ICT Smart Water Management System for Real-Time Applications

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Abstract: This paper presents an innovative and low-cost water quality and quantity monitoring system in real-time applications. The proposed application consists of various sensors used to measure water quality parameters. These parameters such as pH, Total DissolvedSolids (TDS), Ammonium (NH4), Sodium (Na), and Chloride (CL). The Arduino Mega is used as the micro-controller and Wi-Fi model to transfer the data from and to the database uploaded into the cloud. Water Level Sensor, Water Flow sensor, and Water Solenoid Valve are used to control water quantity. Liquid Crystal Display (LCD) and Keypad input and display the data. Finally, a web browser displays and manages all data uploaded into the cloud from anywhere. The proposed system can be a part of a smart city and intelligent building.

Keywords: ICT in water, Smart city, Water management, Water quantity, Water quantity.

1 INTRODUCTION

Per capita water is relatively low [1]. This is due to limited water resources, an increased population and refugees, a widening gap between available water and demand, and decreased rainfall [2]. It is worth noting that water resources are relatively low. Consequently, water pollution causes the loss of this resource to the countryin general [3] [4]. For all these reasons, there is a need for intelligent water management equipment to reduce and maintain wastewater [5]. Therefore, smart water management solutions became essential to protect this natural resource from loss. Fortunately, technological development in this age has been a vital factor in the intelligent management of water [6-8]. Moreover, with the development of technology, smart cities have emerged. All countries seek to make their cities smart as they strive to conserve natural resources, reduce energy consumption and preserve human effort [5]. This paper proposes an intelligent water management system to keep abreast of current technological developments.

On the other hand, in developed countries with limited resources and infrastructure, clean and drinkable water is filtered in local water stations with limited capacity and is transferred daily by local transportation. These water stations given as an example in Jordan are increasing in the last decade exponentially because of refugees and the lack of clean water from the water resources in general. The water stations, in general, became most popular in every even small site population. This paper will present Smart Water Management System (SWMS) for these local stations. SWMS addresses water quality and quantity challenges for these stations.

On the water quality side [9][10], it is essential to verify the effectiveness of the filter process, and to ensure the safety of drinking water, the water quality should be re-examined before it is filled in gallons at local water filtration stations. These processes help save lives from contaminated water and keep water from being lost. SWMS detects the quality of water by measuring the values of pH, Total Dissolved Solids (TDS), Ammonium (NH4), Sodium (Na), and Chloride concentration (Cl) using the appropriate sensor for each parameter. If the water quality is not good, SWMS automatically closes the water valve to prevent the filling of the gallons and then sends an alert message to the administrator.

On the other hand, on the water quantityside [11], It is essential to know the quantities of water produced by the station after filtering and the amounts sold daily. To calculate the financial profits and discover the amount of water waste, whether it was hidden by station employees or leaked from the water valve. SWMS asks the employee to enter / her username and password through the LCD and Keypad before opening the valve. The employee then orders a specific quantity of water to fill the gallons. SWMS checks the water quality, and if the result is good, it automatically opens the valve and closes it after filling the required water quantity. User login and exit time are stored in addition to the amount of water requested by the user in the database. This helps the administrators make daily, weekly, monthly, and annual financial reports and provide statistics such as the month with the immense amount of water sold per year and the user who has the most considerable amount of water sold per day, month, and year.

SWMS provides another service to measure the water level in the water tanks using a particular sensor. Suppose the water level drops to 5% of the original story. In that case, SWMS sends an alert message to the administrators and asks the main center to supply the station with an appropriate amount of water. The main center is responsible for managing all stations and providing water for them. When the main center receives water requests from the stations, it uses an intelligent algorithm to deliver water to the stations. This algorithm works to supply water requests to stations through local transport. This algorithm seeks to reduce the cost of water transport by choosing the shortest paths with the most significant number of stations, thus reducing the number of local transporters that will transport water to all stations.

The rest of this paper is organized as follows: Section 2 shows the related work, Section 3 shows system characteristics, Section 4 describes the components of the system, and Section 5 displays the results and analyzes them. Finally, Section 6 concludes this effort.

2 SYSTEM CHARACTERISTICS

Water is a vital source of survival for living organisms, so it is essential to preserve it from waste and pollution. To achieve this goal, water should be managed smartly [9]. In this paper, SWMS will be discussed at water filtering stations. SWMS contains two subsystems that aim to conserve water quality and smartly manage water quantity. The following two subsections discuss the characteristics of the subsystem of the quality and the subsystem of the amount, respectively.

3 WATER QUALITY MONITORING

Polluted drinking water is one of the causes of diseases among the population, especially in developing countries. As most people do not drink water until it is filtered, water filtering stations became important in maintaining the population's health by maintaining water quality. Meanwhile, the traditional way to detect water pollution is to manually take samples from the water source to the laboratories. This method consumes a long time and thus delays making the appropriate decisions [11]. SWMS solves this challenge by intelligent pollution detection, which maintains human effort and provides accurate results in real-time. Different sensors such as pH, Total Dissolved Solids (TDS), Ammonium (NH4), Sodium (Na), and Chloride concentration (Cl) are used to monitor the water quality. The value of these sensors is detected every x minutes and uploaded to the cloud by the Arduino Mega controller through the Internet.

SWMS ensures that these values are in the normal range for each parameter shown in Table 1. Otherwise, SWMS sends an alert message to the administrator, whether by SMS or email. Moreover, SWMS turns off the water valve automatically.

Table 1: Normal quality range of drinking water param.

Parameter	Quality range	Unit
pH	$6.5 < pH < 8.5$	pH
TDS	$300 < TDS < 1500$	mg/L
NH4	$0.05 < NH4 < 0.5$	mg/L
Na	$20 < Na < 175$	mg/L
CL	$25 < Cl < 200$	mg/L

The following code illustrates the Measure Quality Sensors (MQS) Algorithm responsible for detecting the water quality based on the measured values of the sensors.

```
Measure Quality Sensors (MQS) Algorithm
L1:     Start.
L2:     Turn on all sensors.
L3:     Read the water level sensor L4:
        IF (tank water level < 5%) L5:
        {
L6: Send an appr. Msg to the admin. L7: Turn off the water control valve.L8:  GOTO L3.
L9:     }
L10: ELSE L11:
{
L12: Read all qual sensors values. L13: Store the data in the database.L14:  IF (Water qua value ∉ Range) L15: {
L16: Send an appro msg to the admin.L17: Turn off the water cont. Valve.L18:  GOTO L3.
L19:      }
L20:   ELSE
L21:      {
L22: Turn on the water control valve.L23:   }
L24: }
L25: GOTO L3.
```

The measured quality parameter values $QPV(r)$ of each parameter QP ={pH, TDS, NH4, Na, CL} are stored in the database and uploaded to the cloud. This action enables administrators to conduct future studies on the quality of water used in this country. QPV(r) is measured for each $r = \{r_1, r_2, r_3, \ldots, r_n\}$ where r_1 and r_n are the time slots when the station is opened and closed respectively, not that

$$r_n = r_{n-1} + 15\, min \qquad (1)$$

One of the objectives of SWMS is to register the quantities of water produced by the station to achieve the following objectives: 1. Preventing wastage of water in the water filtering stations may be caused by workers in the station, 2. Comparing profits with produced desalinated water quantities

1. Tank Water Level: The water level in the tank is continuously measured. In case of the water level becomes less than 5% of the tank level, SWMS sends an alert to the administrator, so he can take appropriate action and request additional quantities of water promptly. The requested amount of water by station s on day d is:

$$parentRQS(s,d) = \sum T(t,s) * TQ(t) \qquad (2)$$

Here $T(t,s)$ number of tanks t are sold to station s and $TQ(t)$ is the quantity of each one of them.

2. User's Actions: each user has a separate table containing the time, date, and amount of water requested each time—also the total amount of water sold by this user.

3. Daily Action Report: The administrator can view the users' actions for each day, determine which user has the most considerable amount of water sold, and select the total amount of water sold in a given day. The water quantity sold by the user u (station worker) on day d is:

$$\text{SdQ (u,d)} = \sum_n SdQu(n) \qquad (3)$$

Where n is each time during d, the user sold a new quantity of water. Based on that, the amount sold by the station during d is:

$$\text{SdQ(s,d)} \sum_u SdQ(u,d) \qquad (4)$$

with daily income:

$$\text{DI(s,d) = SdQ(s,d) * GP} \qquad (5)$$

Where GP is the price of one gallon of water.

4. Monthly Action Report: As the daily report, the administrator can view the monthly report that determines which user has the most significant amount of water sold in one month and the total amount of water sold this month. The monthly revenue for month m is:

$$\text{MR(s,m)} = \sum_1^{mx} \text{DR(s, d)} \qquad (6)$$

where mx is the last day of the month m, and the monthly income is

$$\text{MI(s,m)= SdQ(s,m) * GP} \qquad (7)$$

Where SdQ(s,m) is the station sold quantity during that month and equal to :

$$\text{SdQ(s,m)} = \sum_{d=1}^{mx} \text{SdQ(s, d)} \qquad (8)$$

Accordingly, QPMnN < QPV(r) < QPMxN, where QPMnN and QPMxN are the minima and max normal quality parameters.

3.1 Water Quantity Monitoring

helps control financial issues, 3. Preparing future environmental or commercial studies based on these records, and 4. Providing easy station management and control. To achieve these objectives, SWMS offered the following options:

5. Yearly Report: This report displays sales statistics every month of a particular year. The yearly revenue is:

$$\text{YR(s,y)} = \sum_1^{12} \text{MR(s, m)} \qquad (9)$$

and the yearly income is:

$$\text{YI(s,y) = SdQ (s,y) * GP} \qquad (10)$$

where SdQ(s,y) is the sold quantity by that year and equal to :

$$\text{SdQ(s,y)} = \sum_{m=1}^{12} \text{SdQ(s, m)} \qquad (11)$$

In addition, they classify the year due to the consumed quantity, where month MxCM is the month with the maximum consumed quantity and is equal to:

$$\text{MxCM = m (max (SdQ (s,y)))} \qquad (12)$$

and MnCM is the month with the minimum consumed quantity and equal to:

$$\text{MnCM = m (min (SdQ (s,y)))} \qquad (13)$$

6. Station Bill: When the station asks for water from the main center, this order is saved in the database. All orders not paid for are displayed as bills to the station. The total price is calculated as the following:

$$\text{P(d)} = \sum_d \text{RQS(s, d)} * \text{LP} \qquad (14)$$

Where LP is the price of one liter of water and $\sum_d \text{RQS(s, d)}$ is the all requested quantities that are not paid for.

One of the objectives of SWMS is to register the quantities of water produced by the station to achieve the following objectives: 1. They are preventing water wastage in the water filtering stations, which may be caused by workers in the station, 2. Comparing profits with produced desalinated water quantities helps control financial issues, 3. They prepare future environmental or commercial studies based on these records, and 4. They provide easy station management and control. When all of these components are combined, the system block diagram is shown in Figure 2.

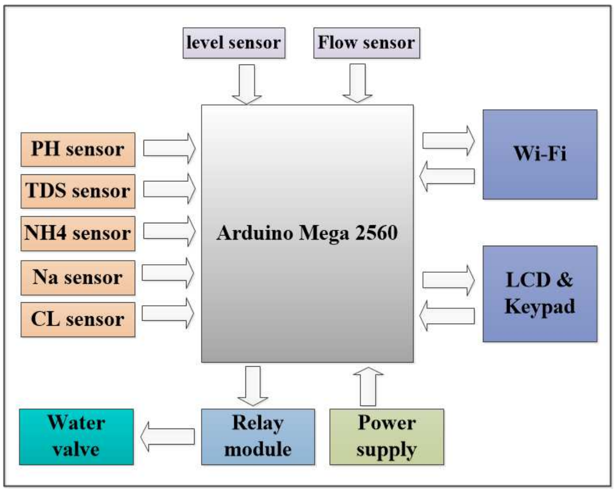

Figure 2: System Block Diagram

4 EXPERIMENTAL RESULTS

The proposed system is divided into two parts. The first one represents the hardware side, responsible for water quality monitoring. Five sensors (PH, TDS, NH4, Na, and Cl) are connected to the Arduino Mega to make the device embedded. This device is placed in water taps (valves) at the station. All data generated by this device is loaded into the cloud so that it can be viewed from all over the world. Figure 3 illustrates the final view of the System that is applied in the station and combined with the cloud.

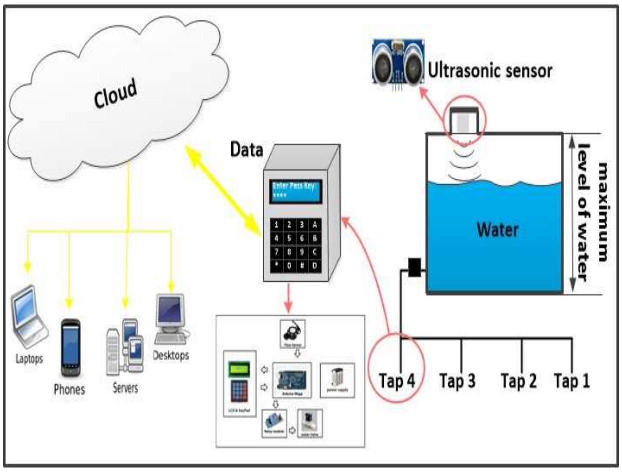

Figure 3: Overall view of the SWM System

On the other hand, the second part represents the software side and is responsible for data mining. The proposed system can manage all data uploaded in the database on the cloud from anywhere. For example, Figure 10 illustrates Quality sensors values which allow the administrators to see the measured values for any parameter on a given day for any station.

5 CONCLUSION

This paper presents Smart Water Management System for water filtering stations. The proposed system is generated with five sensors to measure the quality of the water, Arduino Mega as controller, and Cloud to store the data. Also, the proposed system is responsible for recording the amount of water entering and leaving the station to prepare different statistics and reports using these values. It is still being modified as more features will be added to increase its efficiency, and the proposed system can be part of the smart city.

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