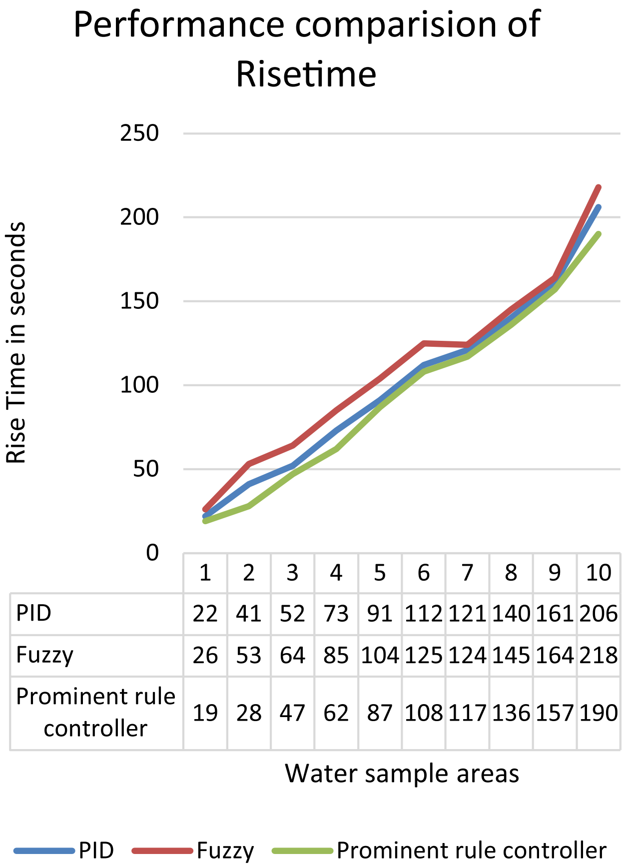

Fig. 17 Performance analysis of rise time using prominent rule controller based aqua care-IoT

reduces the Settling time as small within a tolerable limit. Benefits of ST is used improve the performance.

The various water quality metrics are examined based on the separate controller models. The dissimilarities in the graph display a rich vision of CE, RT and ST parameter which varies for the different water sample. Further parameters are needed to evaluate to make a comparison that to improve the standards of the water quality monitoring system. Prominent rule controller is presented with the three parameters of water quality monitoring using IOT, and compared with the PID and Fuzzy controllers and ensure the proposed prominent rule controller is more efficient than the two methods as shown in Fig. 19. The values of CE decreased from 0.058 to 0.029 within a tolerable limit. Benefits of RT and ST are 19 and 21 reduced small, which is used improve the performance.

The suggested aqua care-IoT scheme purpose is to determine the security issues in network based system and also to assure sensible overhead of computational with less execution time delay. In this section, the comparison of proposed aqua care-IoT water quality monitoring system is carried out with the existing networks such as Alarm-net [21] and Median [13] embedded and to address the security necessity and confidentiality of the thoughtful information.

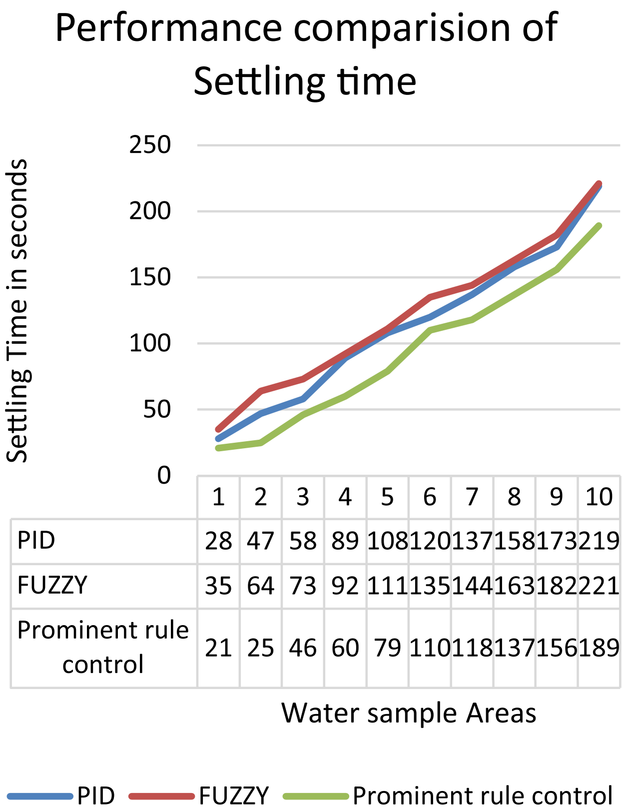

Fig. 18 Performance analysis of settling time using prominent rule controller based aqua care-IoT

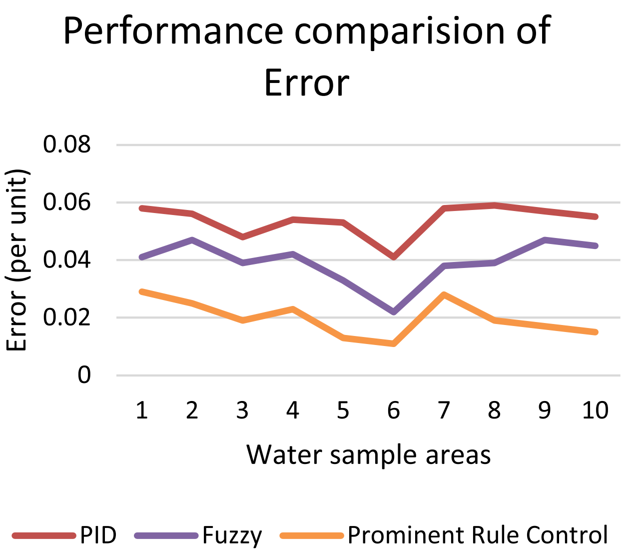

Fig. 19 Performance analysis of Controller Error using Prominent rule controller based aqua care-IoT

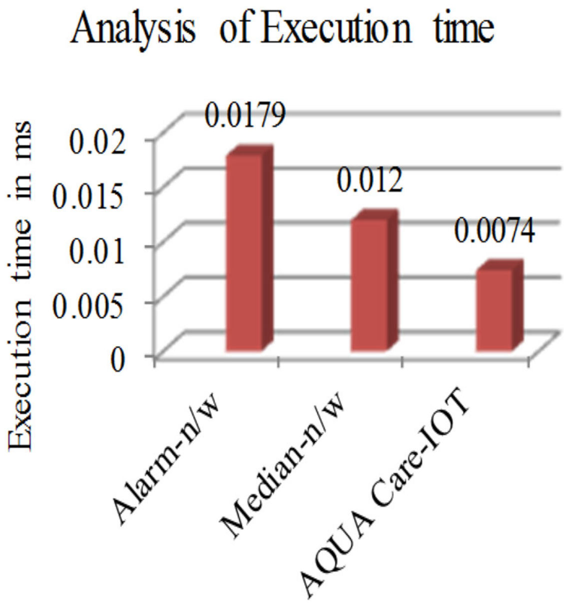

Fig. 20 Performance Comparison based on Execution time

Therefore, to analyze the performance of the proposed aqua care-IoT scheme is shown in below graphs. The analysis related to previous system was specified because of differences and the involvement of the parameters of water quality on the respective site. The evaluation was expert the outcomes depend on the substantial parameters performance of the entire area.

The computing power or resource of Agent Server and Agent Client are different. The analysis of performance based on CPU cycle and the execution time is shown in Fig. 20.

6 Conclusion

In this paper, the interface of aqua care IoT for system monitoring of water quality based on the IoT atmosphere via WSN is described. The information gathering of sensor system is carried out logically via network and developed the system based on a combined device of embedded prototype, IP address and communication application of IoT. This process will be suitable for the application of real time and concrete necessities of gaining system processed the information faster in the atmosphere of IoT. The planned system makes simpler the circuit design and system with high extensible and reliable. As per the Ip the integrity of information is enabled and various sensors are associated and connected, until the system terminates the process.

As a final point, the water quality real time monitoring and reporting is performed better than the previous system. The simulation processed is tested to show the system efficiency of the aqua-care IOT practical application, which produces effective performance with low computational cost and less execution time.

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