BattLeDIM: Battle of the Leakage Detection and Isolation Methods

2nd International CCWI/WDSA Joint Conference, Beijing, China (http://www.ccwi-wdsa2020.com/)

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1. INTRODUCTION

Drinking Water Distribution Networks (DWDN) are susceptible to infrastructure failures, which may lead to water losses. Typically, these water losses are due to background leakages and pipe bursts which may occur anywhere within the distribution network. Background leakages are normally difficult to detect due to their small size, whereas pipe bursts are easier to locate as they are of larger size and may appear on the surface. The early detection and localization of some leakage event is extremely important, as this would reduce the time required for accommodating the event and therefore reducing the risk of further infrastructure degradation, contamination events and consumer complaints. In previous years, a number of methodologies have been proposed to detect and isolate the location of leakage events using various types of sensor measurements. These methods were commonly evaluated on private commercial datasets, and as a result, it is not possible to objectively compare these methods in their ability to detect and isolate leaks. In the past year, a leakage detection dataset has been proposed, LeakDB [1], based on benchmark networks and created using the WNTR tool [2], using pressure-driven demands and realistic leakage modelling [3]. Inspired by the "BATtle of the Attack Detection ALgorithms" (BATADAL), which focused on the detection of cyber-physical attacks [4], our team decided to organize a similar "battle" focusing on leakage events.

The **Battle of the Leakage Detection and Isolation Methods (BattLeDIM),** organized as part of the 2nd International CCWI/WDSA Joint Conference in Beijing, China (http://www.ccwi-wdsa2020.com/), aims at objectively comparing the performance of methods for the detection and localization of leakage events, relying on SCADA measurements of flow and pressure sensors installed within water distribution networks. Participants may use different types of tools and methods, including (but not limited to) engineering judgement, machine learning, statistical methods, signal processing, and model-based fault diagnosis approaches.

2. CHALLENGE DESCRIPTION

L-Town (see Fig. 1) is a small hypothetical town with a population of around 10,000 people. The water utility of L-Town is responsible for delivering drinking water to consumers through a network of pipes with a total length of 42.6km. In previous years, the utility was experiencing a large number of pipe breaks and water losses, affecting its service quality. The water distribution network of L-Town is receiving water from two (2) reservoirs, and the water utility aims at providing water with a pressure head of at least 20m to all of its consumers. A Pressure Reduction Valve (PRV) is installed in the lower part of the town ("Area B"), to help reducing background leakages. PRVs are also installed downstream of the two main reservoirs, to help regulating the pressure. A pump and a water tank have been installed in the higher part of the town ("Area C"), to provide sufficient pressure to the consumers of that area. The tank has a diameter of 16 meters with a cylindrical shape. The pump has been programmed so that the tank should be refilling during the night and emptying to "Area C" during the day. There are three consumer types in L-Town: residential, commercial and industrial. During workdays (Monday to Friday), water consumption follows a similar pattern, whereas during the weekend (Saturday and Sunday), there is higher consumption during late hours as the result of night life. Areas with industrial users do not follow the same pattern of consumption. L-Town is located in the Northern hemisphere, thus higher water usage is expected around July/August, and lower in December/January. For the purposes of this challenge, there are no significant variations of water consumption during holidays or other special days.

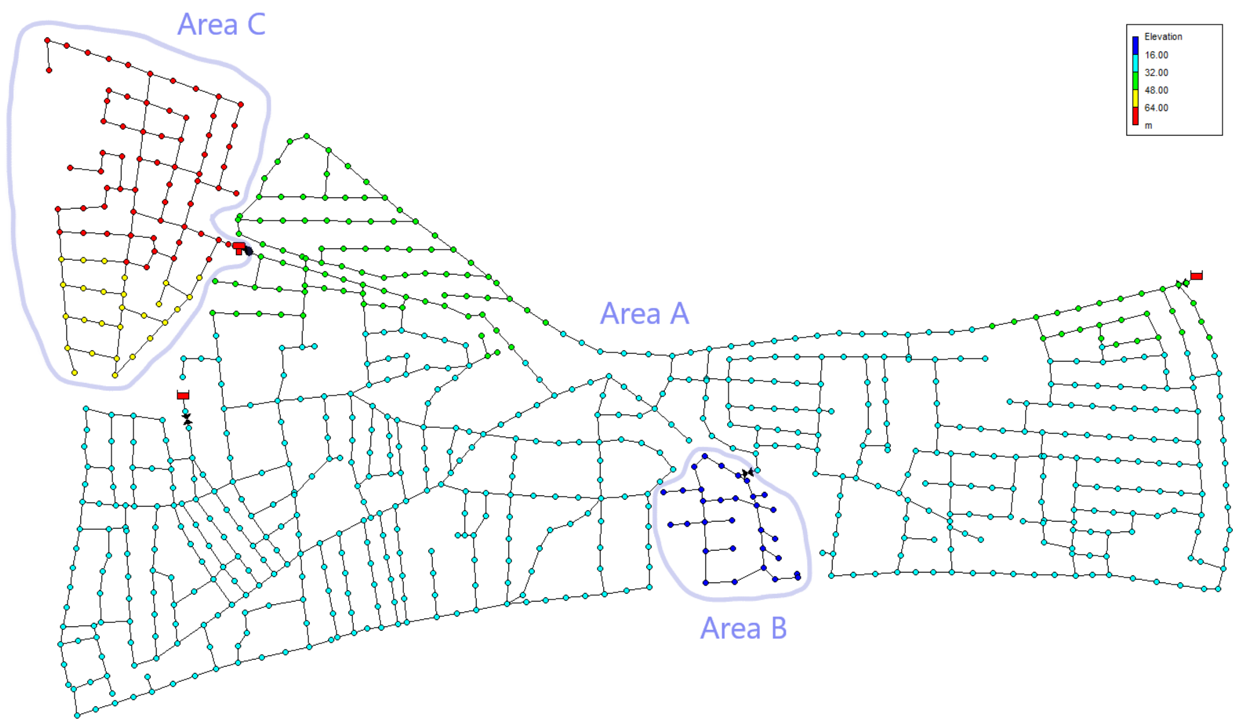

Figure 1: The L-Town Benchmark Network

To enhance its capability in monitoring water losses, the water utility of L-Town decided to install one (1) tank water level sensor, three (3) flow sensors, and 33 pressure sensors (see Fig. 2), all transmitting their measurements every 5 minutes to the utility's Supervisory Control and Data Acquisition (SCADA) System. Pressure sensors give an average value of the last 5 minutes, which mitigates the uncertainty due to pressure transients in the system. In addition, 82 Automated Metered Readings (AMRs) have been installed in “Area C”, for delivering water consumption data directly to the SCADA system (see Fig. 3). Each AMR gives the aggregated consumption of many users in the AMR area.

During 2018, a number of leakage events occurred, which were detected and fixed by the water utility. However, it is believed that a number of smaller leakages occurred but not revealed. It is also assumed that some leakages occurred abruptly, whereas others developed gradually, as incipient events, from background leaks into pipe bursts.

To assist the L-Town water utility decision-making process, the utility developed an EPANET-based nominal model of the distribution network, in which base demands were assigned to nodes, following historical data of proximity consumers. Moreover, two nominal demand patterns were identified for residential and commercial consumer types (with some discrepancies). The utility believes that there might be some inaccuracies in the model, e.g., with respect to the pipe roughness and pipe diameters. In addition, the utility was not able to confirm the status of all the valves in the network (i.e., whether they are open or closed).

The L-Town water utility is searching for a solution to help them analyzing the SCADA dataset, and detect leakage events as fast as possible. In addition, it is crucial for the utility to have an indication where approximately the leakage occurs, so that the field workers can inspect those potential leaks using their equipment.

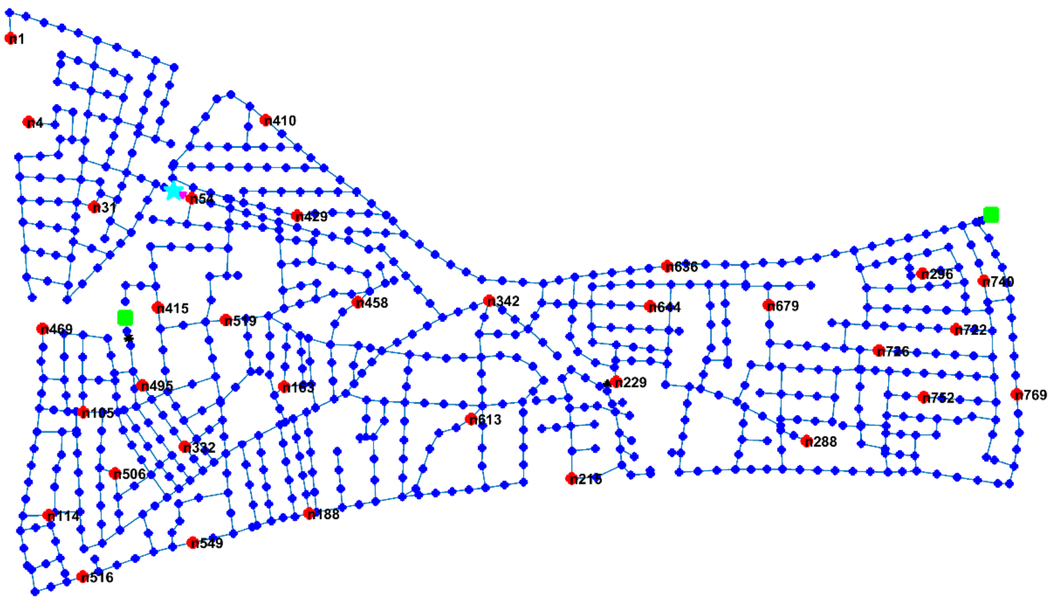

Figure 2: The locations of the 33 pressure sensors placed in L-Town are indicated with yellow color along with their node ID.

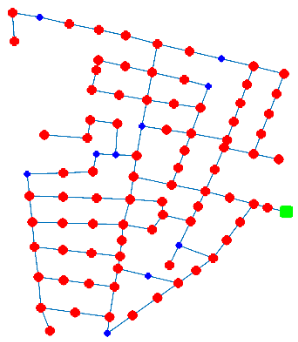

Figure 3: 82 AMR locations (nodes with red color) in "Area C" of L-Town. Nodes colored in blue do not have AMRs installed.

3. COMPETITION GOAL

The L-Town utility has created an open call for teams to demonstrate their ability in detecting and localizing leakage events. The teams will be given a historical SCADA dataset along with information related with the leakages detected and fixed by the utility throughout 2018, to use for training purposes and for calibrating their models. It is possible that more leakage events occurred during 2018, however the utility was not able to detect and localize them.

Throughout 2019, the utility conducted periodic surveys using additional sensing equipment, pipe inspections and other methods, and was able to detect and isolate all the leakage events that occurred within that period. The most critical of these events were repaired, however it was not possible to repair some of these leakages due to financial reasons.

The overall goal of this competition, is to identify methods which are able to detect and localize the leakage events that occurred in L-Town in 2019, as fast as possible (with respect to time) and as accurately as possible (with respect to their location), in order to minimize their overall financial costs, both in water losses, as well as due to the hours spent in isolating the leakage by the utility staff. The L-Town utility will compare the different solutions and select the best one based on that objective. More details regarding the evaluation procedure will be released in January 2020.

4. DATASET

The participant will be provided with the following data:

1. **"2018 SCADA.xlsx"** historical dataset (also in CSV): The historical data have been collected for the period 2018-01-01 00:00 until 2018-12-31 23:55, at 5-minute time steps The SCADA dataset is comprised of the water tank level, the flow sensors, the AMR measurements and the pressure sensors.
2. "**2018 Leak Report.txt**" (TXT): The repair times of pipe bursts that have been fixed are provided.
3. **"L-Town.inp"** EPANET Model (INP): A model of the network is provided with nominal parameters for all the system elements. The nominal base demands for each node are based on average historical metered consumption. In general, the difference between the actual and the nominal values for each consumer type (residential and commercial) is less than 10%. Weekly demand profiles for two consumer types (residential and commercial) are also provided, however they do not capture the yearly seasonality. Furthermore, the EPANET model parameters may be different from the actual network parameters (e.g., diameters, roughness coefficients), and it is assumed than in general this difference is no greater than 10% of the nominal values.

4. “**2019 SCADA.xlsx**” evaluation Dataset (also in CSV): The evaluation data have been collected for the period 2019-01-01 00:00 until 2019-12-31 23:55, at 5-minute time steps. The SCADA dataset is comprised of the water tank level, the flow sensors, the AMR measurements and the pressure sensors. **This dataset will be used for the evaluation of the competing leakage detection methodologies, and will be disclosed within January 2020**.

Sensor details:

- Three (3) flow sensors exist in the system, two at the DMA inflows and one at the pump. Measurement units: cubic meters per hour (m^3/h).
- 33 pressure sensors exist in the system which give the average pressure of the last 5 minutes at the sensor location. The pressure sensors were placed using a methodology which maximizes the collective sensitivity of the sensors to any possible leak. Measurement units: meters (m).
- One (1) water level sensor has been installed in the tank. Measurement units: meters (m)
- 82 AMRs installed in “Area C” which give the aggregated consumption from a number of consumers in the AMR area Measurement units: Liters per hour (L/h).

5. SCHEDULE

Date	Event
27/12/2019	Announcement of competition and release of 2018 dataset
20/1/2020	Update 2018 Dataset
27/1/2020	Release of the evaluation 2019 SCADA dataset
1/3/2020	Submission of the detection and isolation report by participants
1-4/9/2020	Public presentation at CCWI/WDSA 2020
	Development of jointly authored journal manuscript

6. HOW TO PARTICIPATE

Participants will be provided a template “Results” file, in which they will be asked indicate the following information:

- Start time of each detected leak
- Pipe ID of the detected leak

Details on the evaluation procedure will be provided on a separate document.

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REFERENCES

[1] Vrachimis, S. G., Kyriakou, M. S., Eliades, D. G. and Polycarpou, M. M. (2018). LeakDB: A benchmark dataset for leakage diagnosis in water distribution networks. In Proc. of WDSA / CCWI Joint Conference (Vol. 1).

[2] Hart, D., Klise, K.A., Bynum, M.L., Laird, C.D. and Seth, A., (2019). Water Network Tool for Resilience (WNTR) v. 2.0 (No. WNTR). Sandia National Lab (SNL-NM), Albuquerque, NM (United States).

[3] Crowl, D.A., and Louvar, J.F. (2002). Chemical Process Safety: Fundamentals with Applications, 3rd edition. Upper Saddle River, NJ: Prentice Hall, 720p.

[4] R. Taormina *et al.* (2018). "Battle of the Attack Detection Algorithms: Disclosing Cyber Attacks on Water Distribution Networks," *Journal of Water Resources Planning and Management*, vol. 144, no. 8, p. 04018048.