Water Management And Metering System For Smart Cities

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Abstract— This work puts forth an idea to provide a solution for water management effectively and efficiently. The growing demands of water in urban areas due to the increased population and the lack of standardization among the water distributors lead to affect the quality and quantity of drinking and domestic water supply. This raises the special concern of water management, which needs to improve the efficiency in the water distribution system. The various advancements in the wireless sensor network technologies provide solution to overcome these challenges. This paper presents a water management system which will continuously monitor and analyze the quality and quantity of water being dispensed at each house through the flow sensor, pH sensor and also allows the user to customize their limits in terms of quantity of water needs. The sensors data are gathered online and stored in the cloud for further data analytics and processing by means of IoT. This helps in the ease of billing and also for prepaid payment. This system cuts down the water flow and notifies the user when the water usage exceeds the limit with respect to the prepaid amount and also when there is an anomalous water quality in the distribution system. This system can be of a great help in smart cities to regulate the supply of water for effective use of the depleting resource.

Index Terms— IoT; Zigbee Communication; Water Quality Management; Flow sensor; pH sensor; Xampp;

1 INTRODUCTION

Water is always playing a vital and crucial role in our everyday life. Wasting of this precious resource will create an adverse situation in future in terms of cost. Meanwhile the United Nations has estimated the world's population will reach 9 billion by 2050.According to the survey by FAO and water.org by 2025, 1.8 billion people around the world will face the water scarcity, and 2/3rd of the world will be living under water stressed conditions. By 2030, almost half of the world will live under high water stress condition. Mainly in developing countries like India, development in industrialization, urbanization and population growth led to water demand and water pollution. India faces the high to extremely high-water stress which is approximately almost 600 million people are at higher risk of surface-water supply disruptions. Studies from World Research Institute found that around 130,600,000 people live in districts where at least one pollutant exceeded national safety standards in 2015. In traditional water system the money payment will be done prior or after, irrespective of the usage or the manual examination of water meters for billing purpose which result in human error and manipulation. Apartments and commercial complexes uses a common meter and the bill amount is shared equally, providing incentives for residents to conserve water. Hence, the traditional water metering has to get some improvements in terms of both infrastructure and billing schemes. The recent technologies like wireless sensor networks, IoT [1] etc., helps to monitor and determine the quality of drinking water in a large water distribution networks. This water management system consists of several nodes and each node consists of sensors to measure the amount and quality of water distributed in each segment, and a microcontroller where the sensor data will be processed and uploaded to the cloud storage [13].

The server is loaded with Xampp for processing the data and provides solution using MySQL. Such a framework [9] of measurement and analysis of water usage will provide a solution for water management [4] effectively and efficiently. This will also provide solutions to leakage management [12], demand management, asset management and for the future predicament of water needs.

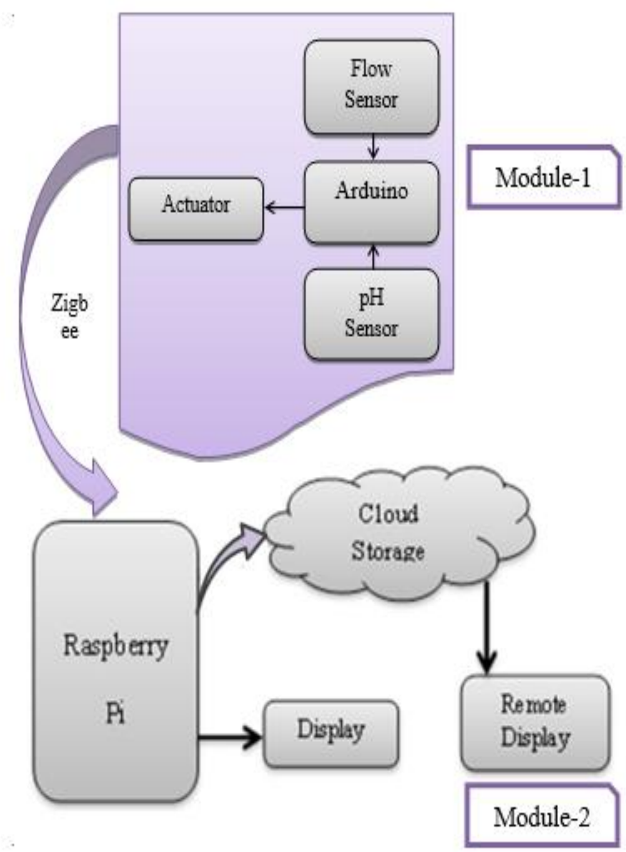


Fig.1 - Block diagram

2 SYSTEM ARCHITECHTURE

Smart sensor network [2] will be deployed in each distribution system in order to monitor the volume of water used for the particular day in regular intervals. Each distribution point will be taken as separate node. The recorded data will be analyzed [8] for future distribution of water to the respective nodes by means of Internet of Things. The system architecture composed of two modules. Module-1 is made of a flow sensor, a pH sensor, actuator and arduino where the amount of water consumed will be calculated along with the pH. The Module-2 comprises of raspberry pi and display where the received data from the arduino will be transmitted to the cloud server for the user interface. The Module – 1 and Module – 2 will communicate via ZigBee communication protocol.

3 HARDWARE DESCRIPTION

The major hardware for this system includes arduino, flow sensor, pH sensor, actuator, raspberry pi, and zigbee.

3.1 ARDUINO

Arduino is an open source flexible platform for electronic prototype with easy to use hardware and software. Arduino UNO is an ATmega328 based microcontroller has 14 digital input/output pins, 6 analog pins, a USB connection and a reset button. This simple computer will run only one program at a time.

3.2 RASPBERRY PI

Raspberry Pi is a general purpose, fully functional credit card sized computer. It has a dedicated processor, AUX port, USB ports, and graphics driver for output through HDMI. The system generally run on Linux OS and has an ability to run multiple programs at a same time. The SD card slot provided by the R-Pi will house the flash memory for the entire system. R-Pi-3 is the third generation in Raspberry-pi comes with the 1.2GHz 64-bit quad-core ARM V8 CPU with 1GB RAM and also with in-built WLAN and Bluetooth.

3.3 ZIGBEE

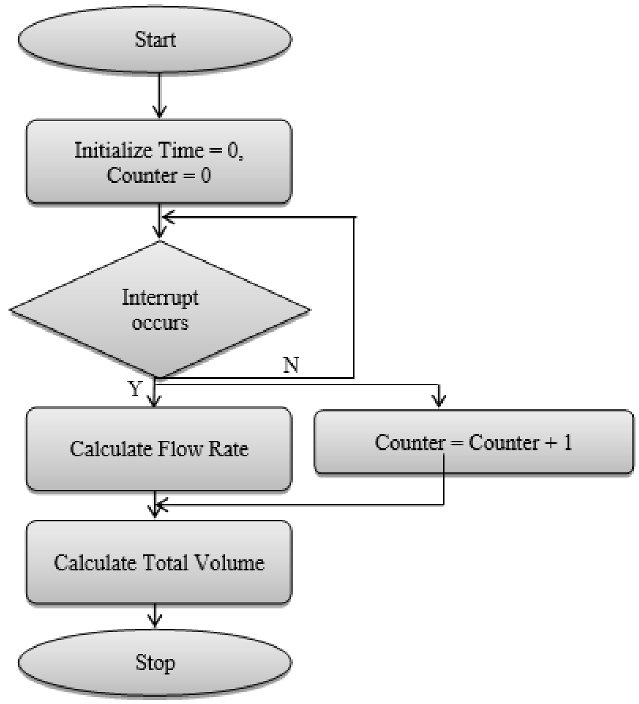
Zigbee is an open global standard low cost, low power wireless M2M transmission technology. This high-level communication protocol is used to create personal area network with small, power digital radios designed for point-to-point, mesh and star communications. Zigbee S2 and S2C will have the indoor/urban range of 40m and 60m respectively. and outdoor RF line-of-sight of 120m and 1200m resp. Zigbee operates in a standard frequency of 2.4GHz and operating voltage of 2.8 - 3.6V.

3.4 SOLENOID VALVE

The ½" Nominal NC, one directional water solenoid valve works on 12V DC with the temperature range from 1-75°C. When the voltage is applied between the two terminals the valve gets open and the water flows through. The gasket arrangement inside the valve will require a minimum working pressure of 0.02MPa.

3.5 FLOW SENSOR

The YF-S201 is a cost effective, Hall Effect water flow of water being dispensed simply quantity. The sensor containing a Hall-Effect sensor that outputs a pulse rate proportional to flow rate with every revolution. The sensor will work effectively in 5V with the working temperature range from -25 to 80 °C and measures 1-30 l/min with 2.0 MPa.



3.6 pH SENSOR:

The pH Circuit is a highly compact pH monitoring system that can be interface with any of the development boards. This pH sensor will communicate through UART communication. This locally made pH sensor will also ably find the level, temperature, turbidity. The sensors have the same attributes of what the Atlas pH scientific sensor does. This sensor will work in an operational voltage of 5V and the range from 1.5 to 9.

4 SOFTWARE DESCRIPTION

4.1 ARDUINO IDE:

Arduino IDE is an open source software platform was written in java, especially for arduino boards to write code easily. This IDE accepts both C and C++ and all the libraries are written in C++ without object oriented and it is supported by Windows, Mac and Linux.

4.2 RASPBIAN OS:

Raspbian OS is specially optimized for the raspberry hardware. The OS will have a set of basic programs, libraries and utilities over 35,000 packages, pre-compiles software bundled in a format for the easy installation of raspberry pi.

4.3 PYTHON

Python is a general purpose, free, open source, interpreted, dynamic programming language widely being used as same as normal C programming languages. Python supports multiple programming paradigms approach including object oriented.

4.4 XAMPP

Xampp is a free open-source web server solution package for the scripts written in PHP - a general purpose programming language designed for web app development, supported by Apache HTTP – web server software.

5 SYSTEM METHODOLOGY

The water management system is primarily divided into two modules. Module 1 and module 2 deals with the hardware setup of the system. The third part deals with the server and the webpage.

5.1 MODULE – I

The flow sensor and the pH sensor is initially calibrated and interfaced with Arduino. The flow sensor is used to measure the flow rate as well as to measure the total volume of water used. In further the same flow sensor can also be used to discriminate the leakage by calculating the amount of water dispensed actually from the water user received. The pH sensor is implemented in order to monitor the quality of the drinking water. The solenoid valve is interfaced to open way for the water flow when the system starts and also in order to stop the flow when the user exceed the limit of water used according to the payment and if there is any anomaly in the quality. This entire setup forms one node, like this several kinds of nodes [7] will be added. In the Module-1, Arduino will be the microcontroller used to receives data, co-relate and send the received data to the Module-2.

5.2 MODULE – II

Initially Raspberry Pi is installed with raspbianOS and the initial update and upgrading process is done. It is also loaded with the Xampp webserver along with Apache and MySQL. Both Arduino and R-Pi is interface with Zigbee, from Arduino side it will act as a router [5] and in R-Pi side it will act as a coordinator. For every second the Arduino will sense the data from the sensors interfaced and transmit to the r-pi via ZigBee in star topology. Raspberry Pi will send the received serial data from the Arduino, to the cloud server and also save the data in the form of .CSV file for future reference.

5.3 SERVER AND WEB PAGE

Once the data from the arduino entered into the R-Pi, it segregates the data to its respective field. Xampp is loaded with apache server, so that based on the HTTP request from the user side or from the admin the system will able to respond. API port access may be of HTTP or HTTPS and it only works if the request is in the form of PHP. MySQL will have the total database and the Hypertext Pre-processor will access the database by means of querying. From the cloud server the data will be entered into the webpage for the user end. Separate user names and passwords will be given to every user and they can pay the bill amount which is metered [3] online for the water been used by means of IoT. The system flow chart clearly explains the working of the Module -1 and Module -2.

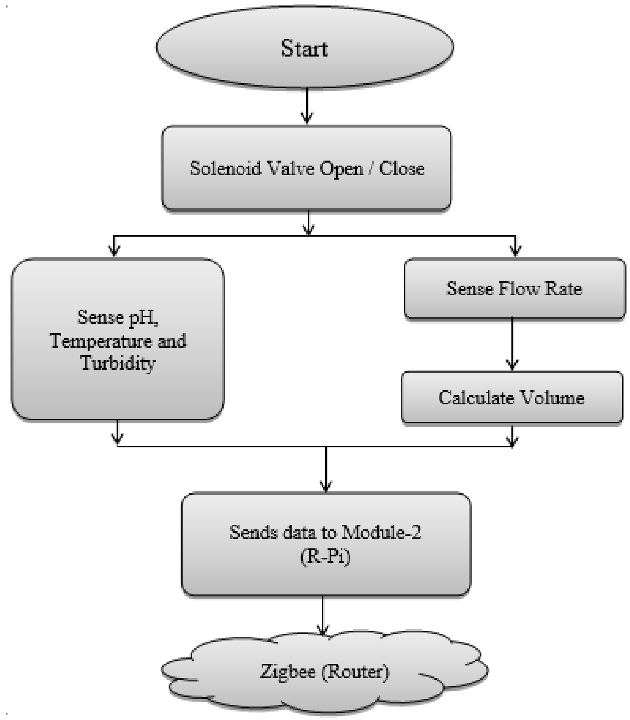


Fig.3 – Module -1 Flow Diagram

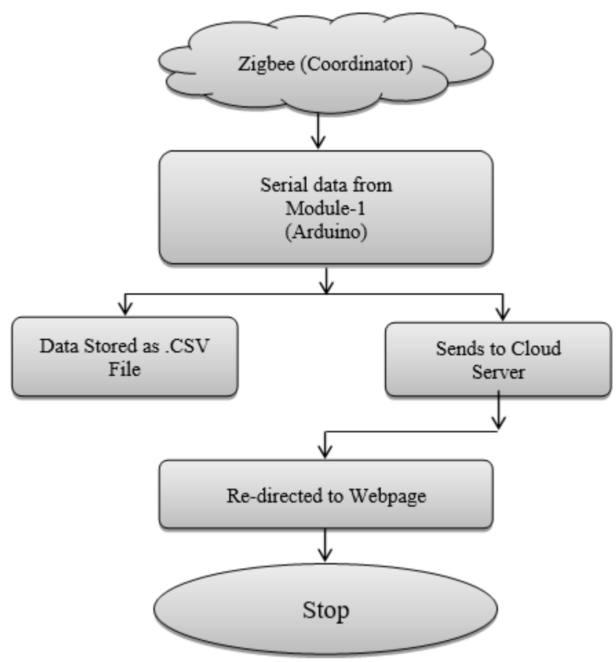


Fig.4 – Module 2 Flow Diagram

6 SYSTEM ARRANGEMENT

The IoT based water management system for smart cities involves two levels [11] of communication. The first level communication includes the IEEE 802.15.4 standard makes the Module-1 and Module-2 interface [10]. The second level includes the IEEE 802.11 which makes the application layer interface. The water management system arrangement is implemented as shown in Fig.5 and Fig.6,

Fig.5 – System Prototype

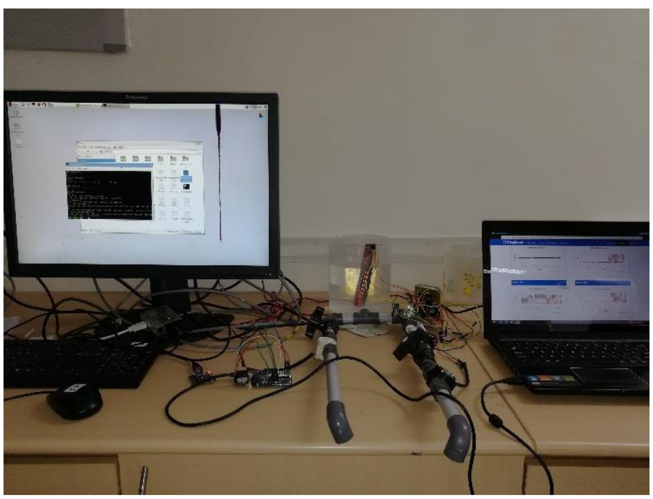


Fig.6 – Module -1 and Module-2 Interface

S. No	Time (Sec)	Measured Flow Rate (L/hr)	Actual Flow rate (L/hr)
1	13	280	276.9
2	15	236	240
3	22	159	163.63
4	27	135	133.33
5	45	74	80

Table.1 - Measured vs. Actual flowrate.

7 CALIBRATION

The comparison between the standard and the measured readings for the flow sensor and pH sensor is shown in Fig.7. The time it took to fill with various flowrate of 1liter water.

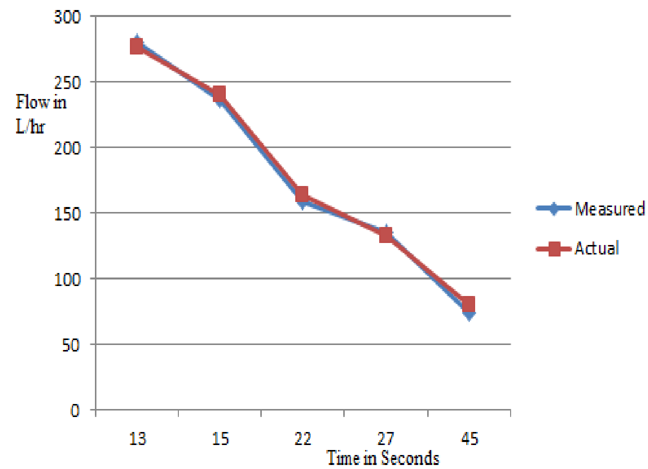


Fig.7 – Calibration Graph for 1 Liter [Table.1]

The time taken to fill 2liters of water with constant flowrate is shown in Table.2

S.No	Volume (ml)	Time (Sec)	Constant Measured Flow rate (L/hr)	Actual Flow rate (L/hr)
1	300	4.50	240~245	243.079
2	600	9.36		
3	1000	14.68		
4	1300	20.81		
5	1600	27.23		
6	2000	29.62		

Table.2 – Time vs. Volume with Constant and Actual flowrate for 2 Liters

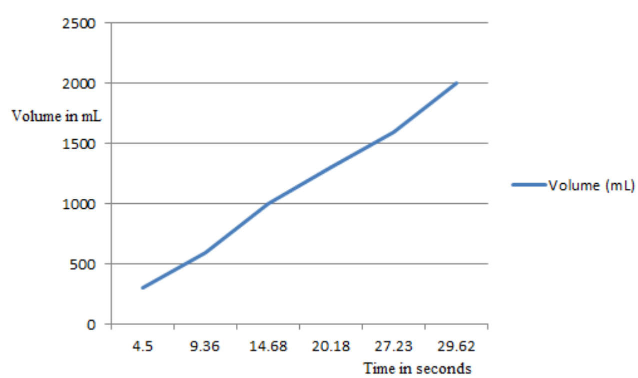


Fig.8 – Calibration graph for Time vs. Volume [Table.2]

The efficiency of the flow sensor is calculated from the [Fig. 6.1] as follows,
Efficiency = Actual flow rate / Measure flow rate → eqn.1
Mean = 98%
Thus, the calibration resulted with an accuracy of +/- 2ml.

The pH sensor is calibrated in two methods in order to get efficiency as well as accuracy. One with the acceptable standard permissible pH vs measured pH. Secondly the pH sensor is compared with the calibrated pH meter.

S. No	Solvents	Permissible pH Range	Measured pH Range
1.	Drinking Water	6.5-8.5	7.45
2.	Milk	6.5-6.7	6.49
3.	Vinegar	2.4	2.32
4.	Lemon Juice	2	2.4
5.	Soda Water	3-4	4.06

Table.3 – Permissible vs. Measured pH range for different solvents.

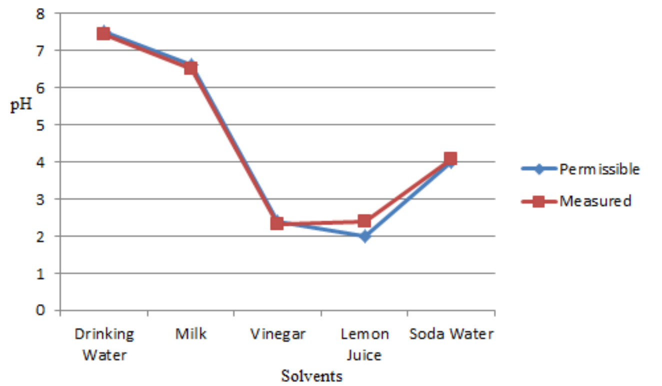


Fig.9 – Calibration Graph Permissible vs. Measured pH for different solvents [Table.3].

S. No	Solvents	pH Meter reading	pH Sensor reading
1.	HCL	3.05	3.02
2.	Distilled H_2O	7	7.04
3.	NH_2SO_4	4.6	4.68

Table.4 - pH meter vs. pH sensor Calibration

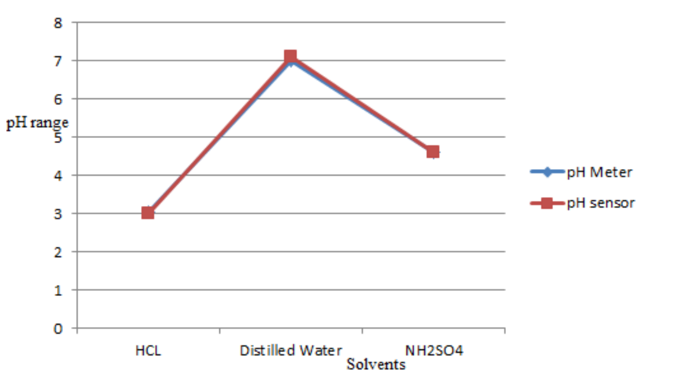


Fig.10 – Calibration graph for pH meter vs. pH sensor [Table.4]

The efficiency of the pH sensor is calculated from the [Fig. 6.7] as follows,

Efficiency = pH Meter/ pH Sensor * 100 → eqn.2

Mean = ~99%

Thus, the calibration resulted with an accuracy of +/- 0.02.

8 OUTPUTS

The serial data transmission from arduino to R-Pi and the data gets stored in R-Pi as .CSV file. The two aduinos are consider as two nodes such as ‘node a’ and ‘node b’ which forms the Module-1 and the R-Pi forms the Module-2 as shown in Fig.1.

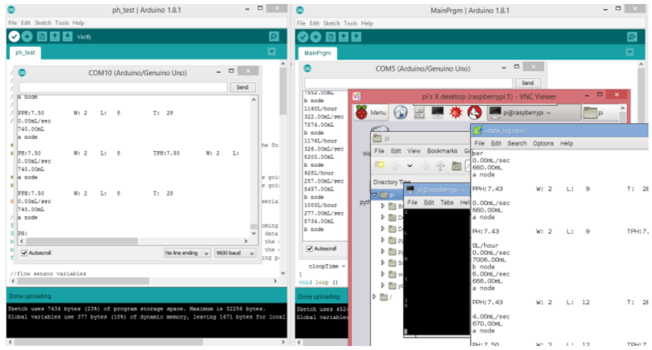


Fig.11 – Data Transmission

After the sensor data gets processed in the local server R-Pi, the data gets pushed to the cloud by means of IoT. The user login page is shown in the Fig.12 where the user is provided with the fields to enter user name and password to proceed to the selection window.

Fig.12 –Login window in webpage

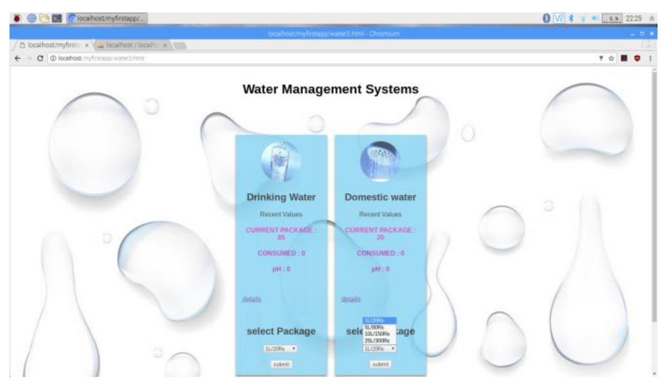


Fig.13 Main and selection window in web page

Once the user is enrolled and enters the user name and password the system will proceed to the main window. In the main window, the system will show the drinking and domestic water consumption rate along with the pH values. The main window in the web page will also allow the user to choose the package for the domestic and drinking water. Once the user chooses the required package the system will proceed to the payment gateway where the user can pay the amount in a prepaid mode.

9 CONCLUSION

The proposed system prototype consist of nodes from which the quantity and quality of drinking and domestic water has been measured for the respective distribution. This study gives the solution for the water demand management and water conservation schemes by emphasis on smart metering technology. Smart metering technology in general can be used to reduce apparent or commercial losses. By introducing such advancement in the water metering system provides improved efficiency compared to the traditional billing method. The user can also get the accurate results in this billing system compared to the traditional method. This working model may implement in complex apartments, large villas etc., and the can also be implemented in our municipalities for each and every house. In further the proposed work can extent up to fault diagnosis in the sensor by using GSM and demand management using optimization technique.

10 REFERENCES

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