Edge-centric Computing for Smart Water Supply: Management and Service

Yang LIU*, Zhi-bin LEI, Kang-heng WU, Hua CAIL, Xiao-li LI, Xiao-yu ZHAO  
Hong Kong Applied Science and Technology Research Institute Company Limited  
Hong Kong, P.R. China  
yangliu@astri.org

Zhao-hong LI, Xue-hua SHUAI  
Zhuzhou Zhu Hua Water Industry Science and Technology Development Co. Ltd  
Zhuzhou, P.R. China  
yxz2887785@163.com

Zhong-min TANG  
Hengyang Water Investment Group Co. Ltd  
Hengyang, P.R. China  
hyszlszgs@163.com

The smart water supply management system targets for the efficient water supply network management, optimization, and water supply service provisioning. It is an essential component of smart city application. The smart water management system monitors the water supply network operation status via installed sensors (e.g. water pressure, flow speed, water leakage etc) in a large scale. It analyzes the potential risk in the distribution network and integrates the water supply information in a user friendly GUI. It is efficient and cost effective to detect the abnormal situations and take corresponding measurements without much human interference. The water service system provides the users many traditional and new value-added services. 

Keywords: Water Supply; Edge-centric Computing; Smart Management; Water Service.

1. Introduction

With the rapid development of modern cities, there is an increasing demand for the water supply system to be more “smart”. It is expected the water supply system can monitor the water supply network operation status, detect the abnormal situations, analyze the potential risks and provide the water to users with less human interference.

Traditionally, the water supply system abnormal detection is based on transient detection, which is conducted in either time domain or frequency domain. With time domain method, the consistent measurement is needed for water flow import/export and water pressure change over time. As a contrast, the
frequency domain method will cost less computation time with the calculation on the frequency response [5][7][8][10]. Accordingly, the risk alert is generated by simulation results on various water usage/flow models. [2][6][9]

Complex Event Processing (CEP) engine deals with not only a single event, but also the complex event consisting of a plurality of events. Specifically, CEP monitors and analyzes a complex event processing flow, triggers certain actions when a specific event occurs. CEP-based real-time processing has been successfully applied in the network, telecommunications, and finance fields. The distributed framework supports good scalability and continuous calculation, which helps to handle the big data and achieve better business intelligence [1][3][4].

This paper proposes an application of a smart water supply system with CEP support over an edge-centric computing environment. The smart water management system monitors the water supply network operation status and analyzes the potential risk. The edge computing builds trust in the end nodes to offer efficient management and service. Due to the event urgency and timely response requirement of water supply system, the integration of the intelligence of event detection and handling in the edge can be very helpful in the service. Therefore, the water supply events need to be modeled, the network will be optimized via big data analysis, and the system can be real time monitored in terms of devices and services.

2. System Structure

2.1. System overview

As indicated in Figure 1, CEP engine is the core of the smart water management platform. In addition, there are three scenarios at the edge. Scenario 1 is on smart water service while scenario 2 and 3 are on water supply management. In scenario 1, smart meters report data to the data collector and data collector relays the report to the CEP core. The application may use human user information nearby and therefore the trust lies between the human (smart phones) and the control point (data collector). As a contrast, in scenario 2, the data collector relays the report from smart valves to the CEP core and the trust needs to be established between the smart valves and the control point. In scenario 3, the valves can volunteer as the control point and the trust has to be established among all the valves.
2.2. **CEP core**

CEP engine conducts modeling for implicit and explicit events, analyzes real-time data flow of water supply and input of event flow, and outputs information of auto control and dispatch. The related distributed streaming data process platform can support many kinds of quantitative modeling and computing architecture. It is suitable for large scale of stream data with multiple data formats.

The technical methods include adopting hydraulic modeling, numerical analysis, hydraulic transition process analysis and experimental verification, analyzing characteristic parametric curve of critical equipments, as well as conducting real-time online monitoring and healthy diagnosis for adjusting performance, preventing water hammer formation, and modeling cavitation and vibration properties of normal, invalid, and multiple loading condition and emergency states. By means of setting up database, we can also utilize...
structured and unstructured data to build intelligent synthesis and pipe network management.

Furthermore, the system mentioned above includes the following features: integration of multichannel data; building up a statistical calculation model and relevant computational support framework for uncertain data source; and anticipating system risks and their causes with quantificational analysis technique for big data, customizing strategies for risk management and dispatch control according to the characteristics of water supply systems.

The platform efficiently integrates the multi-channel data, supports quantitative modeling, which develops complex event platform and information process engine for processing the data needed by the backend. We can input this data into computing engine to conduct analytical computation, dispatch decision, to provide remote control and monitoring for critical devices, and to report real-time data and information about water supply and service operation.

3. Management in the Edge

In China, there is a need for a complete and unified control target, a technology strategy, and a universal criteria for the pipe network leakage control management. By using data analysis on our intelligence platform to study the background leakage of the water supply network and the economical leakage control methods, the water companies can assess the water supply network and give a systematic analysis of water pipe leakage status in order to select the most appropriate strategy for leakage control.

Figure 3. GIS information integration example of water supply network in a region in Hengyang City.

For example, our CEP engine will do calculation according to input parameters from cloud platform and a set of predefined rules, which will generate output event streams for the operator’s reference on a user friendly interface (such as figure 3 with GIS information integrated).
3.1. Trust and Control

Detection and diagnosis technology for critical devices of water supply systems (such as gates, pumps, valves) comes with the development of mechanical fault diagnosis technology. Big data technologies can help continuously capture data and events that might affect system stability and security. For example, the longer the water pump station pipe is used, the easier it will cause gas-liquid two-phase transient flow and low pressure pipeline, which can lead to pipe crush and liquid column separation with huge pressure. That could cause severe water hammer accident.

To avoid this, we must not only build a system that can monitor, diagnosis, and prevent hazardous conditions of pumping station, but also decide the measuring points and their layout, select the type and accuracy of data and sensor, design data acquisition systems and data processing mechanism, determine the method of signal analysis and feature extraction, and select control unit parameters and presentation method. The trust lies between the smart water devices. The control device may be one of the smart valves or the data collector.

Using the ultrasonic technology for long-distance real-time detection of water pipeline network, it includes the amount of detectors, simulation and modeling of installation position of detectors, detectors’ lifecycle and replacement, parameters that reflect water pressure and throughput, filter and conversion of collected signals, as well as the alternative plan for development of network breakdown.

3.2. Proximity and intelligence

Since for the collected parameters, there may not be an explicit model to describe the relationship between the parameter sets and various working conditions, the proposed method is to use artificial intelligence to extract parameters set and assign weights. AI includes planning, learning, natural language processing, motion and control, intuition, social, creativity and multiple intelligences, and several other modules. And unsupervised learning method in learning module will be used in this project. The difference between unsupervised learning method and supervised learning method is there is no human involvement (or unsupervised) in training set for learning methods which allow to do automatic clustering of training set. Therefore, using this method to extract parameters for pipeline system provides support for establishing a healthy diagnostic knowledge base.
The health diagnostic knowledge library based on historical events and data of key equipment of system can be used to train machine learning models and simulate the operation in order to obtain a model that can produce similar result compared with predicted result. With this model, equipment failures or accidents can be automatically identified, early warning and solved in advance. Specifically, the historical events and data should focus on the smart devices in the neighbor. Accordingly, the impact of the node in the near edge is most important. For example, if one of the valves reports an abnormal message, the algorithm will check the data from nearby valves. If none of the neighbor reports a similar error, the abnormal message from the first valve may be a false alarm.

Based on established health diagnosis knowledge library, we can monitor real-time working status of the network to determine the occurrence of faults and accurate fault locations. It helps to automatically take actions to prevent further expansion of the problem and generate an alarm report, at the meantime, notify service personnel.

In addition, the water supply management team can retake the control on site. When a risk is alarmed and confirmed, human operator will be dispatched to the error point. The smart device in the human operator will be the controller to collect data quickly without relayed from the central platform.

4. Service in the Edge

The smart water supply service includes smart water meter service and other value-added services.

4.1. Trust and control:

For the smart water meter service, a collector integrates all the smart meter data from various end users and transmits the data to service reception module. Accordingly, the data is analyzed, stored, and presented for various applications. The collection frequency can be determined by the system previously or performed on need basis. The trust is between the water meter and the data collector. In addition, there is trust between the data collector and user devices nearby.

User friendly web interface can be developed for the smart water management system. An example of user interface is shown in figure 5.
4.2. Proximity and Intelligence

With the user information nearby, it will be more convenient and accurate for various value added services to analyze the user requirements. This feature is very useful since it only considers the proximity user status.

On the other hand, for the value added services, the users’ information will be specifically useful. For example, with the analysis to the water consumption amount and pattern, the system can estimate the family size as well as the family usage pattern. Consequently, for a big family, the large-capacity water heater will be promoted. In addition, people may learn tips to save water in the social platform offered by the system.

In addition, for the smart water meter devices, the integration of user location can help detect the abnormal scenarios. For example, one user may have a water consumption pattern with a small usage in the daytime and a large usage at night. If the daytime water consumption increases in day time, then there are two possible scenarios behind: the user is either at home that day or there is a water leakage in the house. The position data from the user can help to identify the real situation.

5. Summary

This paper presents our overall platform for a smart water supply system based on edge-centric computing paradigm. Integrating with the user/device information collected nearby at the edge, the system is expected to simulate and alert in advance, monitor and process in real time, and analyze the data and events to establish a water supply domain expert system over time.
References