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AN IOT-BASED SYSTEM FOR MONITORING THE QUALITY OF RIVER WATER IN REAL-TIME

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Abstract

The existing water quality monitoring system is a labor-intensive and time-consuming manual system with a repetitive procedure. This study presents a method for monitoring water quality using sensors. The primary constituents of a Wireless Sensor Network (WSN) consist of a microcontroller for system processing, a communication system for both inter and intra node communication, and many sensors. Real-time data access may be achieved via the use of remote monitoring and Internet of Things (IoT) technologies. The data acquired at the flat site may be visualised on a server PC using Spark streaming analysis with the assistance of Spark MLlib, deep learning neural network models, and the Belief Rule Based (BRB) system. Additionally, it can be compared to standard values. If the obtained value exceeds the predetermined threshold, an automatic SMS alert will be delivered to the agent. The novelty of our suggested work is in the development of a water monitoring system that has a high frequency, high mobility, and low power consumption. Hence, our suggested approach would greatly assist the Bangladeshi community in raising awareness about water contamination and preventing water pollution.

Keywords: Water quality monitoring; sensors; Big Data Analytics System; Internet of things; Real-time

Introduction

The surrounding environment has five essential components, namely soil, water, climate, natural flora, and landforms. Water is the most essential ingredient for human existence. Additionally, it is crucial for the long-term existence of other ecosystems [1]. Safe and easily accessible water is essential for public health, whether it is utilised for drinking, household needs, food production, or recreational activities [2]. Therefore, it is crucial for us to sustain the equilibrium of water quality. Alternatively, it would cause significant harm to human health and disrupt the natural equilibrium with other species [3]. Water contamination is a significant worldwide issue that requires continuous assessment and adjustment of water resource management principles at both the international and individual well levels. Research has shown that water contamination is the primary factor responsible for deaths and illnesses on a global scale. According to the data, water contamination is responsible for the daily deaths of over 14,000 individuals globally. Dirty or polluted water is being consumed without adequate previous treatment in several developing nations. One of the causes of this occurrence is the lack of awareness among the general public and government officials, as well as the absence of a comprehensive water quality monitoring system, resulting in significant health concerns [3, 4].

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This research presents the architecture of a Wireless Sensor Network (WSN) [4-7] that is used to monitor the quality of water. The network use sensors that are submerged in the water to collect information. This system is capable of gathering a wide range of characteristics from water, including pH, dissolved oxygen, turbidity, conductivity, temperature, and more, by using multiple sensors.
The rapid advancement of Wireless Sensor Network (WSN) technology offers a new and innovative method for collecting, transmitting, and analysing real-time data. Distant customers get access to continuous water quality data.
Currently, the Internet of Things (IoT) is a cutting-edge technical phenomenon. It has a significant role in creating the contemporary world and is used across several domains to gather, monitor, and analyse data from distant places. The integration of the Internet of Things (IoT) is present in several domains, including smart cities, smart power grids, smart supply chains, and smart wearables [7-12]. Although the use of IoT in the subject of environment is relatively limited, it has significant promise. It may be used to identify forest fires and detect earthquakes in their early stages, mitigate air pollution, monitor snow levels, prevent landslides and avalanches, and so forth.
Furthermore, it may be used in the domain of water quality monitoring and control system [4, 13]. Researchers in the twenty-first century have shown increased interest in water quality monitoring. There are several completed and continuing projects in this field that examine different facets of it. The primary objective of all the initiatives was to create a highly efficient and economical real-time water quality monitoring system that would use both wireless sensor networks and the internet of things [14]. This study involves the monitoring of the physical and chemical characteristics of water bodies located inside Chittagong city. This is done by using a sensor network based on the Internet of Things (IoT) technology.

Literature Review

In order to create a high-quality model, we thoroughly examined many pre-existing systems that were built by researchers. Various authors have put forth distinct methods for assessing water quality via the analysis of characteristics such as temperature, pH, conductivity, and others. After taking into account all of these factors, we developed an intelligent water monitoring system capable of carrying out all of these monitoring tasks. Stephen Brosnan conducted a study on a Wireless Sensor Network (WSN) with the purpose of gathering real-time data on water quality parameters (WQP). Quio Tie-Zhn created an online water quality monitoring system that utilises GPRS/GSM technology [15]. The information was sent over the GPRS network, allowing remote monitoring of the WQP. Kamal Alameh developed a web-based wireless sensor network (WSN) that utilises ZigBee and WiMAX networks to detect water pollution. The system gathered, analysed, and sent data from sensors, and routed it via a ZigBee gateway to a web server over a WiMAX network, enabling real-time monitoring of water quality across long distances.
Dong He created a Water Quality Monitoring (WQM) system using Wireless Sensor Network (WSN) technology [14]. The remote sensor used the ZigBee network as its foundation. The Wireless Sensor Network (WSN) conducted a test using the Wireless Quality Protocol (WQP) and sent the collected data to the Internet using the General Packet Radio Service (GPRS). Using the Internet, data was collected from a distant server. Vijayakumar et al. developed an inexpensive system for real-time monitoring of water quality in the Internet of Things (IoT). This system utilises sensors to measure many crucial physical and chemical properties of water [16]. It is possible to measure factors such as turbidity, temperature, pH, dissolved oxygen, and conductivity of water. Our project entails the proposal of an Internet of Things (IoT) based system for monitoring the quality of water.

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Proposed system

The primary objective is to create a system that can continuously monitor the quality of river water in distant locations. This will be achieved by using wireless sensor networks that have low power consumption, are cost-effective, and provide high detection accuracy. pH, conductivity, turbidity level, and other factors are measured and analysed to enhance the quality of water. The objectives of concept implementation are as follows: (a) The objective is to remotely monitor water characteristics, such as pH, dissolved oxygen, turbidity, and conductivity, using sensors that are readily accessible. (b) To collect data from several sensor nodes and transmit it to the base station over the wireless channel. (c) To simulate and assess quality parameters for the purpose of quality control. (d) To regularly send SMS notifications to an authorised individual when the detected water quality does not meet the predetermined requirements, in order to prompt appropriate measures. Figure 1 illustrates the comprehensive design of a water quality monitoring system.

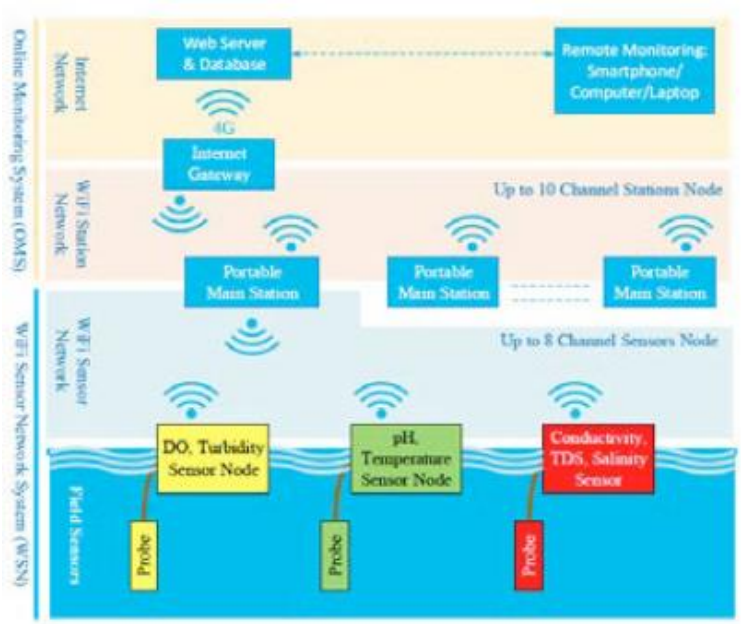

Figure 1 displays the whole diagram of the system. Each water reservoir in the proposed design will be connected to a sensor node that is equipped with a collection of sensor probes capable of detecting parameters such as pH and turbidity. The signal conditioning circuit will be developed to produce the sensor output to the processor board using an Analogue to Digital Converter, based on the specifications of the sensor probes and the processor board. The processor board executes data processing operations in accordance with the specified quality requirements and communicates the processed data to the central server via the transceiver. The collected data from each reservoir will be sent to the central server via the corresponding transceivers, either directly or indirectly through other sensor or repeater nodes.

Hardware design

Control surface refers to a component that is used to manipulate or control the movement or operation of a device or system.

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An Arduino Mega is used as the central component. The Arduino used here is the Mega 2560 because many analogue signal sensors need to be connected to the Arduino board. The system includes a collection of registers that use RAM for additional functionality. The registers for on-chip component resources are explicitly mapped into the assembly graph. The addressability of a store is contingent upon the instrumentation series and all PIC devices. Various banking procedures are used to leverage addressing for greater capacity. Later iterations of devices have move instructions that may be executed via the use of the register. Therefore, the mechanism operates by using the inherent coding capabilities of the Arduino UNO R3 board.

Monitoring Sensors

pH sensor

The pH of a substance is a useful parameter to consider, since both high and low pH values may have significant impacts on the individual. The pH scale ranges from 1 to 14. A pH sensor is a device that monitors the concentration of hydrogen ions in bleach, indicating its acidity or alkalinity. The pH of the substance ranges from 0 to 14. The extreme pH levels also affect the solubility of metals and compounds, rendering them toxic. The mathematical representation of pH is given by the equation pH = -log [H+].

Turbidity sensor

The turbidity sensor is a device used to measure the cloudiness or haziness of a liquid. A turbidity sensor is used to detect the level of clarity or murkiness present in water. The turbidity of the exposed excavated food typically ranges from 255 NTU. The amount of turbidity is obviously over 80 NTU. The acceptable range for turbidity in fluids is between 130 NTU and 250 NTU. The turbidity device comprises a soft sender and acquirer. The sender must emit a clear and intense signal, which is indicative of turbidity. Turbidity results in decreased water clarity, which is aesthetically displeasing and hinders the rate of photosynthesis, while also raising water temperature.

Temperature sensor

The temperature sensor is a component that measures the temperature. The DS18B20 is considered an outdated temperature device. Typically, its primary function is to measure the temperature of the surroundings. If the device is incorrectly positioned with the conductor electrode in the water, it may also detect the temperature of the water. The average body temperature of individuals typically ranges from 25 to 30 degrees Celsius.

LCD display

The LCD display is a component used to visually present information. An LCD (Liquid Crystal Display) panel is a thin, electronic screen that is used in a broad range of applications. The 16x2 LCD demo is an essential and often used power in many devices and circuits. These modules are preferable to heptad segments and other multi-segment LEDs.

Wi-Fi module

The Wi-Fi module is a component used for wireless communication.

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Wi-Fi, short for Wireless Fidelity, refers to a wireless local area network technology that allows devices to connect to the internet. Devices capable of using Wi-Fi include personal computers, video game consoles, cellphones, digital cameras, tablet computers, digital audio players, and advanced printers. Wi-Fi enabled devices may connect to the internet via a local area network (LAN) and wireless technology. The maximum range of this amount or point is around 20 metres (66 feet) inside and much farther outside. Wi-Fi may be used to provide Internet access to devices that are within the range of a wireless network linked to the Internet.

Designing the software

The water quality monitoring system presented, which is based on Wireless Sensor Network (WSN), may be categorised into three components:

- Internet of Things (IoT) platform
- Utilisation of neural network models for Big Data Analytics and water quality monitoring
- Water quality may be monitored in real-time by using the Internet of Things (IoT) combined with Big Data Analytics.

IoT Platform

The IoT Platform is a system that enables the connection and communication between various devices and applications in the Internet of Things (IoT) ecosystem. The quality parameters consist of labelled datasets that contain the intended results for various combinations of inputs. The neural network will provide output to categorise water quality as hazardous, requiring caution, or satisfactory. The classification layer will be executed on the Hadoop cluster [17]. The benefits of using neural network-based analytics, such as Artificial Neural Networks (ANNs), include its ability to effectively learn and model non-linear correlations, particularly in highly volatile data [18]. While neural networks are susceptible to overfitting, the neural network model used in the water quality monitoring system is not sufficiently intricate to induce overfitting. Additionally, there are several strategies to prevent overfitting. Furthermore, the system's reaction will not be delayed due to calculation overload, since there are only a limited number of water quality metrics. The comprehensive layout of the Internet of Things (IoT) platform is shown in Figure 2 (a and b).

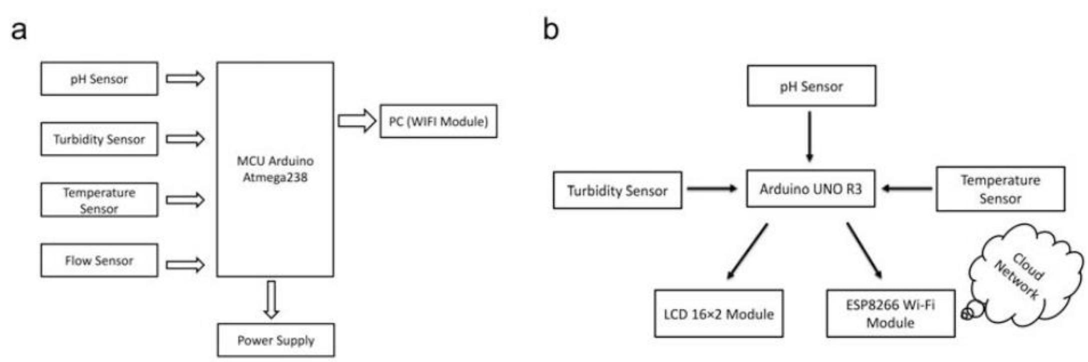

Figure 2 displays the block diagram and IoT Platform of the system that has been suggested. The turbidity sensors, pH sensor, and temperature sensor are directly attached to the microcontroller to detect water turbulence, pH levels, and temperature, respectively. The microcontroller gathers the data and carries out its processing using a Wi-Fi module. The Wi-Fi module (ESP8266) transmits data to the PC for data

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processing. The LCD display has accurately shown the relevant output. (a) The IoT platform layer will be classified to operate on top of a Hadoop cluster.

The use of neural network models in the fields of Big Data Analytics and water quality control. Prior to [19], there has been much research on the use of artificial neural networks in predicting water quality metrics. The diagram below illustrates a multi-layer neural network model with five input nodes. The input layer consists of five neurons labelled In 1, In 2, In 3, In 4, and In 5. The hidden layer has four neurons, while the output layer contains three neurons. There are two input neurons that are biassed, which are coupled to neurons in both the hidden layer and the output layer. The intricate structure of the Multilayer Perceptron Model, which has been created using Neuroph Studio, is seen in Figure 3. The neural network model consists of 5 inputs, namely pH value, temperature, turbidity, ORP (Oxidation-Reduction Potential), and conductivity. It produces 3 outputs, which are categorised as harmful, be cautious, and good. Prior to training the neural network model, several additional parameters must be established. These include the learning rate, set at 0.01, the learning method, which is Back Propagation, the bias input, which is set to 1, the connection weights, which are randomly allocated, and the activation function, which is the sigmoid function. The result of a neuron using the sigmoid function, given inputs Xj, weights Wj, and bias b, is:

$$F(X) = 1 / (1 + \exp^{(-\Sigma_j wjxj - b)})$$

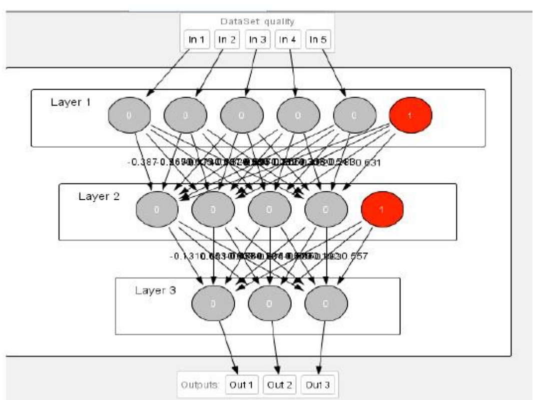

Figure 3 displays the Multilayer Perceptron Model that was created using Neuroph Studio. The diagram above illustrates a multi-layer neural network model with five input nodes. The input layer consists of five neurons labelled as In 1, In 2, In 3, In 4, and In 5. The hidden layer has four neurons, while the output layer contains three neurons. There are two input neurons that are biassed, which are coupled to neurons in the hidden layer and neurons in the output layer. The quality parameters consist of labelled datasets that include the intended results for a certain combination of inputs. The neural network will provide output to categorise water quality as either favourable or unfavourable.

Water quality may be monitored in real-time by using an integrated Internet of Things (IoT) system. Analysis of large and complex datasets Internet of Things (IoT) devices use a range of sensors to gather continuous data on turbidity, oxidation-reduction potential (ORP), temperature, pH, conductivity, and other parameters of river water. In addition, IoT devices have the capacity to transmit the acquired data wirelessly to a distant Data Aggregator Server located in the cloud. In addition, the amount of semi-structured data grows over time at a rate that can only be effectively managed and analysed by systems using Big Data Analytics [18].

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The system must include both reliability and scalability. The data management layer will be implemented and functional on the Apache Hadoop cluster. Hadoop facilitates the distributed storage and processing of large-scale data across a cluster of computers.

In addition, this operating environment has the capability to scale horizontally, meaning that more nodes or computers may be added to a cluster at a later time if the volume and velocity of data streaming increases. The fault tolerance of the Hadoop cluster is ensured by automatically redirecting workloads to functioning nodes in the event of node failures. The data in Hadoop is extremely accessible because to the presence of redundant copies stored in data nodes, which are maintained by the name node, standby name node, journal nodes, and failover controller.

IoT applications need fast data read/write speeds and a highly reliable database for storing data. The system will use the Apache HBase NoSQL database to hold large volumes of data. HBase operates on the Hadoop framework [17]. Therefore, the data is dispersed over the Hadoop distributed file system (HDFS) [20]. In addition, HBase has the ability to do both real-time queries and batch processing. HBase ensures high availability of data by storing it in HDFS.

Hadoop clusters consist of several servers that are overseen by Apache ZooKeeper. Centralised administration of the cluster is necessary to provide the provision of cross-node synchronisation services and configuration management. Applications have the ability to generate a znode, which is a file that stores the current state of the cluster in the memory, inside the zookeeper. Nodes will use znode registration to achieve task synchronisation throughout the cluster by exchanging and updating status changes in nodes via the zookeeper znode. Apache ZooKeeper is responsible for managing Apache HBase. The IoT application will enable users to visually represent the findings of water quality analysis generated by the data management layer across several continuous time series. The data visualisation programme is compatible with many client devices, including smartphones, laptops, and desktops. The root users will have the capability to create water quality reports on a daily, monthly, and annual basis using the data management layer. These reports may then be seen on client devices. Figure 4 displays the comprehensive structure of the integration of the IoT Water Quality Monitor Station and Data Management Layer Architecture.

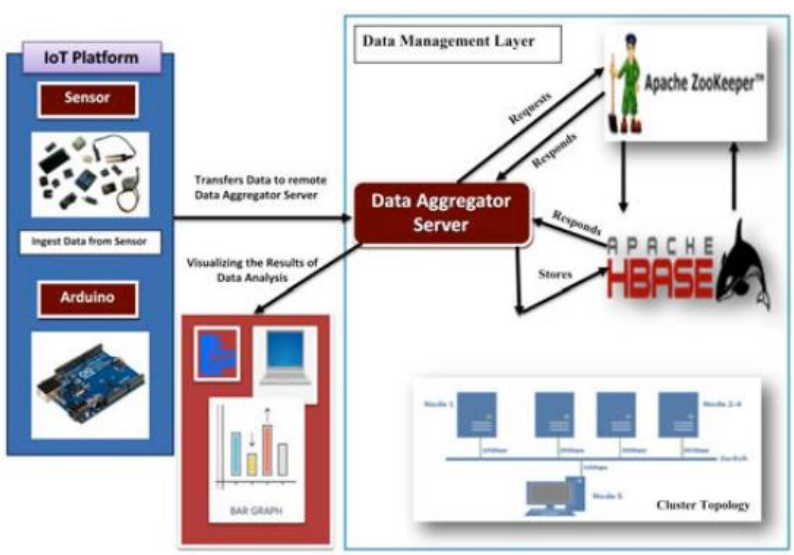

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Figure 4 illustrates the integration of the architecture of the IoT Water Quality Monitor Station and Data Management Layer. IoT devices continually collect data on turbidity, oxidation reduction potential (ORP), temperature, pH, conductivity, and other parameters of river water. IoT devices has the capacity to transmit the acquired data wirelessly to a distant Data Aggregator Server in the cloud. This data is then effectively stored and analysed using Big Data Analytics apps. The Data Aggregator Server is capable of retrieving the analysis result and transmitting it to the apps operating on smart phones, tablets, laptops, and desktops in the cloud.

Results

Figure 5 (a) presents the measured pH, temperature, turbidity, and ORP values. The device constantly detects the pH, temperature, turbidity, and ORP readings and promptly displays them on the LCD, PC, or mobile device. If the obtained result exceeds the threshold value, comments will be shown as 'BAD'. If the obtained result is less than the threshold value, comments will be shown as 'GOOD'. A bar or line graph will be shown to enhance comprehension. Figure 5 (b) displays the time series depiction of sensor data with choice.

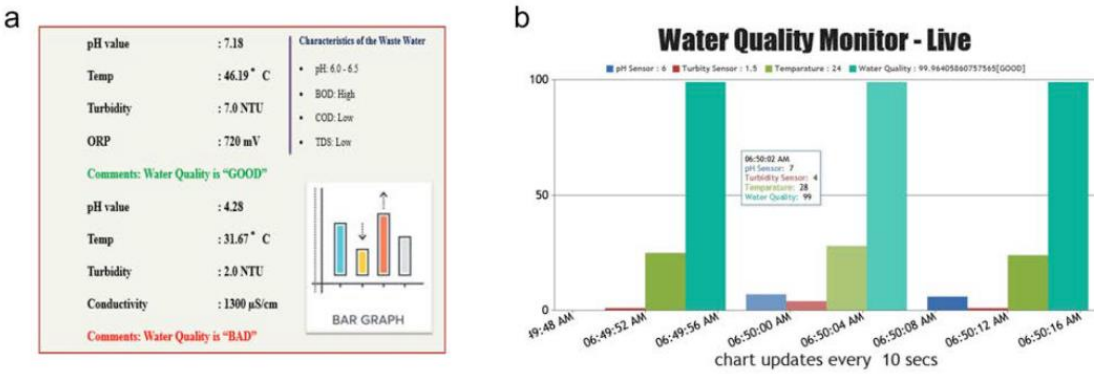

Figure 5. (a) The diagram illustrates the measured pH, temperature, turbidity, and ORP values. The device constantly detects the pH, temperature, turbidity, and ORP readings and promptly displays them on the LCD, PC, or mobile device. If the obtained value exceeds the threshold, comments will be shown as 'BAD'. If the obtained result is less than the threshold value, comments will be shown as 'GOOD'. A bar/line graph will be shown to enhance comprehension. (b) The temporal depiction of sensor data accompanied by a decision.

Conclusion

The use of IoT integrated Big Data Analytics for real-time monitoring of water quality would greatly enhance people's awareness of the use of polluted water and the prevention of water pollution. The study is being carried out with a specific emphasis on real-time monitoring of river water quality. Hence, the integration of IoT with big data analytics is seen to be a superior option due to its capacity to provide dependability, scalability, speed, and permanence. During the project development phase, a rigorous comparative examination of real-time analytics technologies, including Spark streaming analysis using Spark MLlib, deep learning neural network models, and the Belief Rule Based (BRB) system, would be undertaken within the specified timeframe of 20-27. This study suggests doing systematic experiments on the offered technologies using various quality of river water in Bangladesh.

As a result of funding constraints, our primary emphasis is only on assessing the quality of river water characteristics. This project has the potential to be expanded into an effective water management system for a specific local region. In addition, additional metrics that were not the focus of this experiment, such as total dissolved solids, chemical oxygen demand, and dissolved oxygen, may also be measured. Therefore, an extra expenditure is necessary to enhance the total system.

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