Green engineering principles for global water quality monitoring using IoT

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Abstract: Water is a vital resource without which most of the living beings cannot survive. The quality of drinking water depends on its source and storage conditions. Drinking water quality should meet the Environmental Protection Agency (EPA) regulations for quality assurance. Various purification methods are available to obtain pure drinking water. However, several industrialisation, globalisation, urbanisation, farming, and similar activities lead to drinking water contamination. Thus, the combined use of green engineering principles and internet of things (IoT) framework can aid simultaneous monitoring of water quality at different locations, at minimal costs and less need for manpower. This study proposes a system for real-time monitoring of water quality and detection of contamination, by using a wireless sensor network (WSN) to collect and transmit data. This system measures turbidity, pH, and temperature; these values are then processed using a controller and transmitted to the cloud through the WSN. The gathered data are highly accurate and can be accessed universally through the Internet by using a specific internet protocol address.

Keywords: IoT environment; green engineering principles; water quality monitoring; wireless sensor networks; WSNs; cloud computing.

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1 Introduction

Ensuring the quality of water is a difficult task to overcome due to the vast range of pollutants. Exploitation, rapid industrialisation, agricultural growth, extensive use of fertilisers and pesticides are some of the leading causes of water pollution. Water pollution together with other factors; pose a threat to global water security and river biodiversity (Vörösmarty et al., 2010). Figure 1 shows the polluted water. Ecosystems that are affected by the poor quality of water could face harmful effects which range from body disorders to increased fatality and water-borne diseases to total annihilation. The technological progress of the 21st century could accelerate the depletion of portable drinking water exponentially.

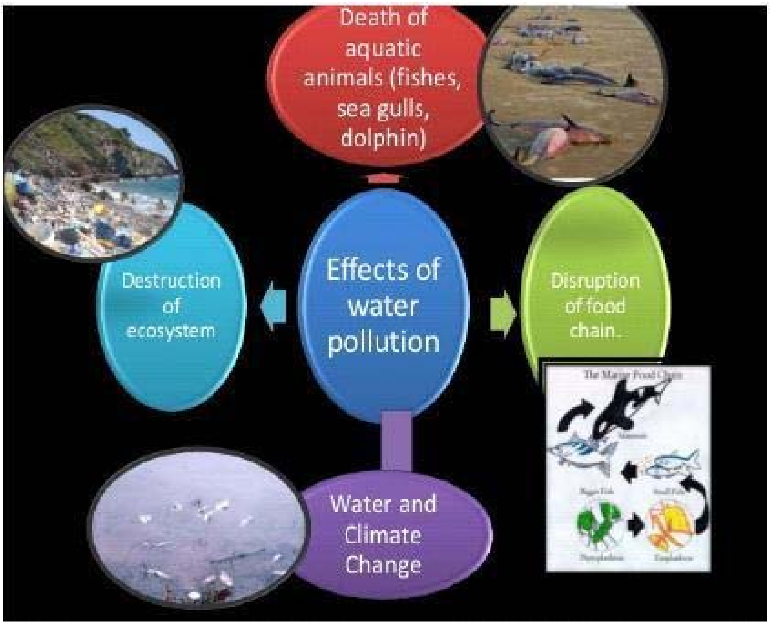
Figure 1 Water pollution (see online version for colours)

Water sampling method is the most popular choice for water quality testing. Water sampling method starts with the collection of water samples from a selected location at a particular time. Then the water sample is taken to the laboratory for chemical and biological analysis. This method is tedious for in-depth water analysis. The main drawback of this method is that the analysis is accurate or considerable only for that particular location and at the particular time when the sample is tested.

This water sampling method is resource intensive and therefore as a replacement of a sensor is perfect for overcoming these issues, the sensor is a fast, continuous and reliable device for monitoring the water quality. Also, the sensor can sense a multitude of parameters which the water sampling method cannot do. Hence, it may require for creating preferred methodologies that screen those water calibre parameters progressively.

The proposed framework enables automation, discernment action and water quality monitoring with the help of internet of things (IoT). The sensor devices that are installed at different locations are possibly communicated via IoT. The IoT is all about the things communicating with each other. Embedded IoT is extended to bring smart and intelligent devices in the system and consumes less power to operate. Different types of sensors are used to acquire data from the environment. The wireless sensor networks are the key component of IoT applications to enable machine to machine communication. Water quality monitoring is one of the applications and it is a challenging task. High-speed data acquisition system is used to increase the efficiency (Lan et al., 2002; Peng and Qingbo, 2006; Silva et al., 2011). Figure 2 shows the effects of water pollution.

Figure 2 Effects of water pollution (see online version for colours)



2 Related works

The concept of real-time water quality monitoring in IoT environment relies on four essential streams namely water sources, water tank, caution framework and water wellsprings. Beforehand, an alert system for wandering an outright controller interfaces with water individual fulfilment standard sensors that constantly ensure the quality by guaranteeing determinations. These past characteristics cut-off after that it communicates something specific on the compact for administration on conduit supply that water might not be extraordinary to drink. The water quality data is collected and send to water board to clean the contaminated water (Vijayakumar and Ramya, 2015).

The arrangements for those amounts from claiming units hosting particular sensors and the gathered information from known units would accumulate in the centre controller raspberry pi by means of Zigbee protocol IEEE 802.15.4. The microcontroller is introduced to collect data from sensors and to process on them to make compatible with Zigbee module. In place on transmitting information of the IoT; passage may be made on the raspberry pi utilising File Transfer Protocol (Ye et al., 2002). On cloud computing, separate IP address is provided which makes it conceivable in order to screen information from any place in the reality using the web (Surgient, 2014; McLeod et al., 2015).

The design of underwater sensor networks for water quality monitoring introduces a system that keeps the tabs around river/lake water with minimal effort sensor hubs utilising hierarchic correspondence structure. Therefore, an extensive number of the sensor hubs can be deployed to disguise an extensive checking territory with sufficient thickness. The sensor network consists of one super-node and a number of small sensor nodes. The entire network is partitioned into groups depending on the indicator quality. Every bunch needs a mind hub and the bunch hub that sends information to the bunch mind hub. Those bunch leader hubs send the assembled information of the super-node (sink). Every one of little sensor hubs utilises the low-power Zigbee radios, and the long-separated Ethernet radios are utilised the middle super-node and the station at the shore (Shakir et al., 2012).

The concept of a water level monitoring system in real-time mode using WSN provides a standout amongst the key parameters on duct checking is that inherent weight of the channel. Blocks might conceivably modify the ordinary weight in the channel thereby screening the weight and identifying the water quality. This includes both water monitoring system as well as water level indicator (Rasin and Abdullah, 2009). Distinctive push buttons are furnished for perusing those temperature, pH and turbidity qualities. Once the client clicks the switch of the board, the Zigbee handset on the recipient side sends a sign to the Zigbee transmitter looking into the transmitter side requesting the relating information ideals to dispatch and saved in a database (Vidya et al., 2016).

Nitrate and sulphate estimations in water sources using a planar electromagnetic sensor array and artificial neural network method provide programming modules that permit clients to visualise that information from that WSN without introducing a particular product. This model is suitable for long time to open-air situations and actualises the entire minimal effort passage module. The WSN sensor hub is that principle building of a square which created WSN framework model (Misiunas et al., 2003). Each sensor hub is further prepared for EM-506 GPS recipient. This may be a finish GPS keen radio wire collector that incorporates an installed radio wire which also GPS collector circuit. The module is arranged to work clinched alongside, a purpose will multipoint topology to sleeping-mode work due to its low inactivity correspondence in the middle of those remote WSN sensor hubs and the WSN passage hub (Nor et al., 2015).

The artificial neural network-based smart water quality monitoring system is proposed to forecast water quality in which code division multiple access (CDMA)-based technology is incorporated to communicate with isolated local area networks (Xiuna et al., 2010). The development of distributed wireless sensor networks-based water quality monitoring systems is challenging in real-time environment. This platform is used to monitor large areas like sea and lake water applications through wireless communication. Smart water quality approach is used to monitor parameters such as chlorophyll (Francesco et al., 2015), dissolved oxygen concentration (Christie et al., 2014; Faustine et al., 2014) and temperature (Peng et al., 2009). The anomalous activities of animals can be considered as an indication of water contamination. The biosensor-based system is used to monitor aquatic pollution and animal behaviour in the forest area (Gerson et al., 2012).

The solar-based sensor networks are introduced to reduce complexity and result in low power consumption. Solar-based water quality monitoring system with oxygen density; pH and turbidity parameter measurement has been proposed (Ruan and Tang, 2011). Monitoring of chlorine concentration in water distribution system has been developed (Eliades et al., 2014). Monitoring water quality in aquaculture centres brings the healthy growth of aquatic creature (Goib et al., 2015). The combined air and water quality measurement is introduced with added sensors (Mitar et al., 2016).

3 Proposed system

The main concept behind the proposed IoT technology is "devices are integrated with the virtual world of internet and interact with it by tracking, sensing and monitoring the objects and their environment" (Davis, 2005).

Those offers a 'smart device' that can go as apart from claiming IoT system which gathers information more than transmitting data to incite units dependent upon the majority of the data with a caution framework. The WSN sensor hub is the principle building block, a square unit of the produced WSN framework model (Allen et al., 2011). It is prepared with sensors, micro-controller units and transceivers. The sensor unit mainly comprises of a few sensors utilised for identification of water calibre parameters.

Figure 3 Block diagram of the proposed system

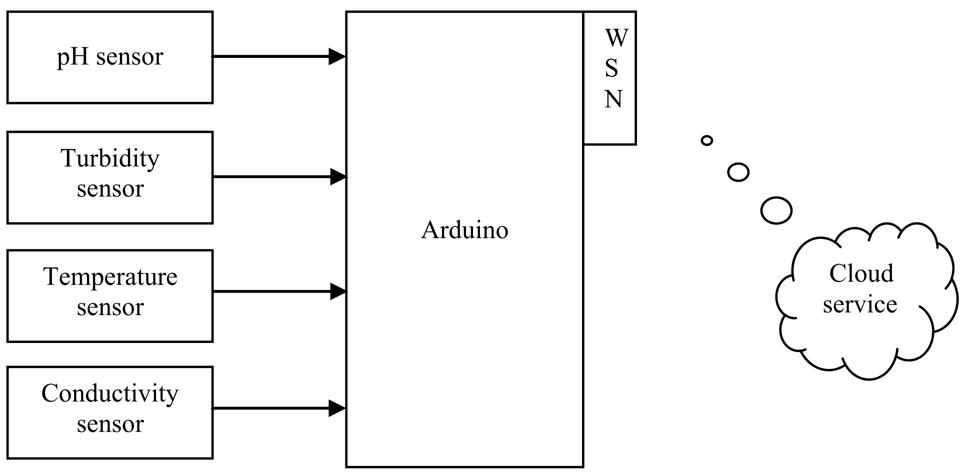


Figure 3 explains the block diagram of the proposed system. In this prototype, four sensors for measuring pH, turbidity, conductivity and temperature are utilised. Arduino is used to handle the computing. The Arduino board accumulates the information starting with sensors and uploads that information to the cloud-enabled framework for safely delivering information to the client. The pH sensor is used to measure the acidic or basic nature of water. Normal water should have a pH value of four. Then only it can be used for domestic and irrigation purposes. The pH sensor unit consists of two electrodes, one is reference electrode and another one is measuring electrode along with a temperature sensor.

The temperature sensor is used to measure the temperature variations in water. The normal temperature range of DS18B20 sensor should be between –55 and +120. If the temperature is higher, then it is not preferred to use for irrigation or to grow any organism inside the pond or lake so average temperature has to be maintained for a living organism to survive.

The turbidity sensor is used to identify the contamination of water. The contamination of water could be raised due to mixing of drainage water or waste water from industries. A nephelometric turbidity unit (NTU) is the scale of measurement. If the reflection in the water is 90º then the water is said to be pure. There can be ±5 values of deviation in the measured value. The flowing water does not have high turbidity and it may be contaminated due to the flow. The conductivity sensor is used to measure the conductivity of the water. There are different types of ions present in the water that contribute to the conductive nature of water. The TDS of water can be determined by multiplying the conductivity by a factor of 0.67.

The data is measured with the help of above sensor and it is given to the data management subsystem which helps for easy access of stored data from cloud storage. Then a data transmission is used to transmit collected data to the cloud.

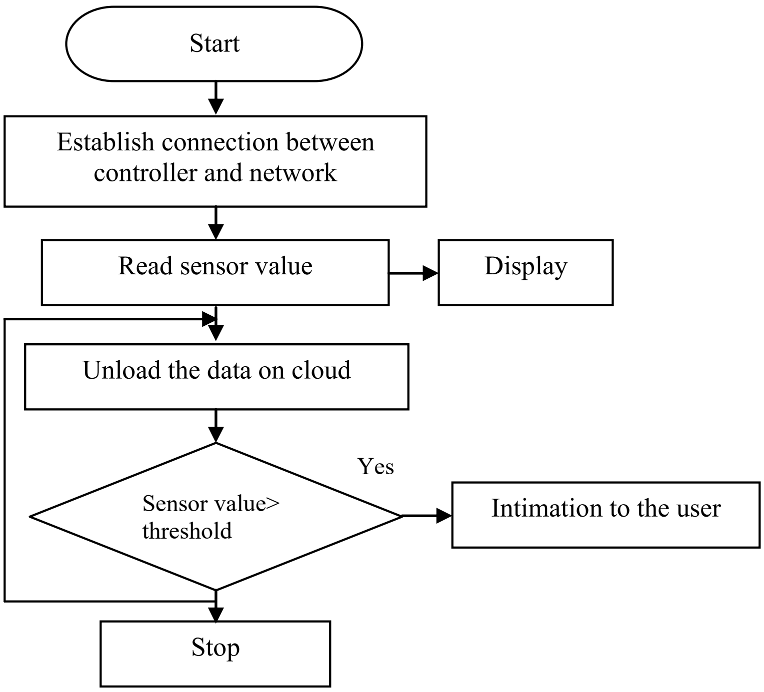
Figure 4 Experimental setup (see online version for colours)

Figure 4 depicts the experimental setup. The major advantage of the proposed WSN is that it is customisable to suit individual water quality standards. Such methodology provides the sensor readings which is accessible to the consumer with proper illustration and description for the reading given by the microcontroller. Custom aggravated vital unit ensures that framework is easily scalable in terms of the number sensors added to the network. Contrasted with the frameworks exhibited in literature, the proposed system offers a low cost, highly reliable and multi-functional alternative. This water quality monitoring system satisfies the 8th principle of green engineering as proposed by Anastas and Zimmerman (2003) which states that it is a crucial part of green engineering to meet need and minimise excess.

4 Experiment and results

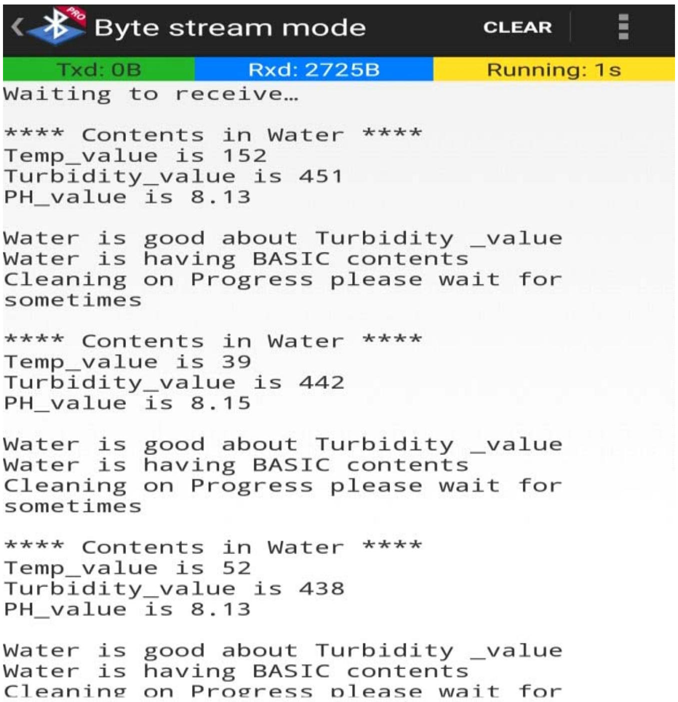
Figure 5 describes the steps involved in the proposed work. Initially, a connection between the controller and the sensor system is established. After the establishment of the connection, the sensor values are collected. At the same time, the values are uploaded to the cloud storage. The cloud storage services can be easily accessed by the end user. The stored value is checked with the threshold value which is already present in the system. If the value is greater than the threshold value, intimation is sent to the end user.

Figure 5 Uploading sensor data in the cloud



Three parameters – temperature, turbidity and pH are measured by using different sensors placed in the water. These parameters are enough to determine the state and quality of water. Figure 6 shows various experimental results for all the three parameters. If the turbidity value is high it is safe to conclude that the water is contaminated and it needs to be cleaned.

Figure 6 Experimental results (see online version for colours)



The pH value determines whether the water is acidic or basic. Each sensor is interfaced with microcontrollers and produces an output voltage depending upon the value of the parameter it measures. The microcontroller then converts the measured values in floating point values to characters. The characters are then transmitted across the wireless modules. The WSN is used to collect all the data with the help of sensors placed and transmit it to the cloud. The water gauge parameters qualities are necessary to help spared in differentiating web server on the cloud. These parameters can be viewed inevitably using a separate IP address and can be viewed from anywhere in this world with the help of mobile phone and cloud services.

The sensors are placed in three different scenarios like source water, distribution network and sewage water monitoring. In source water network, it monitors the changes in water composition and detects the contamination of water. Second, in distribution network, it monitors the proxies of bacteria in freshwater distribution to the people. Then, in sewage water system, it monitors the amount of pollutants present in the water.

The proposed system provides many advantages than the existing systems. The system addresses the lack of water quality and helps to take corrective measures for the existing challenges in the water quality management. It also helps in easy prediction and early warning. The IoT technology enabled method helps to keep the data accessible and accurate to the end user. It helps for easy analysis in laboratory and provides water quality changes.

5 Conclusions

The created framework for remotely estimating and procuring water calibration parameters comprises an effectively coordinated circuit with a cloud-based framework for constant water screening in the IoT stage. Personal water calibration may not be critical for the water supply divisions. Nevertheless, the current low-cost framework can be used by individuals who need to calibrate their drinking water. Furthermore, it is helpful to analyse whether the water can be used for drinking. This cloud-based water self checking system will fill the screening and make it expanded. The state of the water can be predicted using the aforementioned parameters.

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