Smart Water Distribution System

Raghavendra Havaldar & Sruthin Balachandran V.V

Assistant Professor in Electronics & Communication, A J Institute of Engineering & Technology, Mangaluru, Karnataka, India

***Abstract*- Water leakage in water distribution system is a major issue. The leak in pipes could be due to various reasons like poorly constructed pipelines, inadequate corrosion protection etc. The paper consists of a model that is been designed to detect and respond to the water leak at the earliest. During water leakage, real time transmission of information at dynamically changing environment should be achieved. This can be done using Wireless Sensor Network (WSN) technology. Here water flow sensors are used to detect water leak in distribution system by observing change in flow rate. The sensor data is collected using microcontroller and transmitted using an XBee module to the server. At the server the data is processed and is stored in the database which helps in the generation of report on consumption of water. A solenoid valve is used at the water head, which turns off automatically whenever a heavy leak in the system is detected.**

***Keywords*- Xbee, Arduino UNO, Flow sensor, AT89C51 MC**

I. INTRODUCTION

Water, "The Liquid of Life" is true in every aspect. The need for sustainable water supply systems is ever increasing. Though earth's 70% of total area is covered with water, about only 1% of total water is accessible for direct human usage and with the increasing demand for fresh water domestically and commercially in rural and urban areas, utilities can no longer tolerate inefficiencies in water distribution systems and the resulting loss of revenue associated with water system leakage.

Old and poorly constructed pipelines, inadequate corrosion protection, unauthorized connection, poorly maintained valves and mechanical damage are some of the factors contributing to leakage[1]. Of the many options available for conserving water, leak detection is a logical first step. The traditional pipeline leakage detection methods depend on the periodical inspection[2] conducted by the maintenance personnel but this does not provide real-time monitoring of pipes resulting in leakages that might not be detected in time and thus causing the wastage of water in a large scale.

In this paper, we introduce a water distribution system which uses invasive sensors to detect the flow of water. This system is helpful in reflecting detection of the water leakage, generation of report on water consumption and indicates approximate location point of the leak.

Some of the potential benefits of this system include efficient use of water supply, reduced risk of contamination and improved environmental quality.

The paper is organized as follows: in Section II an overview of the way in which a system works is given. In Section III, software simulations are briefed. Section IV and V are devoted to the description and the implementation of the hardware used, while Section VI discusses the results. Conclusions from this work are summarized in Section VII.

II. PROJECT DESCRIPTION

The proposed water distribution system comprises of two parts, the transmitter system or sensor and the receiverpart or server. In the transmitter part, water flow sensors are deployed inside the pipeline which generates pulses as the water flows through it. Pulses are then counted using microcontroller and sent wirelessly to the receiver end using Xbeetransceiver, which works on ZigBee technology[3].

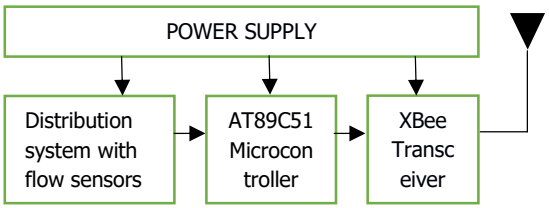


Figure 1. Transmitter system

In the receiver part, the transmitted data are received and then processed using Arduino. The Arduino compares the data with predetermined threshold value to detect leak. This processed information is passed on to the database over an established LAN. The GUI displays the database entries which are recorded at specified time intervals. The stored data can also be used for report generation.

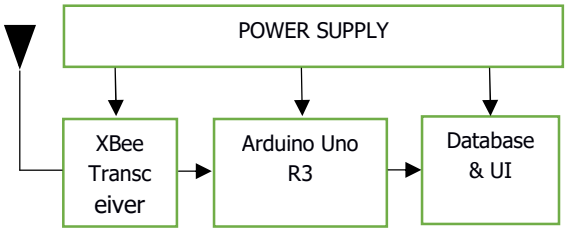


Figure 2. Receiver system

III. SOFTWARE SIMULATION

The software implementation of the proposed water leak detection system was done using Proteus Design Suite software. The circuit schematic to count the pulses generated by the water flow sensor was designed in ISIS schematic capture tool and the program was loaded into the AT89C51 microcontroller[4] and executed.

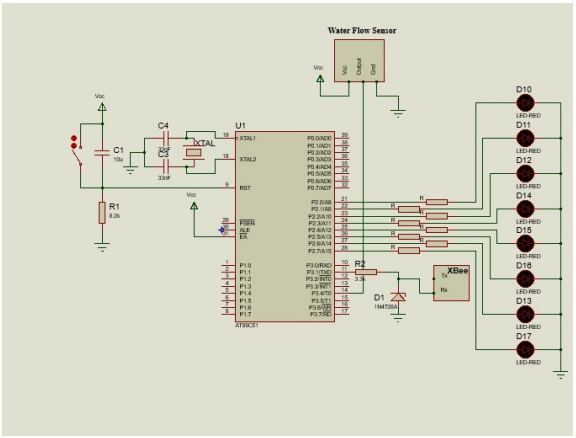
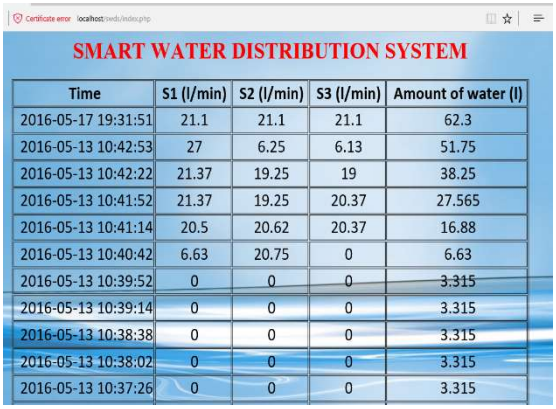


Figure 3. Pulse counter

A database which stores data related to proposed system was designed using XAMPP software. XAMPP is a free and open source cross platform web server solution stack package, consisting mainly of the Apache HTTP Server, Maria DB database and interpreters for scripts written in the PHP and Perl programming languages.



SMART WATER DISTRIBUTION SYSTEM

Time	S1 (l/min)	S2 (l/min)	S3 (l/min)	Amount of water (l)
2016-05-17 19:31:51	21.1	21.1	21.1	62.3
2016-05-13 10:42:53	27	6.25	6.13	51.75
2016-05-13 10:42:22	21.37	19.25	19	38.25
2016-05-13 10:41:52	21.37	19.25	20.37	27.565
2016-05-13 10:41:14	20.5	20.62	20.37	16.88
2016-05-13 10:40:42	6.63	20.75	0	6.63
2016-05-13 10:39:52	0	0	0	3.315
2016-05-13 10:39:14	0	0	0	3.315
2016-05-13 10:38:38	0	0	0	3.315
2016-05-13 10:38:02	0	0	0	3.315
2016-05-13 10:37:26	0	0	0	3.315

Figure 4. Sample page of database

XAMPP is preferred since it is a simple, lightweight apache distribution that makes it extremely easy for developers to create a local web server for testing purposes. Everything needed to set up a web server – server application (Apache), database (MariaDB), and scripting language (PHP) is included in extractable file[5]. XAMPP is also a cross-platform, which means it works equally well on Linux, Mac and Windows unlike WAMP and LAMP, similar application software which work only in Windows and Linux respectively. Latest version of XAMPP is 7.0.3 for all the operating systems.

An Android application was developed using Android Studio v2.1 RC coded using JAVA. The application was built to monitor the status of the system and to access the database on the go. A WLAN connection must be established to connect the android device to the server. This android application works on the basis of simple server client communication where the database is the server and the connected android device is the client. Current flow rates through all three sensor systems are fetched from the server and displayed for the user's reference. A water distribution system model is created graphically to display the current status of the system.

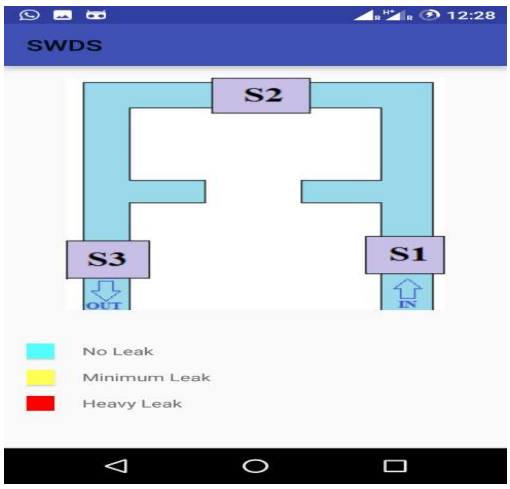


Figure 5. Android application

Following features are included in the developed application:

1. Current flow rate through all sensor nodes are updated periodically
2. Current Status of the system is displayed graphically.
3. Displays the front end of the database.
4. Application is supported on all systems running android 4.0+
5. A user friendly UI is designed for ease of use.

The sensor node XBee's are configured as routers in AT mode. AT stands for Transparent mode where it transmits the serial data falling on Din pin of XBee. The data on Din pin is transmitted over a 2.4GHz RF channel to a pre-fed address. The 64-bit address of the server XBee must be stored in all sensor XBee's so that the data transmitted by sensor nodes is received only by the server node. Configuration of XBee's establishes a WSN. The devices in the WSN must have the same PAN ID to send or receive data in the network. The data received by the XBee is sent to the outside world through the Dout pin. Similar to sensor node XBee's, server node XBee is also configured as router in AT mode. As the server has to transmit data to all the sensor nodes, it is set to broadcast mode. This is done by loading the destination address as 0FFFF. The data received by the server XBee is given serially to Arduino.

IV. HARDWARE DESCRIPTION

AT89C51 Microcontroller

The AT89C51 is a low-power, high-performance CMOS 8-bit microcontroller with 4 Kbytes of Flash Programmable and Erasable Read Only Memory (PEROM). The device is manufactured using Atmel's high density non-volatile memory technology. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel

AT89C51 is a powerful microcontroller which provides a highly flexible and cost effective solution to many embedded control applications. AT89C51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes.

XBee Transceiver

The XBee module is a ZigBee /IEEE 802.15.4 compliant solution that satisfies the unique needs of low cost, low power wireless sensor networks [6]. The modules are easy to use, require minimal power and provide reliable delivery of critical data between devices. It operates within ISM 2.4 GHz frequency. ZigBee supports several network topologies; however, the most commonly used configurations are star, mesh and cluster tree topologies. Some features of XBee include Maximum range is 100m, operating voltage is 2.8V to 3.4V, AES method of encryption is used and Modulation method used is DSSS, operating frequency is 2.4Ghz[6].

XBee transceivers are preferred over RF 433MHz module because there is no interference problem in XBee since 128bit address prevents other signals from interfering. It also offers data reliability, low system cost, good range and a flexible network.it is easier to establish a network using XBee than 433MHz module.

Arduino UNO

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on computer, used to write and upload computer code to the physical board. Arduino IDE uses a simplified version of C++, making it easier to learn to program [7].

Arduino Uno specifications include Operating voltage of 5V,

Recommended input voltage of 7V to 12V, 32KB flash memory, 2KB of SRAM, 16MHz clock.

Internal memory of the Arduino UNO is sufficient enough to accommodate the sensor data. XBee transceiver can also be interfaced with UNO easily using XBee shield. Arduino UNO consumes less power requirement compared to other on-board microcontrollers. Hence it can be concluded that Arduino meets the requirement of the project. Therefore, it has been used.

Flow sensor

Water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, rotor rolls. Its speed changes with different rate of flow. The hall-effect sensor outputs the corresponding pulse Signal.

Some of the features of flow sensor include Working voltage range of 5V-24V, Maximum current that can be applied is 15 mA (DC 5V), Flow rate range is 1～30 L/min, Extent of error is ±5%.

V. HARDWARE IMPLEMENTATION

The microcontroller circuit and the XBee transceiver are the main two parts of the sensor system. The microcontroller circuit counts the number of pulses produced by the flow sensor and sends it serially to XBee transceiver. An XBee transceiver transmits the serially received data to the server XBee. The figure 1.A shows the designed sensor system.

XBee transceiver, Arduino UNO R3 and Ethernet shield are the integral parts of the server system. The figure 1.B shows the server system. As the XBee transceiver sends the received data to Arduino, the Arduino compares the data from different sensor nodes and checks for leak. Finally, the data is entered into the database by accessing the established LAN with the help of Ethernet shield.

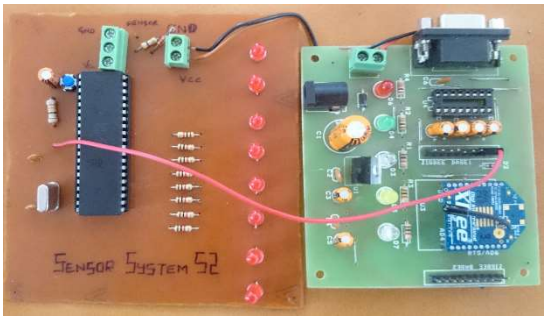


Figure 6. Sensor System

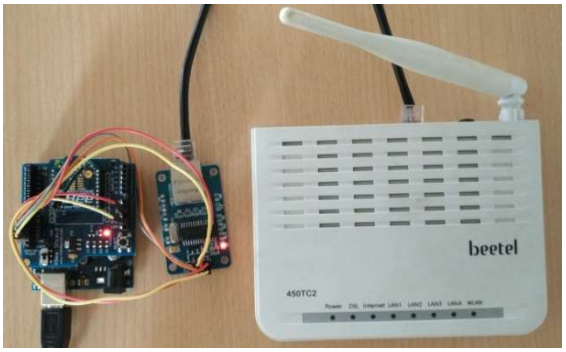


Figure 7. Server System

VI. RESULT ANALYSIS

The pulse width of flow sensor output reduces with the increase in water flow rate i.e. the frequency of the pulses increases with increasing flowrate of water. The difference in the frequencies from two adjacent sensors indicate the presence of leak in the system. To observe the presence of leak, the flow sensor output was connected to the oscilloscope. A sample output is shown in figure 5.1 which indicated the presence heavy leak between two adjacent water flow sensors. Similar observations were done for different amount of leak between any two adjacent water flow sensors. Many trials were conducted and repeatability was established.

The frequency of flow sensor output was found to be directly proportional to the flowrate of water. This matched with the

data obtained from the datasheet. The water flow rate can be obtained from the frequency of pulses. The pulse width and the frequency obtained for corresponding water flow rate value when tested with a 8W aquarium pump are listed in table 5.1.

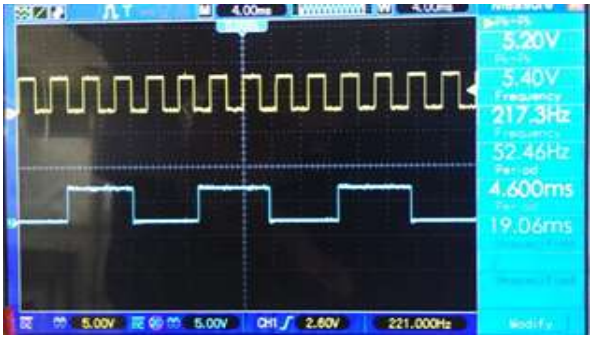


Figure 8. Water flow sensor output

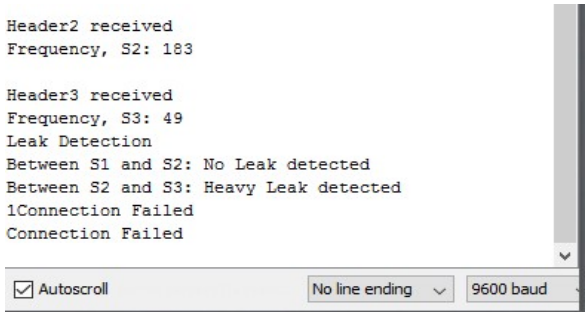
When there is a heavy leak in the system, the difference in flowrate of adjacent sensors is calculated. The result is then compared with two predetermined thresholds to observe the severity of leak.

Table 1. Water flow sensor output

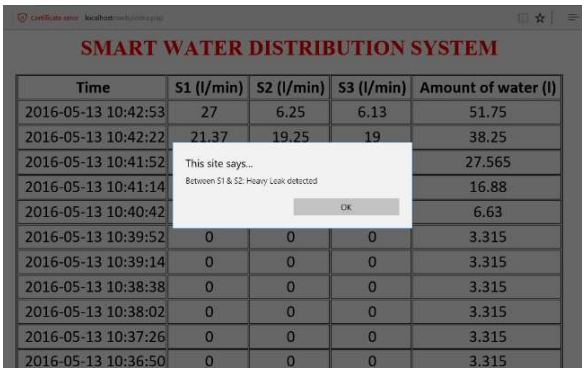
Trial No	Pulse time period (mS)	Water Flow rate (Lt/min)	Pulse Frequency (Hz)
1	19.00	6.6	52.6
2	19.12	6.6	52.3
3	19.22	6.6	52
4	23.80	5.2	42
5	26.92	4.6	37.1
6	31.76	3.9	31.5

Arduino serial monitor displays the received data and compares them. A message will be displayed indicating the status of the system. The data obtained is entered into the database and a popup will be generated in case of leak. Android application developed used the data from the database and indicates the status of the system. Application also indicates the flowrate of water at different sensor nodes.

A heavy leak was introduced in the system and figure 5.2 shows the data output at different parts of the system.



(a)



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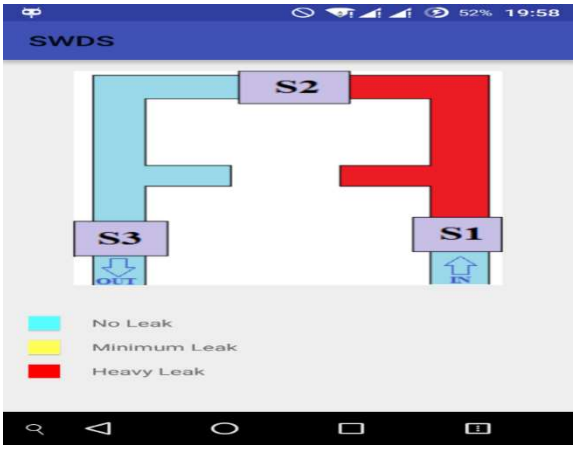

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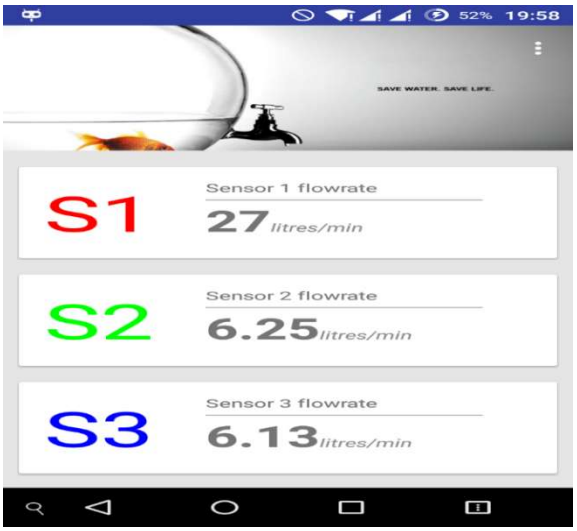

(d)

Figure 9 (a)Arduino Serial Monitor (b)Database GUI (c)Android application displaying system status (d)Android application displaying flowrate

VII. CONCLUSION AND FUTURE SCOPE

Conclusion

The final outcome of the project is a novel smart system that monitors the water leaks in water distribution system and prevents wastage of water. The project also keeps track of the

water consumption in different sections of water distribution system and enters the values to the database. The values are displayed in the GUI and those values can be used for report generation. In this project a major module i.e. Leak Detection in Water Distribution System is successfully implemented using which water leaks were detected in different parts of the system by comparing the data from different sensor nodes which are transmitted over RF carrier using ZigBee protocol. Hence, database is updated and the leak is notified in different parts of the system using popups in the GUI page. The android application installed in a device connected to the established local area network displays the status of the system along with the flowrate of water at different sensor nodes. The project has given a cost effective solution for real time water leak detection and recording of consumption information by detecting the leaks at specific parts of the water flow system and updating them to the database.

Limitations

1. The RF transmission and reception range is limited to 100 meters.
2. Remote control of the system from a distant location is not possible as LAN is used.
3. The already existing system's integrity should be disturbed in order to install the sensors as the method used here is invasive.
4. The sensor system is unfeasible for underground systems due to its structural properties.

Scope for Future Work

The outcome of the project is a novel solution to detect the leaks in the water distribution system and to keep track of water consumption. Though the project looks complete in all aspects, there is room for further improvement. Some of the improvements which can be considered are listed below

1. System can be implemented using a non-invasive sensor whose installation does not affect the integrity of an already existing system.
2. A WAN can be used for remote controlling of the system from a distant location.
3. The entire sensor system can be built on a chip making it feasible for any application.
4. Long range RF communication protocols can be implemented which enables the server to handle more number of sensor systems.

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