SMART WATER FOUNDATION -IOT PHASE 5 PROJECT 7125-PPG INSTITUTE OF TECHNOLOGY COIMBATORE

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Abstract
Water is the most important natural element present on earth for humans, yet the availability of pure water is becoming scarce and decreasing. An increase in population and rise in temperatures are two major factors contributing to the water crisis worldwide. Desalinated, brackish water from the sea, lake, estuary, or underground aquifers is treated to maximize freshwater availability for human consumption. However, mismanagement of water storage, distribution, or quality leads to serious threats to human health and ecosystems. Sensors, embedded and smart devices in water plants require proactive monitoring for optimal performance. Traditional quality and device management require huge investments in time, manual efforts, labour, and resources. This research presents an IoT-based real-time framework to perform water quality management, monitor, and alert for taking actions based on contamination and toxic parameter levels, device and application performance as the first part of the proposed work. Machine learning models analyze water quality trends and device monitoring and management architecture. The results display that the proposed method manages water monitoring and accessing water parameters efficiently than other works.

Keywords Water quality monitoring · Real-time · IoT · Sensor · AI · Wireless · Embedded · Microcontroller

Introduction

Just 2.5% or even less of the 71% of the water that coats the Earth's surface is safe for consumption. This resulted in serious impact in terms of elevated pollutant concentrations in freshwater sources as well as water shortages in various parts of the world. Freshwater supplies are depleting at an uncontrollable rate, and there is no other option for improving the situation than to track and sustain the highest possible level of water bodies. There were many developments in the twenty-first century, but there are difficulties to track water quality worldwide for clean drinking water in real-time due to the rising emissions and world warming. Water sources are dwindling, according to the Water Crisis Report (Facts and Statitics about Water and its effects, 2020), deaths from a shortage of drinking water or water-related diseases are on the increase, and over 850 million worldwide have limited access to clean water (WHO/UNICEF, 2010). In Africa, 19 million residents do not have access to clean water (WHO/UNICEF, 2010). In India alone, waterborne diseases are expected to cost about $600 million per year. In India, less than 40% of the population has access to well-regulated drinking water. Water poisoning, mostly due to fluoride and arsenic, is found in 2 million homes (Clean Drinking Water, 2021). Additionally, contaminants from old pipes or pollution can suddenly and unknowingly enter the water system, putting consumers at risk. In the USA, nearly 227 billion litres of treated water is lost each day due to leaking pipes (Amazing Facts about water, 2021). Across England, every day nearly 3 billion litres (Tracking down three billion liters of lost water, 2021) is lost to old leakage water pipes, which is equivalent to almost 1200 Olympic swimming pools. Better methods for monitoring real-time water quality need to be established. Given the strong digital presence in everyday life, several service utilities gather data and track devices manually. This inefficient process leads to inaccurate, and incomplete measurements of data and assets. When upgrading, utilities need to think about how to scale to thousands or even millions of sensors, water pumps, meters, and valves. With advances in IT infrastructure, water purification and desalination plants and systems can be integrated with IoT devices, sensors, and embedded systems to improve the storage, monitoring, and alerting for water quality and the devices involved. Using machine learning, systems and sensors can be gathering data and generate alarms in real-time to detect problems and reduce the load on the infrastructure and for staff, who currently manage the processes. Traditional techniques to monitor water quality include a manual sampling of water samples from various sites. When handled correctly, the infrastructure update can unlock new insights and reach unprecedented levels of efficiency.

When evaluating how to start updating infrastructure with this technology, utilities should keep in mind a wide range of possibilities for IoT in water management. At the forefront, security should be a priority. A foreign attack on a community's system can cause irreparable damage. Processing data in an efficient manner involves installation and monitoring of water usage, leak detection, advanced metering, and water quality for real-time data and situational awareness. Highlights of this research are as follows:

- Smart devices monitor, manage and alert real-time water quality, contamination, and toxic parameters.
- Perform proactive monitoring and alerting of systems and devices involved
- Machine learning models to analyze water quality trends and device management architecture
- Random Forest with robust results and achieved an accuracy of 88% with XGBoost of 0.85 even Naïve Bayes displayed the least accuracy of just 49%.

This research is organized in terms of sections. The "Smart Solutions for Water Management" section reviews smart water management solutions and the "Literature Survey" section reviews previous research works and implementations. The "Research Methodology" section presents the proposed framework using IoT; The "IoT-based Proposed Framework" section reviews the critical parameters to monitor and manage and the "Assessment of Water Quality using Machine Learning" section presents a machine learning model to analyze water quality trends and device management architecture. The "Results and Discussion" section presents the results obtained and finally, the conclusion with the future scope is presented in the "Conclusion" section.

Smart solutions for water management

Smart sensors devices aid in efficient and safe water management for consumers and workers through real-time data collection, alerting, and actions to prevent issues from occurring. Depending on the infrastructure, numerous processes can be automated, real-time alert generation, and insights gathered for attaining high-efficiency levels. Water industrial infrastructure having such devices and sensors aids in delivering several benefits to utilities and their teams when it comes to maintaining physical infrastructure and ensuring the safety of utility workers. With the influx of data, service teams manage remote infrastructure, reduce physical maintenance on site. Service teams are alerted when any part of the infrastructure is at risk even as automated processes perform the necessary changes proactively, instead of sending service teams onsite to address the issues.

Water processing, storage, and distribution

Water distribution affects the economic growth of every country; however, water loss due to leakage and others is being prone to contamination. This affects people's health and welfare. There is a need to ensure water safety and waste reduction by using IoT. There are several conventional techniques for collecting water datasets such as hydrologic storages like moisture, streamflow, recharge, ocean-land–atmosphere fluxes, water-land-air quality measures, and energy demand to quantify their accuracy, but handling and tracking the data in real-time is difficult due to the heterogeneity of the data, the time it takes to obtain it, the resources needed for transmission, and the network's coverage and accessibility. With new-age technology, tracking water quality (A concise guide for IoT based water quality monitoring, 2021) in real-time to receive alerts and perform proactive corrective actions becomes possible.

Monitoring water quality

Water management has advanced to a new stage thanks to the incorporation of IoT sensors and embedded technologies. Energy conservation problems in the water delivery system may be solved by combining energy harvesting and IoT. Solar cells, piezoelectric harvesting, electromagnetic harvesting, and thermoelectric harvesting are examples of approaches that combined with the visual application layer help improve the smart water system. Future research on micro-digital-electro and mechanical systems, such as lead (PB) zirconate-titanate films, piezoelectric nanowires, multi-parameter sensors, and iridium oxide films, as well as X-ray photoelectron spectroscopy analysis, can aid in advanced water quality management research. It is essential to ensure that the network and devices are secure which start by mapping and identifying the assets and determining the security strategy. One forgotten device can leave the entire network vulnerable, so both legacy and new devices should be identified as in-place or needed. Isolating the network into different zones helps reduce the attacks across the entire infrastructure. Threat detection and real-time alerts are put in place for the IT team to get notified and can address them immediately.

Process data at the edge

The integration of new IoT devices across the infrastructure landscape will create a massive amount of new data to collect and process. Migrating data to cloud servers can be a heavy and costly lift and delays the processing and alert of essential data for triggering a timely response to a potential hazard. To reduce overall network costs and to speed data processing, intelligence should be embedded at the point where it has been collected. This is called edge computing, which can allow for different types of automatic processes across the system. Utilities can better achieve real-time data analysis and program the devices or infrastructure to have set policies so that they conduct specific actions based on the data output. This is essential for remote pieces of infrastructure and devices that help with preventive maintenance so that issues can be caught as early as possible and actions can be taken. This type of automation can deliver several benefits for utilities with larger footprints. It also allows for the collection of in-depth insights for continued infrastructure improvements and for expanding infrastructure to new areas. When deployed incorrectly, edge applications can get messy. Regular operational tasks such as remote monitoring device performance, keeping it up to date, and applying patches can become a nightmare. Another potential problem utilities can run into when edge computing is improperly deployed is that local decision-making may have to be done at the control centre, slowing responsiveness to a local issue. In the case of data reduction, excessive data amounts that have to be transmitted over the communication network might overrun that communication system's capabilities or incur an unnecessary cost.

Data analysis and computation

IoT cloud mix has made it easier to solve the storage problems of the wireless sensor network. To store and process sensor data in the cloud, secure protocols, interactive monitoring, and cluster approaches were used. Sensor data can be migrated into the cloud using complex algorithms using these techniques, ensuring network reliability. Meeting standards and enforcement codes is another crucial step to take when integrating a new network. A compliance-focused and proactive strategy would give you a better picture of the team skills, and a sense of gaps and steps that should be taken. It is practical to take steps using asset discovery, network segmentation, threat detection, and mitigation, and integrated IT operational tech security. When setting up edge computing, it is vital to deploy in areas where local decisions need to be made regardless of connectivity to the control centre or where large amounts of data can be reduced. Reducing data close to the edge can increase the availability of connectivity between the remote location and the control centre, reducing cost or allowing external data sources to use the same networks.

Management benefits

Sensors that alert device failures or areas inundated with water, can automatically divert any excess supply across the network; or flag that the water level is not at its standard level, thereby alerting teams that are dispatched to resolve issues proactively.

IoT monitor and provide the real-time threshold and location of each team member to help ensure their safety in the field. As infrastructure ages and contaminants or chemicals enter the water, IoT can help alert utilities to these dangers.

Literature survey

Infrastructure, economic backing, technical capacity, capital supply, political will, and population all play a role in the constraints that each nation faces. This section is divided into two sub-sections: studies from developed economies and studies from emerging economies. The academic work in the field of IoT in water management for developed economies is detailed in papers published in the field of IoT in water management.

In the face of dynamic hydro-meteorological restrictions, Dong and Yang (2020) suggested that a data-driven model performs efficient scheduling drainage, pumping and water diversion of pumping stations. The authors proposed a model predictive control system for simulating and then predicting water dynamics and flow quality with supervised learning from IoT data and short-term memory network model. When compared to current benchmark solutions, numerical results demonstrated successfully and increased economic efficiency.

Nasser et al. (2020) used IoT to incorporate smart water meters, with data gathered at regular intervals and automatically transferred to the cloud. For real-time streaming and infrastructure efficiency management, the technology was designed to use microservices and containers. For time series forecasting applications, the authors used machine-learning approaches such as Support Vector Regression and Random Forest. The suggested model was shown to be superior and a testing ground for others after a comparative study.

In Spain, Lopez et al. (2021) deployed Remote Monitoring Systems focused on IoT technology and cloud data management. The writers weighed the benefits and drawbacks of existing solutions before settling on a plug-and-play, personalized approach. Continuous data transmission and retrieval are sent to a web server, which was then visualized in real-time on the web interface. Between the deployed nodes and satellite photographs, the authors ran a Pearson correlation test.

As support for IoT-enabled smart buildings, Minoli et al. (2017) proposed a cost-effective user-level IoT implementation. IoT-based applications can help naturally meet these needs. However, a range of deployment-limiting problems, such as a lack of robust end-to-end requirements, inconsistent cybersecurity solutions, and a scarcity of completely designed vertical applications, are currently limiting the reach of IoT use. This paper examines some of the technological possibilities and obstacles presented by the Internet of Things in the smart building space.

Olatinwo and Joubert (2019) presented new developed wireless technologies to see how they could be used in possible wireless sensor network systems for water quality monitoring. Established wireless sensor network systems for tracking water quality parameters have long had problems, according to the authors. The study offers recommendations for improving the efficiency of the identified contact networks for new-age sensor networks for water quality monitors.

Serra et al. (2019) proposed an analogue front-end designed specifically for a water conductivity measuring device used in water network management. One of the easiest ways to find a problem with the water in the network is to measure the conductivity of the water.

Roy et al. (2021) proposed the concept of a complex irrigation scheduling system based on the Internet of Things for effective water control of irrigated crop fields. Using the Internet of Things offers real-time, automated, complex, and remote manual irrigation care for various growth phases of a crop's life cycle. A low-cost water-level sensor aims to determine the amount of water present in a region. Centred on farmer needs, an algorithm for automated manual and dynamic irrigation was proposed with an interface that gives farmers field knowledge in a variety of ways, including visual view, mobile phone, and Web portal. In various climatic conditions and with dynamic irrigation treatments, it achieves substantial results in terms of different efficiency parameters, such as data validation, packet distribution ratio, energy usage, and failure rate. The findings of the experiments indicate that this boosted crop yield by 14% over the conventional manual irrigation process, increased the network's lifespan 2.6 times over the original system, and achieved reliability of 95% even after 600 h of service.

Solutions and technologies to separate pollutants include isolation processes despite the decomposition these can be recovered. Demissie et al. (2021) presented the surfactant-based process for separating hazardous pollutants from the water as an efficient alternative and energy-intensive replacement. The authors reviewed the process of pollutant removal including the recycling of concentrated aqua with no noticeable deterioration. The authors presented various options for achieving increased efficiency in the process, the challenges, and future research opportunities for wastewater treatment.

Curry et al. (2018) focused on creating IoT-enabled applications for smart houses, offices, universities, buildings, hotels or airports, to include a variety of consumers to improve water and energy knowledge, control, and conservation.

Borelli and Biondi (2020) suggested domain-specific languages to aid in the implementation of dynamic technologies for a range of purposes. Due to the intrinsic deployment and incorporation of a large range of heterogeneous applications, IoT adds to the difficulty of software production (sensors and actuators). The interaction of multiple components that play different roles is required when designing software architectures for IoT. The authors of this paper introduced a new vocabulary intending to assist and streamline the creation of IoT device architectures. Grammar and a compiler are responsible for syntax and semantic analysis, and code creation, in the specification and execution of the language. This made it easier to formalize program architectures using automata, which would otherwise be built on the fly to solve complex IoT scenarios. The developers created an IDE that can read the language and create software architectures in it.

Processing of the electricity demand to accomplish load balancing is regarded as a key phase in the form of smart grids with the Internet of Things technologies, according to Li et al. (2017). By using a geometric water-filling technique, this paper proposes complex offline and online scheduling algorithms to eliminate power fluctuations. For the offline method, complete power demand information is available, presumably via power utility forecasting. This research presented a method for allocating elastic loads based on inelastic load knowledge when taking into account the party- and node-power upper constraints. The reference amount is calculated dynamically using historical demand data in the online method to mitigate grid fluctuation, and elastic loads can only be planned in potential time slots. The use of two dynamic algorithms to accomplish load balancing in the power grid without affecting user experience by real-time reference level adjustment is studied. The proposed methodologies allow power providers to dramatically reduce the cost of increasing power capacity, while customers benefit from more consistent electrical power.

Priya et al. (2018) presented a real-time in-pipe water quality control system that is growing in response to recent advancements in communication technology. This paper discusses recent developments in the field of real-time in-pipe pollution monitoring systems. In addition, a contamination detection device based on the evolving IoT is being developed. Water supplied by pipelines to consumers/public is sampled at regular intervals by the machine. The data is evaluated in real-time using fuzzy synthetic evaluation and then transferred to the server. Where leakage is found in the water, the device notifies customers of the water quality criteria and uses a solenoid valve to stop the flow of water in the affected area of the pipe. The other area of the water delivery network, which provides high-quality water to customers, is also operational. The findings show that the established framework is capable of measuring water quality parameters in real-time, processing, transmitting data to the cloud, and informing users about pollution in a specific area.

Olatinwo and Joubert (2019) looked at some of the newest wireless innovations that could be used in upcoming wireless sensor network applications for water quality control software. The innovations under consideration promise to solve long-standing problems with current wireless sensor network systems for tracking water quality parameters. Energy conservation and long-range water quality data exchange are examples of such problems. These flaws open the door for the use of newly emerging technologies found in this study to advance the field of water quality monitoring through a wireless sensor network. To do this, this paper recommends three main types of contact networks, namely architectural architecture and network implementation for water quality monitoring applications. This paper discusses how to improve the efficiency of next-generation wireless sensor network systems for water quality monitoring applications using the defined communication networks. Even though the advancement of marine electronics and intense network technology has been present in this field for decades, the use of IoT and networks of distributed sensors and actuators in maritime scenarios is still minimal.

Luccio et al. (2020) proposed a mechanism for coastal data collection from sensors and instruments deployed in marine equipment, called the dispersed leisure yachts sensor network for atmosphere and marine observations scheme. The findings reveal that incorporating crowdsourced bathymetry data into the workflow computational model configuration increases final results precision, allowing for a more accurate spatial propagation pattern of the sea current moving the tracers.

Benedict (2020) suggested IoT applications for cloud production, directed water quality or air quality monitoring, energy-conscious societal applications, and smart agricultural economics, all of which are built with a mix of high-end computing technologies like cloud, edge, and fog. Thousands of people, including developers, benefit from IoT technologies that are implemented in an automated/decentralized approach with improved security controls, according to smart cities and regulatory authorities. Owing to the lack of appropriate technology, such as serverless computing, existing IoT architectures are vulnerable to energy inefficiency or resource underutilization issues. This paper introduces a serverless blockchain-enabled IoT architecture for societal implementations in this paper. It examines current IoT architectures and identifies the benefits of using serverless blockchain on these architectures. Furthermore, the proposed IoT architecture is demonstrated using a basic use case of IoT societal technologies, including smart city air quality monitoring. This article describes how air quality sensor data from faulty industries are safely transferred to blockchain networks using serverless and server-oriented functions, bypassing the three layers of computing: edge, fog, and cloud. In addition, this article provides a detailed list of the most useful serverless features for IoT society applications. IoT architecture, as described in this article, would allow IoT developers and researchers to innovate and conduct research.

Clinical haemoglobin-based oxygen carriers should not induce any toxic immunological reactions. Poly-dopamine being a scavenger of free radicals is used for haemoglobin protection against oxidation. Baidukova et al. (2018) synthesized and modified the functional haemoglobin. Plus these exhibited high scavenging activity of free radicals with excellent biocompatibility. Research results illustrated the great potential for using this process.

Chlorination is a popular disinfection process used in the preparation of drinking water. Optimizing this procedure is difficult because of the goals of achieving the desired disinfection effect but still minimizing the formation of disinfection by-products must be met at the same time. To deal with variations in water quality, the chlorine concentration must be adjusted in real-time, and the free chlorine residual at the clear-water reservoir outlet must not surpass statutory limits. To achieve the above goals, Wang (2019) suggested a hybrid control scheme that incorporates disturbance observer and model predictive control. This is used for post-chlorine dose feedback monitoring and has been modified to detect changes in influent water content. In the feed-forward regulation of post-chlorine dose, the approximate value from the DOB is used. The proposed composite control scheme has a greater disturbance rejection effect against fluctuations in influent water content than control schemes, and it can effectively balance the quality of treated water, according to simulation and experimental data.

Technological advancements expand the capability of information networks and support a wide range of modern applications as data processing speeds improve. Electronic components, infrastructure, and fuzzy rules control model with applied applications for a next-generation home environment, proposed by Woźniak et al. (2021). Based on 6G network connectivity principles, the technology is being designed for the next IoT stage. Water flow management, windshield monitoring, protection aspects, and carbon dioxide reduction through adaptive ventilation are all effective with the proposed control model. The technology has been developed to support the latest 6G connectivity protocol, which would increase reliability and data flow at the end-user interface and local area level.

Big Data Analytics and Data Science are quickly evolving and growing areas for future industrial demands. Menasalvas et al. (2021) presented a model for recognizing skills required for Data Science. The authors introduced the data skills importance and challenges for education reviewing a few main projects for advanced data skills priorities. The authors also presented a use case for recognizing frameworks of applications in online learning management portals for big data skills.

The interdependence of enablers, and the scale of cause and effect, was proposed by Yadav et al. (2021) as a contribution to an IoT-based food security model. The paper's methodology includes interpretive structural modelling for constructing interrelationships amongst enablers and the Fuzzy-Decision-Making Trial and Evaluation Laboratory for determining the degree of the hierarchical framework's cause-effect strength. This study made a theoretical contribution that was backed up by information processing and dynamic capability theories.

Deep et al. (2020) developed a concept for a low-cost pollution assessment kit centred on a dust sensor that can communicate data to a cloud service through a Wi-Fi module. A system overview of urban route planning is also suggested to provide users with real-time information on pollution concentrations, which may be used to help develop the least polluted path prediction app. In metropolitan settings, the suggested approach can assist passengers in planning a less polluting path.

Dhanwani et al. (2021) emphasized the need for theoretical, practical, and empirical progress in the ways that intelligent technology may assist the ecosystem bloom pollution-free. The secondary goal was to guarantee that a thorough examination of Smart Environmental Pollution Monitoring Systems provided a wide range of opportunities for improving one's understanding of environmental management using contemporary global technology. They partnered with other academics to aid in the proliferation of various "smart" solutions producing a smarter, greener, and brighter future for research and advances in sustainable technologies inventing a pollution-free world by looking at historical trends (López 2020).

Research methodology

There have been different architectures and approaches for water management proposed by several authors. After purifying the seawater, the next critical challenge involves distribution, storage, quality management of water, and monitoring the involved devices. Around 40% of pure water is wasted post purification alone. Manual methods of water quality measurement pose the following challenges:

- Humans are prone to make mistakes and errors when collecting quality or device readings manually.
- Inaccurate and flawed data considerably impact the inference and trend quality output.
- Manual readings involve high-cost effectiveness and efficiency, apart from consuming time and effort.
- Proper training is required for the staff to ensure collecting proper on-site deice readings.
- Manual inspection of sensors, devices, and probes wastes productive time, resources, and effort.

Due to these difficulties, the manual process of calculating water quality has become obsolete. As a result, smart water quality control systems based on the Internet of Things are expected to automatically track different criteria that decide water quality. IoT allows for the development of automated water quality control systems that address the above issues. Several water parameters are calculated in real-time from remote locations using instruments such as sensors and probes. These instruments send real-time data about a water body's condition to a platform suite. An individual or an organization should use this forum to take steps to ensure optimal water quality.

Chemical parameters include the following:

- pH ion concentration is the measure of acidity or alkaline chemical content, 6–9 is considered normal.
- Dissolved oxygen in water, normally this is 0.5 mg/l.
- Oxidation–reduction potential determines the ability of the water to remove the impurities by itself.

Physical factors involve the presence of viruses, algae, bacteria, and pesticides as biological influences impacting the water quality, apart from the following:

- Higher temperature affects oxygen levels in water.
- Turbidity is cloudiness or opacity indicating microscopic constituents, should not be less than 1NTU.
- Conductivity is the ability to conduct an electrical current; this should be around 200 Micromhos/cm.
- Flow sensors measure the flow of water in pipes, this indicates the loss or missions.

Data generated by different water quality systems during distribution, harvesting, and storage, application portal related along with IoT sensor devices and Cloud server systems is considered as an overall water parameter calculation threshold. Water pressure, flow levels, and velocity are considered for these three aspects. The authors propose the use of ultrasonic and flow sensors for detecting the change in flow and velocity. Correlating parameters provide accurate management information. This research focused on fifteen plant systems, Cloud App, Servers, IoT device parameters for real-time, accurate monitoring, and alerting illustrated in Table 1.

Algorithm for accessing water management portal:

```
Step 1 → Connect Raspberry PI to Portal
Step 2 → User device should be on the same VLAN
Step 3 → Open Google Chrome browser as https://192.168.43.140:1880/ui
Step 4 → Enter Profile-based User ID/Password

SY = Water Monitoring System such that SY= { Ip, Op, Fn}
where Ip= set of input, Op= set of output, Fn= set of function

Start
Input: IoT Sensor Values Ip= {Ip1, Ip2, Ip3, Ip4}
Ip1= Water pH sensor
Ip2= Temperature sensor
Ip3= Water Flow sensor
Ip4= Turbidity sensor

Function: Fn= {Fn1, Fn2, Fn3}
Fn1= Gather IoT sensor data
Fn2= Store Input data on cloud
Fn3= Display data on website

Output: Op= {Op1, Op2}
Op1= if Ip ≥ Threshold (Th)
        Water contaminated → Water tank outlet to be closed
      else
          Op1= if Ip < Threshold (Th)
          Water NOT contaminated → Water tank outlet kept open
Op2= show data on webpage
End
```

To create a Python program for a smart water fountain with a Raspberry Pi, you can use the RPi.GPIO library to control the GPIO pins. Here's a basic example to get you started:

```python
import RPi.GPIO as GPIO

import time


# Set up GPIO pins

GPIO.setmode(GPIO.BCM)

GPIO.setup(18, GPIO.OUT)  # Example GPIO pin for controlling the fountain


# Turn on the fountain

GPIO.output(18, GPIO.HIGH)

time.sleep(5)  # Fountain runs for 5 seconds


# Turn off the fountain

GPIO.output(18, GPIO.LOW)


# Clean up GPIO

GPIO.cleanup()
```

Remember to connect the appropriate GPIO pin to the fountain's control circuitry.

Output

The Python program for the smart water fountain with Raspberry Pi will control the GPIO pin connected to the fountain. It will turn on the fountain for 5 seconds and then turn it off. You can customize the GPIO pin number and duration as needed.

Table 1 Monitoring and alerting parameters

Plant pumps and systems	Application portal related	IoT sensor, probes and cloud
• Pressure measurement • Flow level • Flow velocity • Leakage emission • Chemical contamination	• App availability • Average response time • Error rates • App instance count • Re-request threads	• IoT device uptime • IoT data process rate • Cloud server CPU • Cloud server memory • Cloud server storage

IoT-based proposed framework

This research refers to the smart architecture proposed by Alshehri et al. (2021) using Cloud and IoT for desalinating seawater and takes research forward. The proposed framework is IoT-based with Cloud computing used for monitoring and alerting and machine learning for analytics. Sensors on plants pumps and pressure values gather data related to pressure (head, static, and stagnation), flow (pressure and depth), flow velocity, pipe leakage or emission flows, and chemical contamination (for pH., dissolved oxygen, TDS, metals, salinity, and turbidity). Data generated is measured for these parameters, measured for water quality monitoring and device management in real-time. Sensors and probes connect to core controllers. IoT devices process the sensor data and transfer using wireless networks to Cloud portal systems running artificial intelligence and machine learning algorithms for dashboard analysis and trends that provide useful insights to take informed actions.

The framework involves two aspects — hardware and software. Hardware involves the use of sensors and probes at three levels — when harvesting water (pressure sensors, motor pumps), during storage (ultrasonic water level sensors) and at the time of final distribution (motor pumps and flow meters). IoT devices, sensors, and probes are integrated with plant systems to measure the real-time hardware values. Raspberry Pi with sensor performs edge computing and local storage, converts the analogue into digital values, and sends the semi-processed information to the cloud servers. The software involves processing modules by IoT edge devices, monitoring agents, Cloud portal applications, and machine learning algorithms and dataset (Beach Water Quality, 2021) to process the output as illustrated in Fig. 1 below.

The proposed model is designed and implemented based on a five-layered approach as presented below.

a) **Data gathering layer** collects the plants' system and IoT devices' data for processing in real-time. This layer consists of IoT sensors, embedded and energy harvesting devices. Various sensors are available commercially to perform water monitoring and data collection. Choosing water quality sensors depends upon the project cost, attributes to measure, and efficiency.
b) **Energy harvester layer** collects energy for the plan and IoT devices from natural sources (wind, light, vibration) and converts it to electricity that powers the device or extends battery life. These modules generate energy using kinetic, thermal, biochemical, and radiant sources to manage the working of network, embedded, IoT sensors device units. This provides low-cost, efficient energy sources.
c) **Network layer** combines the value processing and manages the transmission from the initial layers. This layer manages the network and wireless communication for data communication. Transmission is performed using cellular communication for long distances using 2G, 3G, or 4G. However, these require high power consumption. The second option use short distance protocols Zigbee, 6lowpan, and Radiofrequency identification, which uses electronically, programmed tags for collecting data.

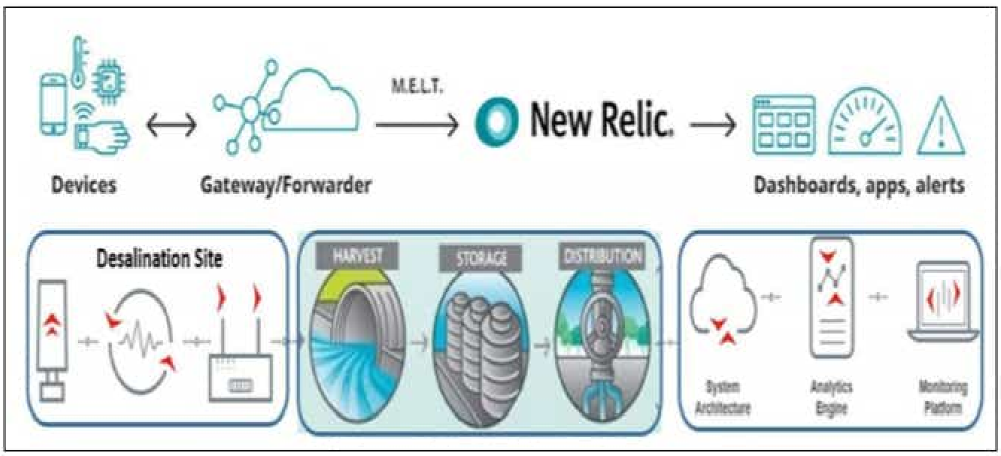

Fig. 1 Water management integration with IoT and Cloud dashboard (New Relic, 2021)

ESP8266 WiFi module provides access to WiFi to the microcontroller. ESP8266 modules are pre-programmed with AT command firmware.

d) **Cloud and application layer** manages the Cloud portal, device agents, and apps. These are designed to provide data encryption and privacy during data-on-move, storage, and processing from multiple devices. The authors used a Raspberry Pi microcontroller board (Pico RP2040) with 14 digital I/O pins.

e) **Analytics layer** performs decision-making, problem-solving, data identification processing. The use of neural networks with neuro-fuzzing algorithms predicts waste-water quality and an adaptive network fuzzy system detects the water quality.

The authors referred to IoT sensors and embedded probes in water for 34,934 dataset values across multiple water bodies in the USA. These sensors captured values throughout the years starting in 2016 till 2020 [30]. Real-time results were gathered based on quality metrics such as dissolved oxygen, pH, temperature, turbidity, and the speed of water flow (Fig. 2).

Figure 3 illustrates the Cloud portal for the IoT device values gathered using the new relic agent, processing the data locally and then transferring it to the Cloud portal for staff to monitor and get alerts. If the data value is greater than or equal to the threshold, an alert is generated with a red output. If the data value is lower than or equal to the threshold, the output is displayed in green. The bar and line graph illustrate the time series of these values.

IoT device health, uptime, sensor temperature, water flow is gathered using the agent at unlimited scale and customization. Any device performance looking to exceed the desired threshold automatically generates alerts for that IoT

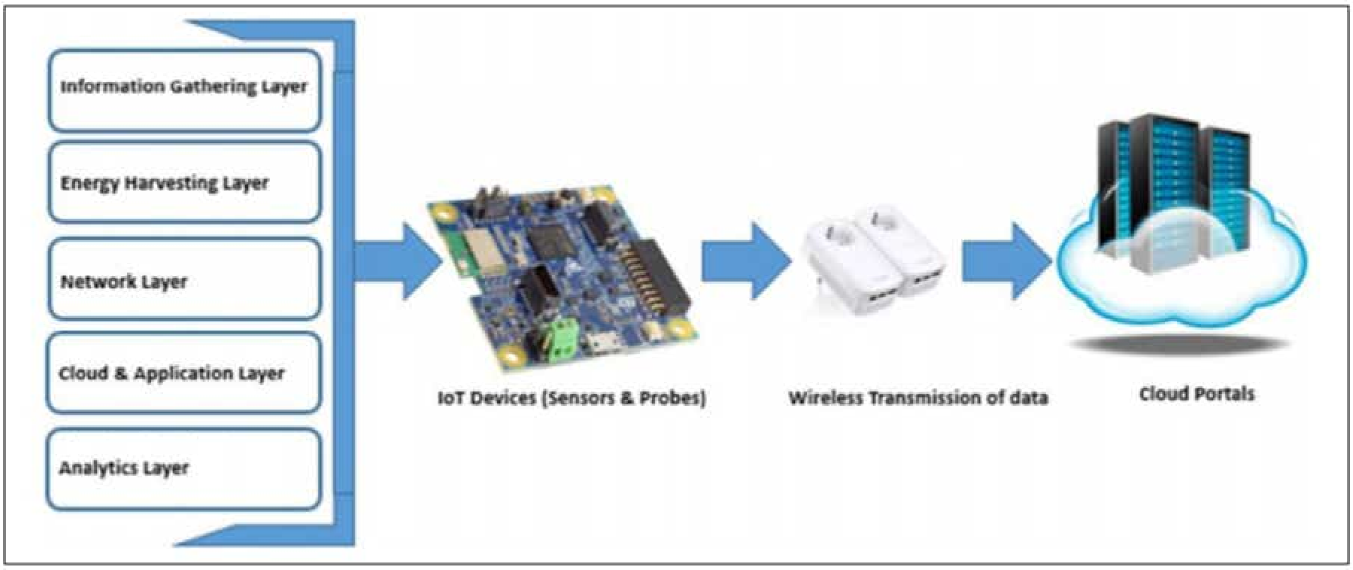

Fig. 2 Proposed water management model

Fig. 3 IoT agent values displayed on Cloud portal (New Relic, 2021)

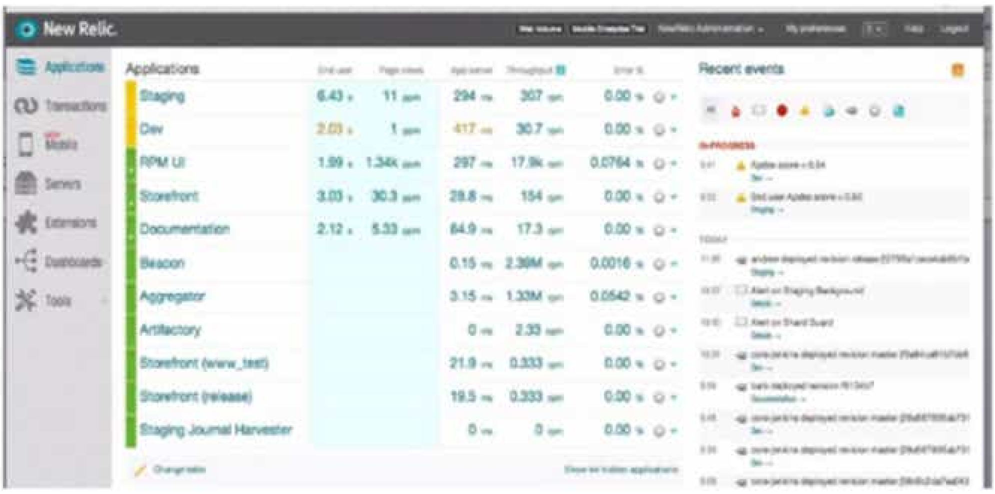

Fig. 4 IoT device health and uptime dashboard (New Relic, 2021)

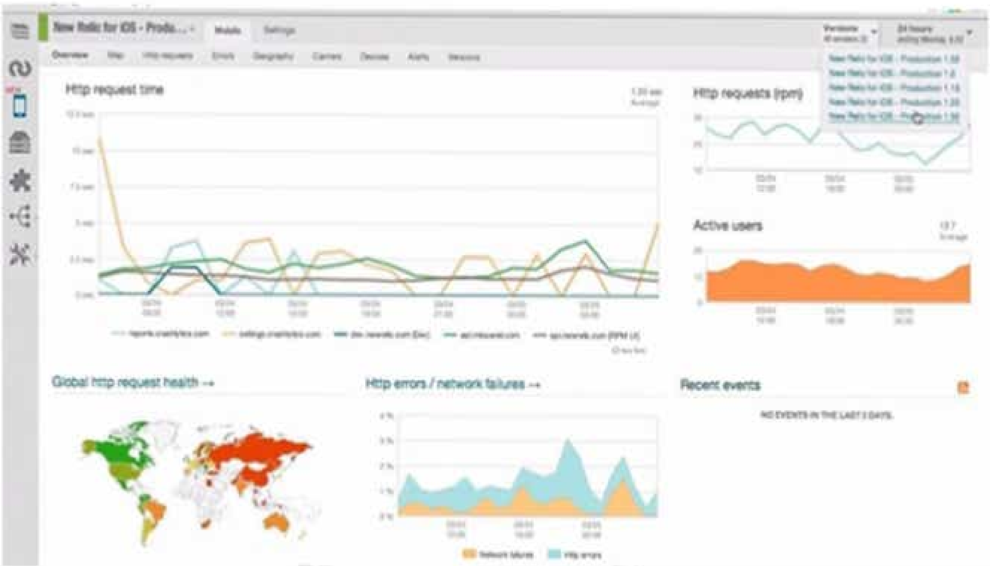

Fig. 5 Cloud application performance monitoring dashboard (New Relic, 2021)

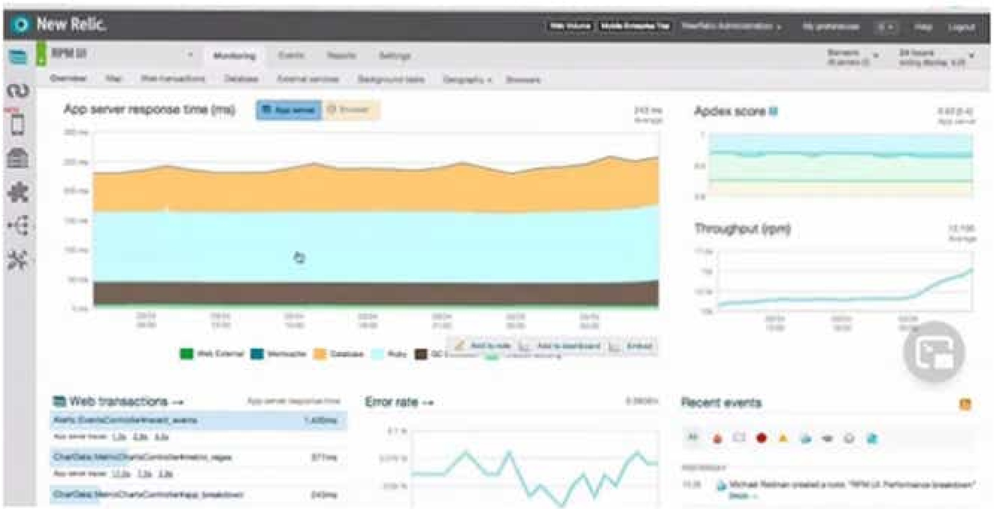

Fig. 6 Water Cloud portal application performance dashboard (New Relic, 2021)

device so the staff can remediate the issue proactively. Figure 4 illustrates IoT device health and uptime dashboard.

Using APIs and SDKs, Cloud server application monitoring, flexible dashboard, and alerting helps to identify incident detection and response related to the servers. Application performance monitoring is illustrated in Figs. 5 and 6 (Application performance monitoring and management 2021, Facts and statistics about water and its effects 2021).

Conclusion

The proposed water quality and device monitoring framework is implemented using different sensors, Raspberry Pi,

and alerting. The authors demonstrated the functionally using

monitoring, IoT device monitoring, and application perfor-

learning techniques to predict and measure water turbidity based on different metrics. The highest scores for classifi-

by Random Forest classifier while naïve Bayes and passive-aggressive classification techniques perform the worst on

Random Forest with robust results and achieved an accuracy

least accuracy of just 49%. The processed data is viewable on

quality is a serious indicator of the health of any country. By using IoT devices, sensors, embedded probes integrated with new Cloud-based technologies require customized IoT architecture designs. These can create low-cost, efficient water

can help analyze the quality, efficiency, and performance of water management systems.