Real Time Water Leakage Monitoring System Using IoT Based Architecture

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ABSTRACT - Water is one of the most valuable resources that is used globally. Many people across the globe lack access to clean consumable water, as only 3 % of fresh water is available for use. Urbanization and Industrialization are the main reasons for the water shortage. Apart from urbanization and industrialization, leakage in water distribution pipelines is the major concern for water shortage if not detected at early stage. Leakage can cause much damage to the building structures and it also leads to a huge loss of consumable water when supplied through water pipelines. In recent years, many studies have been conducted to develop an advance technology for better water management. As a result, a new automated technique, Internet of Things (IoT) is introduced that can connect the actual physical things to Internet. In this paper an attempt is made to illustrate IoT application through an implementation of water leakage detection and monitoring system. This paper emphasis on how sensor system can monitor, detect and locate the leakages in the pipeline system. This research also aims to develop a small scale prototype for real time water leakage alert system and to validate it through experimentation. An intelligent sensor network system consisting of flow sensors and a set of active sensor network platform is used to monitor and detect the leakage in pipelines. The flow sensors provided in the pipes gather the data related to discharge through pipelines. The data collected by sensors is processed by microcontroller- Arduino Uno. Finally, the processed data is monitored on internet using cloud computing.

KEYWORDS: —*Leak detection; flow sensor; Arduino uno; IoT; pipeline*.

I. INTRODUCTION

Water is the most important, essential and limited natural resource responsible for life on earth (Wagan et al, 2013; Kulkarni, 2016). Accordingto U.S Geological Survey Agency, around 97% of total water on the earth is found in oceans and only 3% is available as fresh water for use. Hence water is the basic need for all living things on earth. Water is used for various purposes such as drinking, washing, cooking, cleaning and many other things. It means around 150-250 gallons of water is used by a person daily for his household works (Hossain et al, 2015). In India, as a result of increase in population, more people are depending upon this limited resource and this is why it is extremely important to save & use the water carefully(Reddy et al, 2018;Singh et al, 2013). As per literature survey, more than 1.2 billion individuals lack access to clean consumable water worldwide (Hegde et al, 2016). Urbanisation and industrialisation is considered as the major reason for water shortage, but apart from these reasons, leakage in water pipelines are also major concern for water crisis. In Mumbai city, the leakage rate is reported around 70% because of pipeline leakages (). According to the Environmental Protection Agency, due to water leaks in infrastructures, around 1 trillion gallons of clean and treated water are lost annually. In addition to wastage of water, leaking pipes in buildings can cause some other problems like indoor flooding, wall deterioration, weakening of floor strength, reduction in water pressure in the pipeline etc. The building leakages are considered to be common but it is important to understand the causes and measures for prevention. The basic requirement of a building is to remain dry as far as possible. If this condition is not accomplished, the building may become unsafe from the structural point of view.Hence it is important to protect the premises from water damages by implementing water leakage monitoring system in early stages itself. Development of a proper water management system is considered as a complex and complicated due to the slower implementation of technology and aging infrastructure. In developed countries, high range acoustic devices are used to find sounds and vibrations developed in the pressurized pipes and thereby water leakage is detected while in developing countries, leakages are found only when it is visible on the

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surface (Gopalakrishnan et al, 2017). As a result, wastage of considerable amount of water will be there. To avoid this condition, smart water leakage monitoring system connected with Internet of Things IoT) can be introduced to the world by the advanced technology. Internet of things is a system, consists of linked devices, where the devices can be anything such as actuator, sensor, mobile phone etc. which can send and receive data over a communication channel (Mohammed et al, 2016). In 1998, Kevin Asthon invented the word "Internet of Things" into the world of technology (Santucci G, 2009). According to him, "IoT is about empowering the computers, so that they can see, hear and smell the world for themselves. The concept of IoT is considered as simple and powerful technique. The way how humans are using money transactions with the help of internet, the same way all the civil infrastructures and public service facilities such as buildings, bridges, traffic regulations, pollution, water supply etc. could be efficiently operated, monitored and controlled smartly using IoT (Praba, 2016). Figure 1 portrays the consents of IoT.

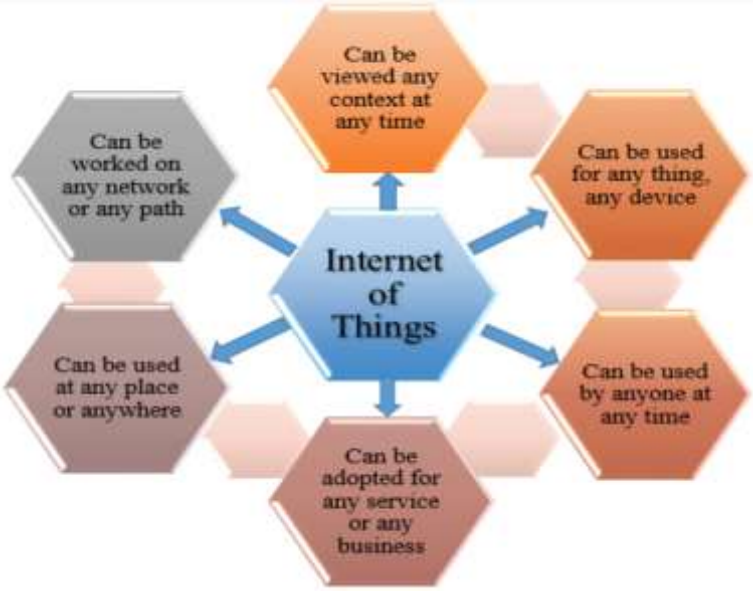

Fig. 1 Consents of Internet of Things

The extreme applications of Internet of things in day today real life can make the human life smart, safe and simple. IoT is having various applications in field of health care, agriculture, transportation, waste management, environment, buildings, bridges etc. Implementation of IoT in all these application zones reduces the human effort as well as increases the quality of life (Sethi, 2017). Figure 2 shows some of the important applications of IoT. This paper explains the real time water leakage monitoring system, which is one of the main applications of IoT. Various methods are available to detect and locate the water leaks in pipes, by connecting water monitoring system with IoT**.** Pressure measurements, flow measurements, vision based systems, acoustic measurements, fibre optic monitoring, ground penetrating radar based system etc. are some of the methods which are used for pipe monitoring. This study deals with flow measurement method using flow sensors integrated with micro controller to detect and locate the water leakage in pipelines.

Many researchers are carried out research on monitoring and detection of water leakages in pipelines. Reddy et al, 2018 have proposed a system which could detect the leakages, monitor and control the water supply through the pipelines. They placed the flow sensors in the water tank for continues information about the water level in the tank and accordingly the motor would function for automatic turn on and off. Flow sensors were placed in the pipelines to check out the water flow through the pipe. If any flow value changed in the pipe, then mechanically the motor will turn off and the supply stops for that pipe not to have more wastage of water and to deal with the flow of water. Saraswathi et al, 2018 have performed a study of the existing water pipeline to detect and monitor the leakage. They developed a real-time prototype to detect the pipeline leakage and validate the developed prototype through experimentation. Mobile phone is configured as the alert sender of the system through which the user gets the information in the case of water leakage. They also designed a sensor system which can able to detect and control the level of water in a water tank. Sadeghioon et al, 2014 designed and developed a system to detect the water leakage in the water pipelines. They used FSR sensors to measure the pressure in the pipelines and temperature sensors are utilized to check the temperature around the pipes. They carried out laboratory as well as field test to validate the developed monitoring system.

In this paper, an intelligent system with flow sensors integrated with Arduino has been mentioned to find the leakage in pipelines. This method is meant to avoid the additional leak when water is flowing through the pipeline. This paper is arranged within the order of methodology that describes the operating of the proposed system, system design and the results that signify the efficient leakage detection in pipelines based on the proposed prototype.

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Fig 2: Application of Internet of Things (www.google.com)

II. METHODOLOGY

The objective of this paper is to develop an intelligent and smart system, which can perform the real time monitoring and detection of the water leakage in the pipelines in early stages itself. Figure 3 represents the major components of the proposed water leakage system. The system mainly consists of Arduino Uno, GSM, LCD, flow sensors and power supply.

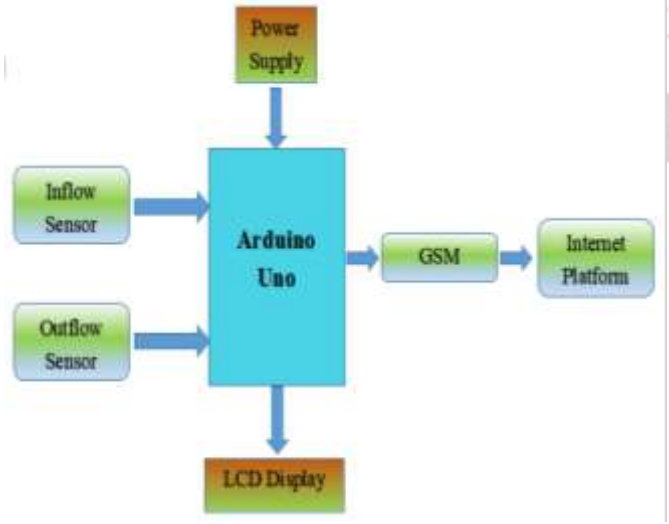

Fig. 3 Block diagram of water leakage monitoring system

Water leakage monitoring system integrated with IoT is developed to save every single drop of water, which is wasted through pipeline leakages in building. The data that is used in this study is the rate of flow from sensors which is provided at the inlet and outlet section. Two water flow sensors are used to determine the inflow and outflow rate of water. In this study, YF- S201 is used as the water flow sensor which is having a working range of 1-30 L/min and water pressure <= 2.0 MPa. This sensor mainly consists of a rotor, plastic valve body and a hall effect sensor. When the water starts to flow through the sensors, the rotor rotates and the speed of that rotation (water) is directly proportional to the flow rate. Hall effect sensor generates pulse/signals for every rotation of rotor (Rahmat et al, 2017).The pulse generated by the hall effect sensors are send to the Arduino to analyse and display the flow rate. The flow sensors are connected by a 2 m pipe to measure the inflow and outflow through the pipe. Flow sensor consists of 3 wires; they are 5v power supply, pulse line and ground line. These are very easy to interface with Arduino, which makes the system smart. The signal line of flow sensor is connected with the digital pin 2 of Arduino where the power line and ground line of sensors are connected with the power line and ground line of Arduino. Figure 4 shows the YF-S201 flow sensor.

Fig. 4 Flow Sensor

A water pump is used to supply the water through the pipeline. When the system starts to work, water is allowed to flow through the pipeline which is connected with the inflow and outflow measurement sensors. Figure 5 shows the position of the water flow sensors in the pipeline.

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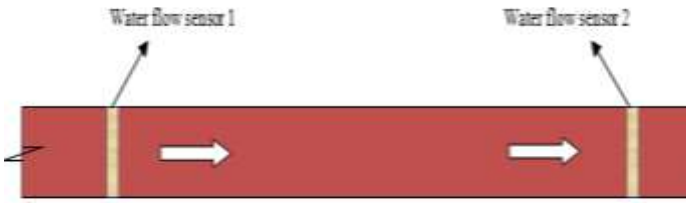

Fig. 5 Position of Water Flow Sensors

Initially, water flows through the inflow sensor and go out through the outflow sensor in the pipeline. The rate of inflow and outflow is sensed by the flow sensors connected to the pipe and have a diameter which is equal to the diameter of the sensors. The data obtained from the sensors are sent to the Arduino for processing while obtained results (inflow and outflow rate) are displayed on the LCD screen. Identification of the leakage in the pipes between the two sensors can be detected through difference in the inflow and outflow rate i.e., no difference between the inflow and outflow rate indicate no leakage while difference greater than 60 L/hr indicates the leakage (Figure 6). When leakage get detected, Arduino will automatically activate the GSM to send alert messages to the registered mobile number and to the cloud system with the aid of a SIM card and external power supply. The flow diagram of the proposed system is described in Figure 7.

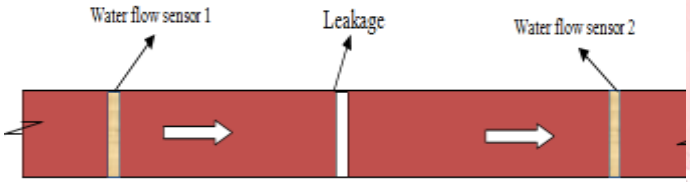

Fig. 6 Leakage in Water Pipeline

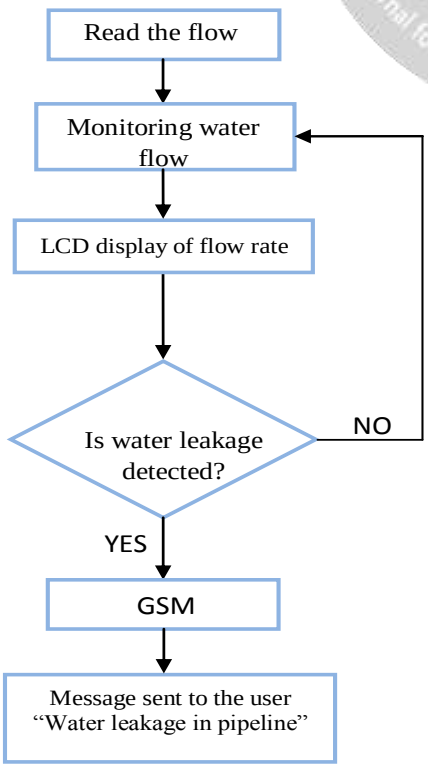

Fig. 7 Flow chart of the water leakage monitoring

- **Calculation of Water Leakage**

The monitoring process starts from water that flows through the pipelines and go through the flow sensors which is placed in the pipeline. When the connection is made as per design, a program is created in the Arduino to detect the water leakage in pipeline. Pipeline leakage will get detected when the initial flow of water neither continues to decrease nor return tothe normal value anymore. Arduino will process the data to detect whether leakage is present or not.

The initial flow through the pipeline in normal condition is found out using the equation,

$$Q = \frac{V}{t} \text{----- (1)}$$

Where 'Q' is the rate of flow of water through pipeline.

'V' is the volume of water collected in't' seconds.

't' is the time in seconds.

The amount of volume of water that passes through an area per time can be calculated from the equation (1). According to the initial flow rate that obtained using the equation (1), the actual discharge or flow rate through that particular pipeline in normal condition (no leak) is fixed. Then using flow sensors, the flow rate of the same system for no leak condition and maximum leak condition can be find out. The data is calculated by taking the wheel rotation count inside of flow sensors caused by water flow through the sensors. Then the wheel count is processed inorder to obtain the flow of water passing through the sensors every second by applying the equation (1) where 'n' is number of wheel rotation, 'Q' is water flow rate through the pipeline and 'c' is calibration factor of the sensor.

$$Q = \frac{n}{c} \text{----- (2)}$$

Calibration factor (c) is a constant value which depends upon the type of sensor used.

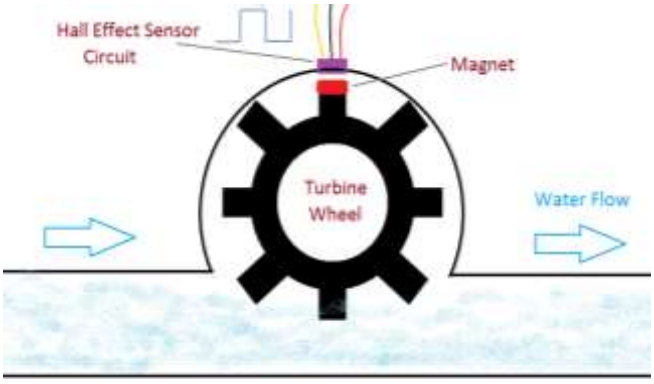

Fig. 8: Working of a Hall Effect flow sensor (www.google.com)

$$\text{Rate of flow (liters/minute)} = \frac{\text{Pulses per minute}}{\text{Calibration factor}}$$

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Rate of flow (liters/hour) $= \frac{\text{Pulses per minute}}{\text{Calibration factor}} * 60$

Pulses (wheel count) per second can be obtained by counting the revolution of wheel inside the sensor (Figure 8).

The rate of flow calculated using the above equation is monitored and compared with the data from both the sensors by Arduino in every second to check whether there is a change in the inflow and outflow rate.

The leak detection process can be done by using the sensor wheel rotation data that are sent to Arduino is illustrated as follows:

(i) Water is allowed to flow through the pipeline and the flow sensors and check out the inflow and outflow rate of flow.
(ii) Check whether then outflow rate data is smaller or equal to the initial inflow rate.
(iii) If the flow rate (liters/hour) that received from the inflow sensor (flow sensor1) and outflow sensor (flow sensor2) are same as the normal flow, then the data is considered as stable and does not have any leakage problem.
(iv) Water flow rate has been sent to the server in every second.
(v) If the flow rate that received from outflow sensor issmaller than that of the inflow value, then leakage is detected and cut down the motor connection immediately to minimize the wastage of water.
(vi) Once the leakage is sensed in the pipeline, the data is sent to the server and at the same time an alert message related to the water leakage is sent to the user's registered mobile number.

III. RESULT AND DISCUSSION

A prototype for real time monitoring of leakage in water pipeline was developed with the help of two serially connected flow rate sensors (Figure 11). The developed prototype is tested in various water flow conditions. Initially, the water flow is turned on and water is allowed to flow through the water pipelines. Both the sensors that are connected in the water pipeline gathered the data regarding rate of flow and analysed in the microcontroller periodically. By using algorithm for rate of flow calculation, the difference of inflow and outflow rate from the two consecutive sensors are found out. The difference obtained is compared and analysed with the threshold value by the micro controller to detect the leakage. Once the leakage is detected, notification regarding water leakage will be displayed on the LCD screen as shown in Figure 9 and also at the same time it sends alert message to the user through sms (Figure 10) for fixing the damaged pipeline system.

Fig. 9 Leakage detection shown in LCD

Fig. 10 Alert sms sent to the user

Fig. 11 Model of the proposed system

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Then the pipeline system is connected with the Arduino to find out rate of inflow and outflow automatically. Both the sensors that are connected in the water pipeline gathered the data regarding rate of flow and analyzed in the microcontroller periodically. The obtained inflow and outflow data is displayed in LCD as shown in Figure 12 and the data get updated in every one second in LCD as well as in server. By using algorithm for rate of flow calculation, the difference of inflow and outflow rate from the two consecutive sensors are found out. The difference obtained is compared and analyzed with the threshold value by the micro controller to detect the leakage.

Fig. 12 Inflow and outflow data displayed in LCD

At the same time, when the water flows through the pipeline, the rate of inflow and outflow readings where displayed in the ThinkSpeak server, which is connected with the wifi module in every one second. Figure 13, Figure 14 and Figure 15 show the graph obtained automatically from the ThinkSpeak, which helps to understand the flow variation easily.

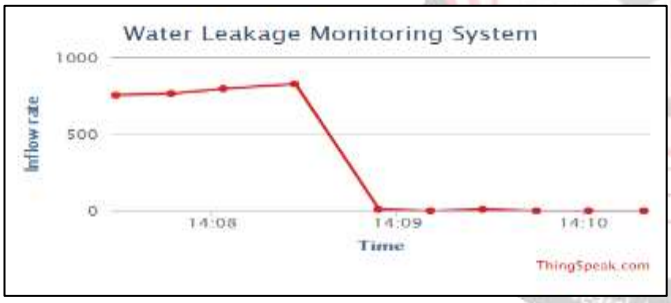

Fig. 13 Rate of flow in water flow sensor 1

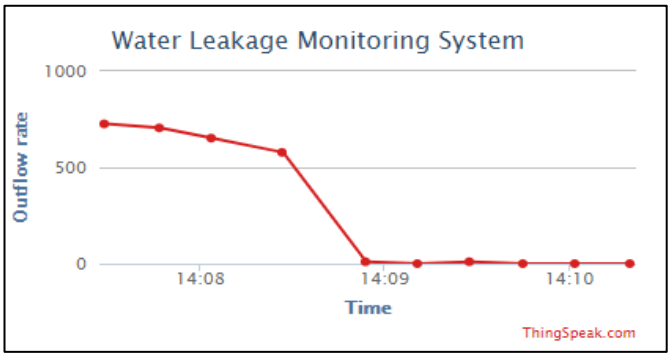

Fig. 14 Rate of flow in water flow sensor 2

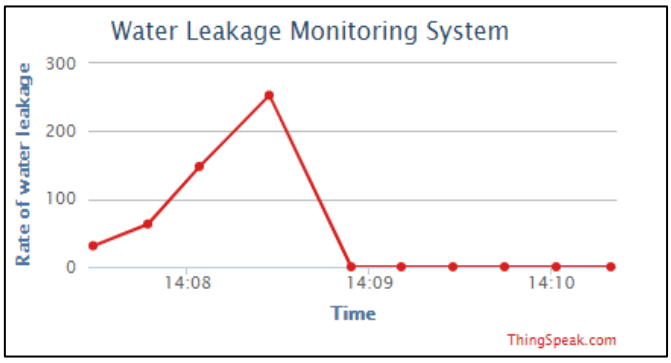

Fig. 15 Difference in rate of flow between inflow and outflow sensors

The graphs in Figure 16 and Figure 17 show the data logged from two consecutive flow sensors in a given interval. Figure 16, shows the normal condition (no leakage) of water flow, where the rate of inflow and outflow are almost same. Initially there will be no water flow through the pipelines hence the flow rate is zero and when water is allowed to flow through the pipes, the flow rate increases which remains constant thereafter.

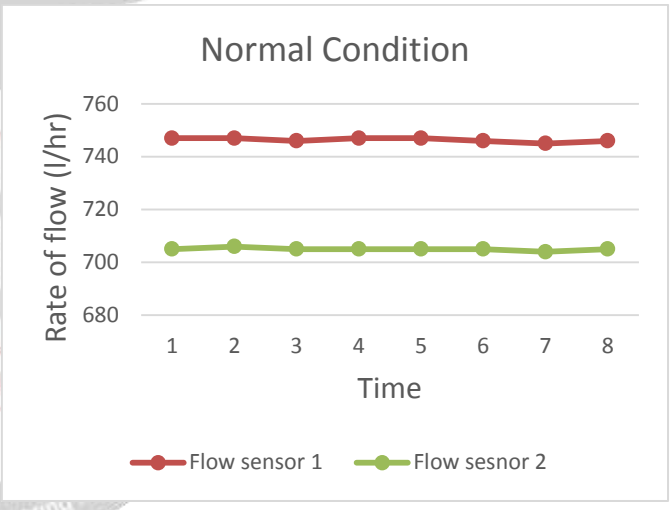

Fig. 16 Flow rate in no leakage condition

Figure 17 shows the leakage condition in water pipeline. When there is a leakage in the pipe, the rate of inflow and outflow does not match with each other while if the difference in inflow and outflow rate is greater than the threshold value, leakages is observed.

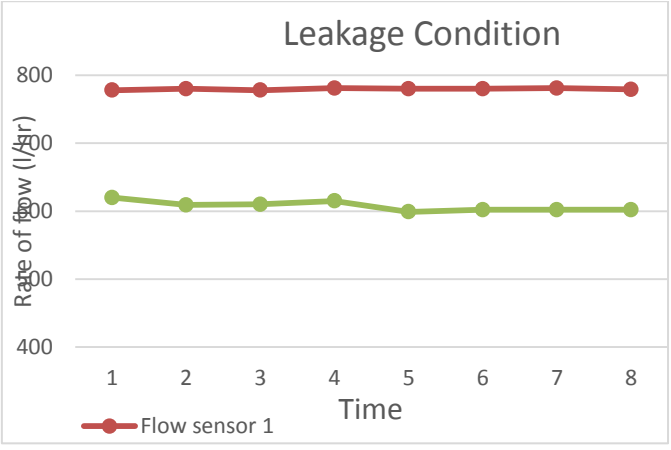

Fig. 17 Rate of flow during leakage condition

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The client who is having the permission to access the web page can monitor the flow rate at any time from anyplace. The page shows the graph of water flow and it automatically updates the graph in every second and displayed in a certain time interval. In addition to this, the client can also get a notification if there is a leak in the pipeline and also see the previous water flow rates in the same page. The previous rate of flow of water gives an idea about the leakage history and thereby can reduce the chances of leakage occurring by providing proper preventive measures.

IV. CONCLUSION

It is essential to prevent leakages in the water pipelines as the amount of consumable water is only around 3% of the total available water on the earth. Normally a large amount of water is being wasted through leakages during the transmission of water using pipelines. Thus the proposed prototype with the modern technology and equipment helps to detect and monitor the leakage in water pipelines. The main advantage of this smart sensor network system is that, it has real time monitoring system with less interruption of user as well as the leakage detection system which rectifies in the early stage so that it reduces the intensity of damage.

A water flow measurement method using water flow sensors has been presented. This method permits easy and simple installation of the sensors in the pipes without disturbing networks of pipes. By using the technology Internet of Things, the flow of water through pipelines can be observed at anytime from anywhere. The monitoring and detection system may increase the initial cost, but in the long run it is cost effective as it reduces human power and maintenance cost.

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