IoT Water Monitor Implementation Strategy

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Abstract. Water scarcity is a serious threat that is directly impacting the lives of over four billion people globally every month. While phenomena like global climate change and pattern droughts contribute to this challenge, they are beyond human control to an extent. However, the challenge of water wastage due to water leaks is one that can and should be controlled. Majority of water leaks are only reported within 4-8 hours of their occurrence and take even longer to be fixed. This paper proposes an implementation strategy for monitoring water leakages in real time by connecting IoT enabled controllers onto the water main lines and automatically/remote control the water main lines to limit the amount of water wastage. The key results of the study show that with the proposed system, water leaks can be detected and reported within an hour of their occurrence and with timely intervention can prevent water loss of up to 50 000 liters.

1. Introduction

With over four billion people facing water scarcity monthly, inventive water management solutions are needed in order to curve the increasing shortage of water availability. [1] However, with half of the fresh drinking water being wasted due to water leaks, the solution is rather to impose proper monitoring and control technologies in cities [2].

A major reason impeding the prevention of fresh water leakage is due to the difficulty in including predictive maintenance in the water lines. To compound the problem, majority of water leaks are usually only reported between 4-8 hours of occurrence, within this time 50 000 liters of water can be wasted.

This necessitates a timely response for monitoring and control for water management. Internet of Things (IoT) could offer the solution by connecting Internet enabled controllers onto water main systems in order to monitor the water pressure, detect any water leaks and automatically/remote control water main lines to limit the amount of water wastage.

With water being one of the most essential resources, strategies have been researched and implemented, in order to reduce the amount of water wasted before reaching households and businesses. Authors; M. Klingajay and T. Jitson [3] use laser monitoring devices in order to actively check pipes for physical wear and cracks that could cause water leaks. This method makes use of a localized monitoring system, although actively checking pipe conditions for maintenance and repair is considered to be expensive.

Authors; B Hieu et al [4] developed an acoustic emissions signal collection system which is able to detect if leaks exist within a water pipe system by recording the frequency. Although the system offers a cheaper solution for leak detection, the system can only verify if there is a leak and not where nor the extent of the leak.
In respects to water leak detection, authors; S. Adsul, A. Kumar Sharma and R. G. Mevekari [5] developed a more popular solution of measuring water flow for detection of water leaks. Although this system is the cheapest and offers an improved means of water leak location, the idea can still be improved on as the water flow system will have no means of backwards leak detection, but only forwards. This is due to the fact that water leaks occurring after the flow will still present a positive flow reading.

Water pressure monitoring systems have the advantage of being able to localize the area of a leak both before and after the device installation. This is due to the ability of water pressure sensors able to detect water pressure drops even if a leak is present before and after the pressure sensor.

Furthermore, automatic control can be incorporated into the device with solenoid valves restricting the amount of water loss, but still able to keep water pressure constant, a feature not present in water flow sensors. Adding to this advantage that sensor networks [6,7] could then perform better with automatic control and no distribution of pressure sensors to communicate with other devices.

2. Literature Review

2.1. The need for Water monitoring
With water scarcity not only affecting the most barren of countries, but also those surrounded by coast lines due to a lack of fresh water supply. This is apparent with cities such as Sao Paulo, Cairo, Beijing, Moscow, London, Tokyo and Cape Town all being at risk of running out of water.

It is reported that water is supplied to these cities but with the consumption rate out weighing the supply rate, the idea of not having water in your house becomes a reality. With developed cities, such as London, having up to 25% water wasted due to leaks and underdeveloped cities running close to 50%, water monitoring and control strategies can be applied worldwide [8].

2.2. Internet of Things
The Internet of Things is a categorical term used to describe internet enabled devices, being able to communicate with one another or any internet platform [9]. IoT is one of the pillars of the Fourth Industrial Revolution and it opens up new communication technologies that will allow for sustainable development in SMART Cities.

IoT brings the ability for devices to communicate with one another and create a seamless, integrable and scalable network. With these, neighboring devices will be able to identify problems and deduce the exact location of the problem. [10]

With device’s placed all along a city’s water line, multiple devices will be connected through a gateway in order to transmit water pressure data to municipalities, as seen in Fig. 1. With these devices strategically scattered across a city, a water pressure sensor node network is created, in order for the sufficient monitoring of water pressure and location of water leaks.
3. Methodology
Water scarcity weakens food security with economic prosperity in countries and with climate change adding additional pressure to water scarcity, greater water management is needed. [11] IoT has the ability to provide seamless integration of devices to the internet, allowing for entire network monitoring grids.

Monitoring on a specific device is broken up into two main checks: Major and Minor leaks. A major leak will occur when large amounts of water leaks from a pipe, causing a large pressure drop in a short amount of time. Compared to normal consumption of water, this pressure drop is several times greater, and will affect multiple devices past the water leak. Minor water leaks occur when there is a small but constant water pressure drop spanning more than 24 hours.

For the monitoring and control aspects, the IoT water monitor is expected to:
• Monitor the water pressure and detect any abnormal water pressure drops (Major and Minor).
• Communicate with neighboring devices and with front end users.
• Automatically shut off water valves attached to the water main lines to reduce water wastage.

3.1. IoT Water Monitor
Based on the design requirements and specifications previously mentioned and shown in Fig. 2 and Fig. 3 defines all the functions to be performed by the system. A modular approach to system design was taken. The system is designed using an Arduino Uno microcontroller based on ATmega2560 microprocessor [12].
The system contains water pressure sensors to detect water leakage in the pipe system. The sensors collect information and the system is controlled by the Arduino, the controller decides the risk and sends the water pressure information to a backend server, according to the sensors information. The decision detection of water leaks is handled

Once the device starts to detect water leaks, it will take a reading of the current water pressure. This water pressure is then compared to the standard water pressure communicated to the device from the user. The device then monitors the difference in water pressure.
If the water pressure drops below the safe set level, then the method of continuous monitoring is called. At this stage the device checks the water pressure over an 18-hour period. If the water pressure has still not returned above the safe set level at least once, then an alert is triggered, and message is sent to a server. This message is sent to inform a server that a minor leak exists in the system.

If rather the water pressure falls below the danger area a major leak is detected. During this occurrence, a method is called to automatically shut off the solenoid valve, shutting off the water supply in that route. This is not to say that all water will be shut off past that point, but rather that the water supply will have to take alternative paths.

This coincides with the backwards detection of devices, where neighboring devices are able to detect major water pressure drops, also shutting off the solenoid valves and isolating the water leak, depicted in Fig. 4.

This is then compensated with further neighboring devices only detecting minor water leaks and sending messages while allowing water to flow. In doing so, clamping the water leak by devices detecting major leaks. The devices then shut off solenoid valves and water flow, additionally send messages to the server, informing that a major leak has occurred.

Each device then communicates back from the server. The server handles communication from each device and calculates the position of a water leak by determining the water pressure drop greatest in between two sensors, similarly as depicted in Fig. 4. The server is responsible for determining where water leaks may lie and the communication to the end user of these leaks.

![Figure 4. Water Leak Isolation](image)

The information transmission and network coverage is handled by the Sigfox Network interfacing by the Arduino on a Sigfox shield [13]. The system also consists of three parts: the first is the automatic control, where if a Major leak occurs, the IoT Water Monitor will sense the pressure drop, via the pressure sensor in Fig. 5, and automatically close the valve, preventing any water to be wasted.
The second part revolves around the communication of the water monitor to the front end for users to monitor water pressure. This water pressure is sent along with GPS location and time of occurrence of events. This will assist in pinpointing exactly where and when water leaks occur.

This information is crucial as proceeding IoT water monitors along the pipeline might experience water pressure drops, only due to previous IoT water monitors shutting the control valves. This is however handled by the backend network server to pinpoint pressure drops and communicate this information in the third parameter.

The third and final part involves communication and remote control of the device. Maintenance crew and users of the IoT water monitor have the ability to send information to the IoT water monitor. This communication allows remote control of the IoT water monitor, by decoding messages sent to the device, allowing users to remote open and close the valves for maintenance and upgrades. This communication is also used to switch off water monitoring if previous water monitors on the pipeline have detected major water pressure drops and have shut off the control valves.

3.2. Water Leak Monitoring Strategy and Network

With most water supplies branching out of the main supply [14], identifying exactly where within a city a leak occurs would require an immense amount of resources and water monitoring equipment. Instead water monitoring can help reduce the search area of a leak, but more importantly initiate control of the water leak. This control is handled by the cut-off of water for major leaks along the pipe where the leak occurs. With the integrated network of the plumbing system, it is not to say that an entire area from below the water leak will have their water shut off, but rather to isolate the issue to only a few houses. Therefore, an optimal placing of devices can reduce the need of redundant water monitors and isolate water leaks.
4. Results
The prototype along with two water pressure sensors and solenoid valves, attached in series in the water line, allowing for automatic control of water supply to reduce water wastage due to leaks. The prototype is tested for various conditions of water flow. IoT water monitor is turned ON initially such that water flows through the water pipelines. The water pressure is obtained by the microcontroller periodically in order to reduced electricity consumption, ensuring responsible resource consumption while not diminishing another precious resource.

![Figure 7. Water Pressure Sensing](image)

The IoT water monitor also uses water leakage detection algorithm to calculate pressure differences between usage of water and water leaks. Similarly, the device calculates the pressure difference between different devices on the backend network server to detect any backlogs of water pressure drops.

The difference is also logged into the Cloud for triggering the leakage detection and communication to users. Once the leak is detected notification is sent to users for maintenance of damaged pipelines. In addition, water flow is stopped when leak is detected.

4.1. Monitoring and Control
With a water pressure drop appearing in the water pipe, subsequent IoT water monitors along the pipe will experience water pressure drops, much larger than that of previous IoT water monitors. This allows for all IoT water monitors to detect major leaks and switch off water control valves. However, with data logging of all attached IoT water monitors in a network, this pressure difference can be detected and the location of the water leak can be determined to lie in between the two IoT water monitors, as seen in Fig. 8.
4.2. Scalability through IoT

With the IoT water monitor being able to detect water pressure drops and have automatic control, a decision needs to be made when to switch off water supply and when to notify users of water pressure drops.

As seen in Fig. 8, if minor water leaks are detected, then water supply to households can continue and users are alerted of the pressure drop. Usually these minor pressure drops are irregularities of that neighboring devices for a period greater than 18 hours.

During major water leaks, a large pressure drop is experienced, much larger than any households can cause during usage. This commonly occurs with bursts in pipes. These major water leaks account for the largest water wastage within a city, due to the amount of water wasted per minute and the amount of time needed to identify the problem.

The IoT water monitor with the automatic control is then able to stop large amounts of water wastage and alert users of the water leak. The performance of the IoT water monitor with respects to major and minor leaks can be seen in Fig. 9.

These two leaks are again compensated for in the entire network of the water pipeline, where water monitors are strategically placed on water lines. This allows for control and monitoring of large city areas, while being able to pinpoint the location of water leaks and isolating the water leak to small areas, while keep the city water running.
5. Conclusion

As to date, leakage monitoring technologies are expensive and limited in their expansion. Offline technology of water metering, involving on-site inspections to occur weekly are time intensive and costly. Furthermore, water monitoring has seen little attention for diversification, with many solutions revolving around water flow detection, costing water resources as leaks can still occur with water flow. Therefore, the idea of inexpensive remote monitoring technologies holds advantages in not only developing countries, but any all countries at risk with water scarcity. It is proven that such devices and systems can be developed cheaper hardware, with reliable life cycles and open source software that can be used globally.

The network of water systems is integrated well with the capability of IoT that allows for precise water leak age detection and containment, allowing entire cities to continue on while isolating the problem, which could not have been achieved before.

With the use of the Sigfox network, entire cities and large majorities of countries could be equipped with the IoT water monitor, along with easily integrated software and communication for users. Transmission of information realized by wireless IoT connection also allows for data storage and maintenance history for future projects to involve predictive maintenance and future planning.

6. References

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