Water Loss Detection by Using IoT-Based Smart Water Meter and Leakage Localization Technique

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Abstract

This paper introduces a solution to the problems faced in the conventional water meter that includes manual billing system, water loss due to leakage in the piping system and unusual water usage. An IoT Smart water meter overcomes these limitations and hence an innovative electronic based water meter and water management system is designed. This device is used as real-time reporting water usage data and automatically informs location of water leakage in the piping system. The ability of internet of thing technology incurs a versatile data access in which the information from data center can create a water usage model, water usage planning and searching leakage location adopting the localization technique. The proposed IoT smart water meter calculates leakage location using the localization technique in which it is installed in the community, large building and smart home. An experimental result provides the validity for the proposed work.

Keywords: Smart water-meter, water management, Water leakage detection

1. Introduction

Many countries worldwide are facing water problem. Water is one of the scarcest resources that should be used responsibly. An appropriate management solution for water resource is necessary to promote the continuity of economic development and to ensure loss minimization. Water is a consumer product that is necessary for all sectors such as household, agriculture, food, industry, energy and transport. Therefore, Information about the usage of water and efficiency of water management can reduce water wastage and will help improving quality of life. Nowadays, measuring of water in the conventional format faces with many problems such as errors of water meter reading, the manual billing system, controlling valve when the piping system is failure due to unexpected circumstances, waste of human resources, hardware lifetime and problem about alarm or searching position of water leaking into the water system. The traditional way of water meter was not only waste but also very inconvenient, especially with the increasing number of population and building in recent years. The conventional platform of the water meter and water management was obviously ineffective. The way to solve the problem is to develop and transform the existing platform water meter to smart water meter. Smart water meters available in the market use wired system to ensure reliable operation in which, in fact, the Wi-Fi technology is currently mature and it is widely used. When compared to the wired devices the Wi-Fi connection indicates lower cost and easy to access. In order to use Wi-Fi technology effectively in the smart water meter, the device should have compatible embedded internet of thing (IoT) technology. The development of smart water meter based on IoT technology is a key to success and it is the way to turn a normal device into a smart body. IoT is the revolution of the internet which will make the world smarter. A wide range of physical objects is connected to the internet, providing them the ability to think and communicate without requiring human to human or human to machine interaction. IoT can be considered as an emerging global technology, in which things can be connected and controlled remotely.

The IoT has been used as a standard solution and is widely known among newly innovators. It works through internet services can afford to make every object to go online and globally connected together. Especially, the perspectives and challenges to develop IoT to fully support the sensor technologies. Hence, the IoT can be easily defined as connecting all items (as things) to the internet and collect information of these “items” by proper sensors to achieve intelligent identification and management.

In other words, The IoTs refer to a new technology in bracing all types of sensors which could demonstrate an easy way to manage via the internet. This is an important milestone in the technology transition especially when a suitable algorithm for the smart system is developed [1]. The growing interests in IoT technologies and the application are exceedingly and lead to an increase in the number of a related research area, such as smart home, smart cities, environment monitoring, healthcare smart business, big data and surveillance. For the smart home application, the utility monitoring such as gas, electric power, and water has become important in everyday life. In this paper, we focus our work on water meters using IoTs technology, which serves to manage water usage, water consumption. We also introduce water leakage detection in the smart home.

Water management solution and the recognition of water usage behavior are parts of smart city elements. Benefits from the development of an intelligent water management system, for example, waterworks are (i) the ability to plan and define the water capacity to be used in a community and (ii) the ability to handling data analytic of water demand and supply in each area. This can be applied to systems that are a smaller size such as Hotel, condominium, apartment or residential building to help the owners access many important data and information. The most important problem in water management in the building or community is water leakage. Although water leakage can be detected, it is difficult to obtain leaking location. The way to solve this problem is to adopt fluid mechanic theory in which some useful parameters can be obtained from a smart water meter and aggregation of smart water meter is made a possibility.

The paper also presents a vision and opportunity for developing smart water meter based on IoT. In many applications such as water volume planning by smart water meter [2] and [3] show the concept of multiple smart water meters for water supply simulation and modeling of water usage based on wireless sensor network technology but wireless sensor network is a limitation of communication in the large deployment area. Atzori et.al. [4] and Durrett et.al. [5] conducted surveys of IoTs in a smart home, which represent a state of the art about RFID [6], Bluetooth [7] and wireless sensor network [8] to work with smart object for utility measurement in a smart home. A variety of research developed the smart meter using the concept of the IoTs to deploy in a smart building which, focusing on self-adaptive service based on IoT [9-10]. This concept represents the intelligence and flexibility IoT scenario. Especially, some research put efforts to develop a self-adaptive location service for smart home and smart device [11] but these are difficult to combine every sensor and actuator from a middleware for communicating data and link all data to other devices. Another problem is the complexity of obtaining right sensor and actuator to fit such complex system conditions, e.g. in case there are many platforms and many different types of sensors and actuators. For this reason, we have been invented a system which enables power to manage water resources, to monitor, to control and to localize water leakage in a smart home system via cloud storage using IoTs technology. In order to solve the problem above, smart water management system can collect vast amounts of real-time water database from the sensor and support IoT concept.

In this paper, the design of a smart water meter device which focusing on monitoring water usage and water leakage detection is presented. This will be able to detect and alert in the customer's property. A function of electronic water valve for remotely water control via the internet is added. Next section explains the design concept on the development and deployment of a smart water meter device using basic concept of sensor/actuator incorporated with IoTs to connect with other systems. Section 3 explains leaks in the system, the pressure loss calculation in the mesh installation of the smart water meter. Result section shows a demonstration of water usage accumulate data and simulation model of water leakage detection using the leak localization technique.

2. Methodology

The development of smart water meter consists of two parts, the first part is hardware and the second part are leakage detection algorithm.

2.1 Hardware Design

The smart meter is based on IoTs technology. The IoTs and sensing technology can enable many sensors and actuator to intelligently actualize by monitoring and management, which engage control machine, analyze data and monitor failing condition. In order to measure important parameters, the smart water meter consists of water flow sensor for measuring flow rate and electronic water valve to control close and open of the water valve.

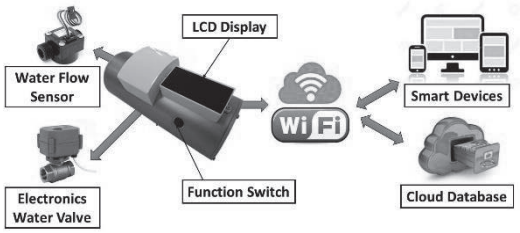

Figure 1 Hardware of Smart Water Meter

Figure 1 shows, the base microprocessor unit board connected to sensors, actuator and LCD display. MPU (Main Processor Unit) Board used in this study is LinkIt smart 7688. This embedded system is an open development board, based on the OpenWrt Linux distribution. In the part of software development, python are used for main control software and Oracle Fusion middleware for connecting to the different platform. The purpose of middleware is for the discovery of another IoT device, Management persons can enable any device in the IoT network and device ontology used for storing informatics data about the heterogeneous devices.

2.2 Leakage Detection

Data from multiple smart meters is used to calculate water leakage. Darcy-Weisbach's equation shown in eq. (1) is used to calculate the leakage location in this work. This equation relates with the head loss or pressure loss due to friction along a given length of pipe, average velocity of the fluid flow of an incompressible fluid. According to this principle the water leakage is increase friction by reducing the pressure in the system.

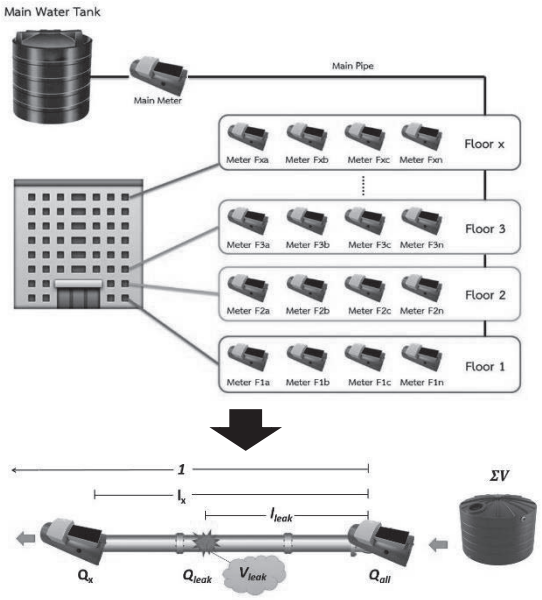

Figure 2 Simulation of the system;

Figure 2 shows the simulation of the system installed in a building. From this structure, it can be converted water flow rate (Q) from water pressure by using Bernoulli's law and after that using equation (1) to find out the location of water leakage (l_{leak}) between two points of smart meter by using friction loss in water pipe concept and estimating the leakage point is another loosing pressure point between two smart meters and this leakage point will increase friction in the system.

$$Q^2_{all} = Q^2_{leak}[1+\lambda(l_{leak}/d)] + Q^2_{x}[1+\lambda(l_x/d)] \quad (1)$$

And Leak Volume by Flow rate

$$\Sigma \square = (V + Vleak) / Time \quad (2)$$

From the above equation (1), we can calculate leak to searching leakage point in the system by input all parameters from a network of smart meter and some parameter such as λ is a Darcy-Weisbach friction coefficient which can be obtained from pipe property. Moreover, in this algorithm can estimate leakage volume of water by using equation (2).

3. Result

Figure 3 Installation and Testing prototype;

The system was installing and tested over 1 year at Thammasat University for monitoring water leakage and daily water usage see Figure 3 The result of this paper is illustrated in Figure 4 Red circle represents abnormal data from the smart water meter database which show the instantaneous impulse of water volume and the system was detected is a water leakage. The leakage position searching technique from equation (1) and (2) can calculate from this situation.

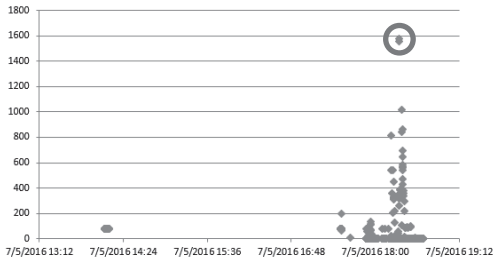

Figure 4 Data from database;

4. Conclusion

This paper proposes the newly design of smart water meter which can manage, monitor and control water using internet of thing technology. The leakage localization technique can detect and search water leakage location in real-time by using basic concept of friction in pipe system (head loss in piping systems) and increasing of flow resistance when a pipe broke to calculate the position of water leakage by using Bernoulli's law.

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6. References

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