WaterWiSe@SG: Continuous Monitoring of Water Distribution Systems

Introduction

A city-wide water distribution system is a critical civil infrastructure that serves a large user population. There is a crucial need for real time monitoring and accurate modelling of such a water distribution system for various goals such as water conservation, optimisation of pump operations, detection and localisation of pipe burst and leak events, and provision of water contamination warning.

This need has become a vision and motivated the team to develop a large-scale sensor network based cyber-physical infrastructure for continuous monitoring of water distribution systems in Singapore. A major research effort called the WaterWiSe@SG project, which stands for "Water Wireless Sentinel at Singapore", has since been set up. Supported by the Singapore National Research Foundation (NRF), this is a multi-party collaboration involving the Massachusetts Institute of Technology (MIT), the Center for Environmental Sensing and Modelling (CENSAM) of the Singapore-MIT Alliance for Research and Technology (SMART), the Intelligent Systems Centre (IntelliSys) and the School of Computer Engineering (SCE) at Nanyang Technological University (NTU), and the Singapore Public Utilities Board (PUB).

Objectives

The overall system design is driven by real-life application requirements. The operational objectives of WaterWise@SG include:

- Performing continuous and high data rate monitoring of hydraulic parameters within a water distribution system. Real time pressure and flow measurements will be assimilated with hydraulic models to improve the operational efficiency of the system through predictions of the consumers' water demand.
- Developing techniques for detecting and localising pipe burst events by analysing pressure and acoustic signatures, and for detecting slow leaks using state parameter approaches. Such capabilities can greatly reduce water loss, property damages and the long-term maintenance costs associated with pipe bursts and leaks.
- Performing integrated monitoring of hydraulic and water quality parameters. The long-term performance and robustness of water quality sensors for measures such as pH, residual chlorine, turbidity, conductivity, dissolved oxygen and various biological and chemical contaminants will be evaluated by the team. They will look to study the usage or development of multi-parameter sensor technologies, and the application of cross-correlation techniques to interpret water quality signatures through in-network processing.

Project Highlights

The WaterWise@SG project is organised into three phases. In Phase 1, a basic system with a small number of sensor nodes is developed and deployed to demonstrate the viability of long-term monitoring and data collection. In Phase 2, this network will be expanded to around 25 sensor nodes. During this phase, various wireless network architectures, collaborative in-network data processing techniques, and large-scale integration of sensor data with hydraulic modelling will be explored. Finally, Phase 3 will be the full-scale deployment of a system with 100 over sensor nodes. During this phase, researchers will leverage on the knowledge gained from the first two phases to operate a full-scale system, and to explore the cyber-physical interplay between its computational and physical system elements.

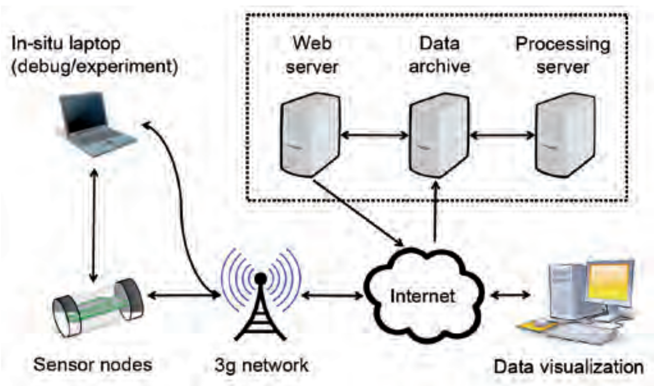

Figure 1. WaterWiSe@SG System Design

Figure 1 shows the system design for the completed Phase 1 of WaterWiSe@SG. The sensor nodes are connected to the water distribution pipes via tapping points. These nodes collect real-time sensor measurements, log system diagnostic data, and transmit the collected data to the backend server infrastructure. The server archives the data, performs data processing, interfaces with hydraulic modelling tools, and hosts a web portal providing various services for data access and visualisation.

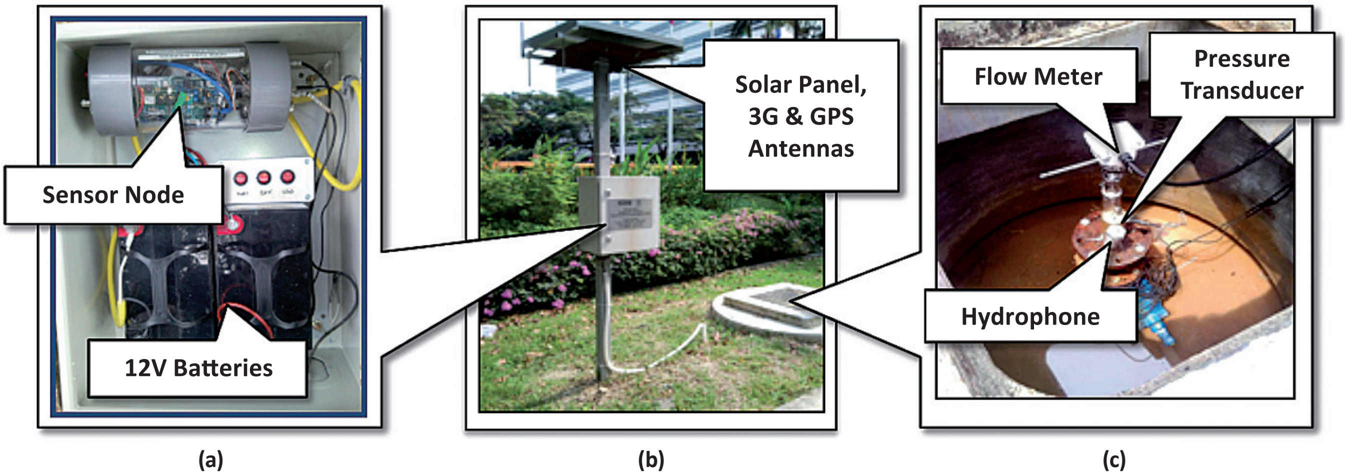

Figure 2. Sensor Node Deployment

Figure 2 shows the deployment of a sensor node and its associated support infrastructure at a site in downtown Singapore. The sensor node is custom designed for continuously collecting sensor data at 2KHz sampling rate and transmitting the data in real time over 3G or Wi-Fi interfaces. It also has the ability to perform local data processing when appropriate.

The operational flow between the main components of the WaterWiSe@SG software and middleware architecture is shown in Figure 3. It shows the system's capability to operate in a distributed manner for sensor data acquisition, on-node processing, data transmission, data processing and archival, hydraulic modelling and data visualisation. Figure 4 shows a snapshot of the WaterWiSe@SG web portal displaying the sensor data.

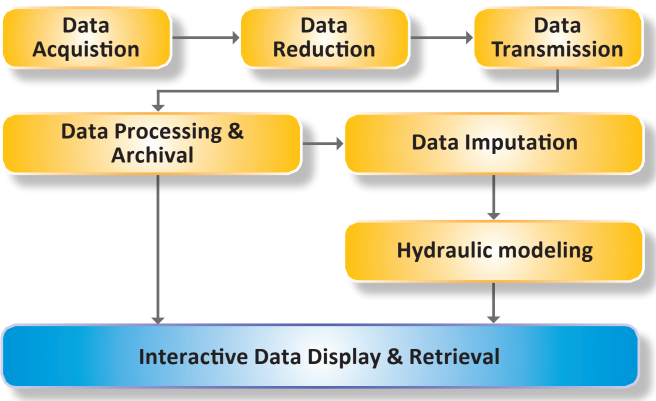

Figure 3. Software and Middleware Architecture

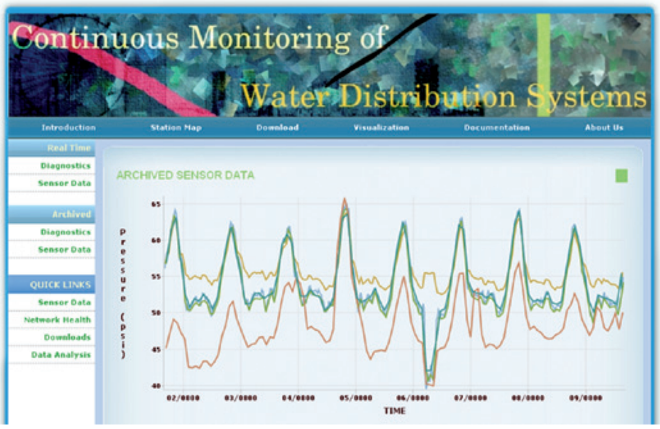

Figure 4. WaterWiSe@SG Web Portal

Applications

The applications of this system include remote detection of pipe burst and leak events, real-time hydraulic modelling for distribution planning through water demand prediction, and water contamination monitoring and mitigation. At present, a suite of statistical and wavelet decomposition techniques to detect pipe burst events in real time is in the process of development and evaluation. Based on the estimation of the arrival times of the pressure front at various nodes after a pipe burst event, the system can determine the location of the pipe burst. The sensor data has also been integrated with hydraulic models to predict the water demand at various demand zones in downtown Singapore.

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