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A Review on Water Leakage Detection in Pipes using Sensors

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***Abstract*: This paper proposes a new leak detection and location method based on sensors. Wireless Sensor Networks (WSN) have been mainly utilized in military application due to its certainty and efficiency. Nowadays, it is considered to be the first-hand in many civilian applications such as leakage detection. Various technical issues, like power consumption need to be considered for different types of application. WSN has lately emerged lately as an effective solution for water leakage. Water is supplied to cities through pipelines from water sources such as rivers and lakes. Non-Revenue Water (NRW) is the amount of water which has been produced and lost before reaching the customer. It may be due to leaks, illegal connection and faulty meters. Bearing in mind that water leakage is a global issue that has already grown to become a critical issue in many areas, the main objective of the paper is to develop a leak and water monitoring system, using the concept of IoT, flow sensor that can be used for detecting the leak and solenoid valves placed in different parts of pipeline cam obstruct the water flow until the defective part of the pipeline is repaired. And further the leak occurred shall be informed to concerned authorities wirelessly.**

***Keywords*: Wireless Sensor Networks**

1. Introduction

Water management plays an important role in the society. Leakage in general takes an international attention because it causes serious water shortage. That doesn’t only cause revenue losses but it also affects the national reserves. In developing country like India, loss of water in domestic sector on account of leakage is approximately 30 to 40% of the total flow in the distribution. By using water monitoring system, we avoid the water wastage, power consumption and easily preserved water for next generation.

Water pipelines leak detection systems are responsible for transporting vital materials such as water, oil and gas. Any leakage in the pipe causes major financial losses and possible environmental damages. Leaks in water pipes may allow contaminants to enter water systems thereby reducing water quality and threatening the health of water users.

Most of the water pipes are buried underground, making it difficult to find the location of leaks. For this reason, water leakage has usually been detected when water flows out of the ground due to massive leaks in pipes. Leakage detection has historically assumed that all leaks rise to the surface and are visible. Leakages are mainly caused by generally aged and consequently breakable water distribution infrastructures. As pipes are not directly visible and accessible, the identification of leakages is not obvious. Losses from water supply system force water agencies to draw more water from lakes and streams there by putting more stress on aquatic ecosystems. Once a leak is detected, the water utility must take corrective action to minimize water loss in the water distribution system. Accurate location and repair of leaking water pipes in a supply system reduces these losses. Leaks reduce the reliability of water supply network. This may lead household and businesses to locate elsewhere, find alternative sources of potable water and otherwise find costly ways to protect themselves from the risk of unreliable water supplies.

2. Related work

Pipeline leakage detection is also affected by the soil type, density, depth, and surface coverage. Water pressure, pipe material and diameter have a significant impact on the detection accuracy due to the interference of frequency.

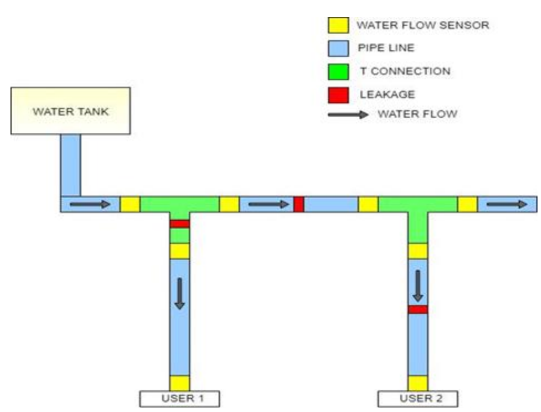

Fig. 1. Generalized pipeline structure

A pipeline structure consists of multiple branches and nodes as shown in fig. 1. Such structure can be broken down into elemental structure which consist of two branches and three nodes. At the point where two or more sub-pipes branch, a microcontroller is placed which takes in data from the sensor placed at each sub- pipes adjacent to it. In the structure water flow rate is measured using water flow rate sensor at inlet and outlet of a pipe. These flow sensors in turn are connected to microcontroller unit. The sensor does not obstruct the water flow but just collects the data of flow rate. Solenoid valve is an electromechanical device which is used to regulate the flow of liquid. The solenoid coil operates the valve as if it is being operated by the human being. When flow of certain quantity of liquid is required it opens the valve to required extent and when the flow is not required it shuts the valve entirely. The solenoid valve will be connected to microcontroller by interfacing with the relay module. The microcontroller units communicate with each other wirelessly. When a leak exists in a pipe, there would be a considerable difference in flow rates measured by two controllers. This can be used to detect leaks.

There are four basic activities for leakage reduction and they pressure management, active leak control, speed and quality repairs and maintenance & renewal of the pipeline. Old detection methods depend on the periodical inspection conducted by the maintenance team which has many disadvantages such as:

1. Requires intensive human.
2. Does not provide real-time monitoring of the pipelines.
3. Cause much larger economic loss.
4. Cause environmental pollution.

Underground wired network for communication suffers from damages and it is very costly. Wireless networks, on the other hand, are much more robust and efficient. It also provides flexibility and simple system deployment, but underground wireless communications have yet to be developed and realized. However, wired base communication can be used for information transmission for long distance for reaching remote administration nodes.

The Microcontroller constantly monitors the flow rate when the system is in On State. The Leak detection algorithm works in such a way that, whenever the Flow rate difference between two consecutive sensors is greater than a calibrated threshold value, a leakage is detected by the microcontroller as shown in figure. The Flow rate difference is also logged into the Cloud through Wi-Fi module. Whenever a Leakage is detected an alert or notification is triggered and message is sent to the concerned authorities.

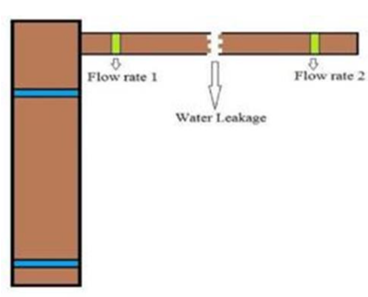

Fig. 2. Flow rate

3. Literature survey

Deepiga and Sivasankari [1] have designed the water monitoring systems such as tank water level sensing monitoring, water pollution monitoring and water pipeline leakage sensing monitoring. The microcontroller based water level monitoring is used to indicate the level of water in the tank to agent. Leak detection in water pipelines, the pressure is calculated using force sensitive resistors (FSR) generated from a leak. It will be indicated by an increase in the LED meter and a rushing sound of water in the pipe which can be heard in the headset.

Adsul and Kumar [2] have proposed a wireless leakage detection system using various sensors and microcontroller which makes system portable and non-destructive techniques (NDT). In the system, the parameters like humidity, temperature, pressure, sound detection and gas detection around leakage areas are detected using sensors and arduino microcontroller.

Jayalakshmi and Gomathi [3] have proposed the design and implementation of a water leakage monitoring and detection system to monitor and detect leak with help of wireless sensor. The objective of an enhanced system is to detect possible underground water leakage for residential water pipes that are monitored from a personal computer.

Daadoo and Daraghmi [4] have focused on an application of wireless sensor networks for leakage detection in underground water pipes to overcome the problem of water dispersion. To address the problem and simplify the leakage identification process, the authors have designed a wireless network system making use of mobile wireless sensors.

Myles [5] has explained the background theory and practical application of a fibre optic based technology that uses Brillouin acoustic scattering to detect subtle changes in temperature in the cable. The paper will outline the background physics of the method, and provide results from a case study for leak detection of a brine pipeline.

Sithole et al., [6] have presented a practical low cost Smart Water Meter device (SWMD) which is capable of determining possible leakages. Flow Meter sensors have been deployed to measure the quantity of water consumed by a consumer.

Medina et al., [7] have introduced a technique based on signal analysis for leak detection in water supply systems. The paper presents the feature extraction from pressure signals and their application to the identification of changes related to the onset of a leak. Example, signals were acquired from an experimental laboratory circuit, and features were extracted from temporal domain and from transformed signals.

Martini et al., [8] have presented the control of water leaks in water distribution networks represents a critical issue for all utilities involved in drinking water supply. The work deals with the detection of water leaks by using vibration monitoring technique. The objective of the paper is to develop a system for automatic early detection of burst leaks in service pipes.

Choi et al., [9] have proposed new leak detection and location method based on vibration sensors and generalised cross correlation techniques. The paper explains the theoretical variance of the time difference estimation error through summation in the discrete frequency domain and find the optimal regularization factor that minimizes the theoretical variance in practical water pipe channels.

Kei [10] describes about the service that install sensors at arbitrary intervals on water pipes in order to capture vibration caused by water leak, sends the acquired data to the cloud computer via wireless network or public switched telephone networks and identifies the leak location with high precision based on the results of data analysis.

Oliver and Scott [11] have proposed a sensor network design method that generates human-readable rules for leak detection. Additionally, for a given network and range of operating scenarios, it discovers the best locations for flow sensors. The method is demonstrated to make acceptably accurate predictions under real-world conditions of uncertain measurements.

Nakhkash and Mohammad [12] have discussed the feasibility of applying Ground Penetrating Radar (GPR) to the detection of leaks in buried water pipes by aid of electromagnetic simulations. The Finite Difference Time Domain (FDTD) model of a GPR system and ground configurations are described. The paper reports the response signatures and features, arising from soil-water mixture, in the GPR data. These results assist in identifying water leaks and confirm usability of GPR for water leak detection.

Siong and Chen [13] have developed an automatic water pipeline leak detection device to continuously monitor the water pipelines to reduce man power involvement. The device not only reduces human resource but also the time used to process collected information. The device allows leak detection staff to remotely listen to leak sounds of any pipelines by focusing their attention on the suspicious area. The leak detection staffs can easily distinguish the real leakage from the false alarm by the system design. If leakage occurred, leak detection staffs will be able to determine the severity of the leak and its precise location.

Araujo et al [14] have described the model to support decision systems regarding the quantification, location and opening adjustment of control valves in a network system, with the main objective to minimize pressures and consequently leakage levels is developed. The research work aims at a solution that allows simultaneously optimizing the number of valves and its location, as well as valves opening adjustments for simulation in an extended period, dependently of the system characteristics. Environmental Protection Agency Network (EPANET) model is used for hydraulic network analysis and two operational models are developed based on the genetic algorithm optimization method for pressure control, and consequently leakage reduction, since a leak is a pressure dependent function. In these two modules, the method has guaranteed an adequate technique performance, which demands a global evaluation of the system for different scenarios.

Lin et al [15] have developed a wireless sensor networks which mainly addressed military applications. However, in recent years, many civilian applications, such as managing inventory, monitoring product quality and monitoring disaster zones have emerged. Various technical issues, such as power consumption, radio propagation models, routing protocols, sensors etc. need to be considered for different applications. The paper proposes a particular application for wireless sensor networks, specifically a water distribution network monitoring system. It also proposes a possible communication model for the water distribution monitoring network, and describe channel measurement approach for the determination of an appropriate path-loss model. The accuracy of the proposed measurement approach has been confirmed using the flat earth two-ray model.

Haqshenas [16] has proposed the method of dealing with acoustical monitoring of leaks in buried water distribution pipes. The basic principle is the fact that water spouting out of a leak in a pressurized pipe generates acoustic noise, and this noise contains information as to whether a leak exists and hopefully of where it is located. Acoustic methods for finding leaks are mainly based upon correlation analysis, where one sensing device is installed at each side of a leak. The two received acoustic signals are correlated and the arrival time difference represents a measure of the leak position. Theoretically, it can provide very high precision for metallic pipes. The main drawback is lack of generality. The correlation techniques nearly always fail to yield a precise prediction when applied on plastic pipes. The study consists of applying and evaluating pulse-echo method for pinpointing leaks. The technique has been used in diagnosis of power lines for many years. The main concept is to send out a known burst and analyse the received signal to detect tracks of leakage. One expects to observe Doppler shift in modulated signal wave due to dynamic disturbances in water pipe in vicinity of leaking point caused by escaping water. The report starts with the introduction section to outline an overview of leak detection problem. It continues with the theory section that explains a model for prediction of sound field as a result of reflection of reference acoustic wave from a moving reflector. The experimental part involves applying the technique in urban water pipeline system and measurements results. Subsequently signal processing section covers analysis of data and final results.

4. Conclusion

Water leakage is a very hassling worldwide matter that needs to be dealt with immediately. Otherwise it will cause huge economic and raw materials losses. In this paper, we introduced four WSN technologies for detecting leaks. Furthermore, the proposed method can contribute to developing an automatic leakage management solution that collects leakage data, alarms about the risk of leaks, and informs about the specific leak locations. It is crystal clear from this survey that the current leakage detection methods have different accuracies, cost of deployment and applicable environments. Nevertheless, combining several leakage detection methods to form a hybrid system is a common practice and is recommended. It is understood from the review presented that the existing methods are to some extent, able to detect burst type leakages.

However, there is uncertainty in their application in detecting background type leakage. In a large-scale piping network, as in water distribution networks (WDN), background leakage is often hidden and difficult to detect compared to sudden pipe burst, which has been the focus of the numerous research work. As a result, the current leakage detection techniques applying signal processing/analysis to abrupt changes in pressure and flow within a pipeline for leakage detection are ineffective in detecting background leakage in a WDN, and do not meet the need for detecting leakages in large-scale water distribution networks. More research effort should be devoted to this type of leakage as a higher percentage of water loss is caused by this leakage.

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