Wireless Sensor Network-based Improved NPW Leakage Detection Algorithm for Real-Time Application in Pipelines

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Abstract— **With increasing population in South Africa coupled with improved standard of living, the demand for water has increased dramatically in the past few years. To meet this demand and for effective water supply, the water loss through leakages of pipelines transporting this resource needs to be reduced. This paper briefly elaborates on work in progress employing wireless sensor networks (WSNs) to an improved negative pressure wave method for real-time leakage monitoring of a water pipeline network.**

***Keywords*— Leakage detection techniques, pipelines, water loss, WSN.**

I. Introduction

Human survival and nearly all modes of economic production depends on water. However, this water is not readily available for use of human as less than 3% of water on the planet is fresh water of which 80% is locked away in glaciers and ice sheets [1], as illustrated in the statistics done by [1], shown in Fig. 1.

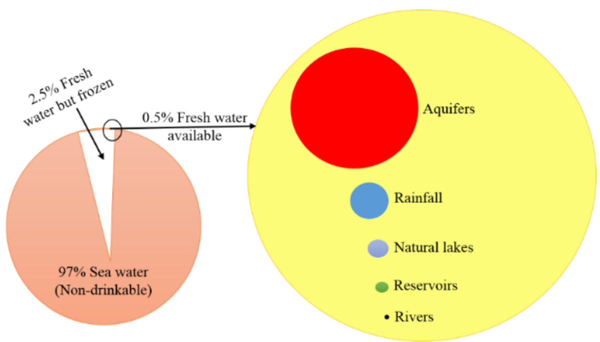

Figure 1: Illustration of water availability [1].

From this figure, it is observed that only 0.5% of all the water on the planet is available for use by man and nearly all of this is beneath the earth's surface in the form of groundwater. Consequently, to have access to this resource, drilling, pumping and treating in a water plant for storage and distribution, among others has to be carried out. However, not all the water produced at the water treatment plants reach the customer and generate revenue for water industries and government. Instead, a significant portion of this water does not generate revenue for water industries, termed as, non-revenue water (NRW) [1].

In most water utilities, the minimization of the NRW is a major priority. Even in South Africa, a water scarce country, the unacceptable NRW threatens its financial viability of the municipal water services with an estimated loss of around R7 billion annually [2]. Reducing the NRW will give the water industries access to self-generating cash flow for investing in new infrastructure and operational maintenance, as well as, providing better value and improved water service to its customers [1]. A major component of the NRW is the real losses as a result of leakages from pipelines. Therefore, reducing these leakages through a leak detection method will, among others, result in a greater volume of water available for consumption, lowers the operating cost and improves the revenue generated.

A large number of leakage detection techniques are available in the literature, each with different accuracy, cost of deployment, applicable environment and research challenges. Moreover, a considerable amount of research is being carried out on the use of wireless sensor networks for real-time leakage detection and localisation within the pipeline [3-7]. However, the strategic location of sensors, energy management of sensor nodes, secure communication between sensor nodes and transmitting of the readings from sensors deployed for underground applications to a remote admin centre in a reliable way, among others, are a major limitation of this technology. In this research, an improved negative pressure wave technique for leakage detection and localisation is proposed. The main motivation behind using the negative pressure wave technique (NPWT) is that of its suitability in detecting small leaks [8], coupled with the fact that about 90% of the water loss is caused by small leakages [9]. Additionally, an integration into a WSN will be done during this research and the overall technique tested on a water distribution network.

II. Research Goal

The goal of the research study is to develop an improved leakage detection and localisation technique and integration into wireless sensor networks for real-time application in small scale water distribution pipelines.

III. Research Methodology

The proposed method of real-time leakage detection and localisation consists of two stages, namely, sensing/transmitting stage and receiving/processing stage. The schematic diagram of the proposed method is shown in Fig. 2. Considering Fig. 2, the system consists of a water distribution pipeline, sensor nodes placed on the pipe surface to measure the pressure drop signal due to leakages and a remote computer acting as a processing centre. Each sensor node consists of a sensor (pressure sensor), a microcontroller (Arduino), a battery and a communication module for transmitting the sensed signal wirelessly to a central node as illustrated in Fig. 3. The microcontroller connected to the sensor, gathers the sensor data, converts it to a digital form stored in a flash memory and then transfers it wirelessly to the central node though the communication module (ZigBee module).

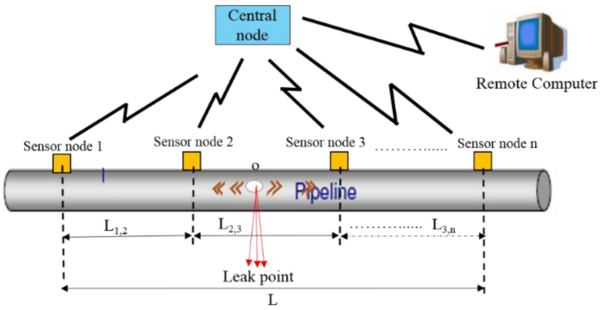

Figure 2: The schematic diagram of the proposed sensor topology.

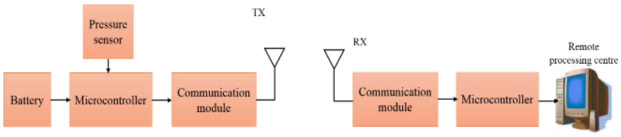

Figure 3: Component of the proposed sensor topology for leakage detection.

ZigBee was chosen because of its low cost and low power consumption capability. The central node receives all the sensor data and transmits them to a remote computer through an RS232 or local area network (LAN) interface as shown in Fig. 3. At the remote centre (processing centre), leakage detection and localisation is performed.

The operation involved at this centre is given by the flow chart in Fig. 4. The raw data from the sensor is filtered to ensure data quality using an appropriate filtering algorithm. Since the leak signal varies under different conditions, it is desirable that, to get accurate result, a feature extraction is performed on the filtered signal [3] to extract special signal characteristics and obtain a proper frequency component of the signal. At this stage, a wavelet transform will be adopted due to its ability to reflect both the frequency and timing of the signal compared to the conventional Fourier transform [3]. After the extraction stage, a pattern matching algorithm is incorporated into the leakage detection stage to distinguish between the pattern of the slope curve of a normal leak and that of the transient operation of the pipeline. In the event of a real leak, a leak alarm is raised and the algorithm computes its location.

IV. CONCLUSION

Leakages have been a major threat to water utilities around the world and has been subject of discussion in the research community. Various leakage detection approaches have been proposed and research work is being conducted within the pipeline research community. This work proposes a WSN-based improved negative pressure wave (NPW) leakage detection method for real-time application in pipelines. The proposed technique is expected to improve leakage detection reliability in pipeline network.

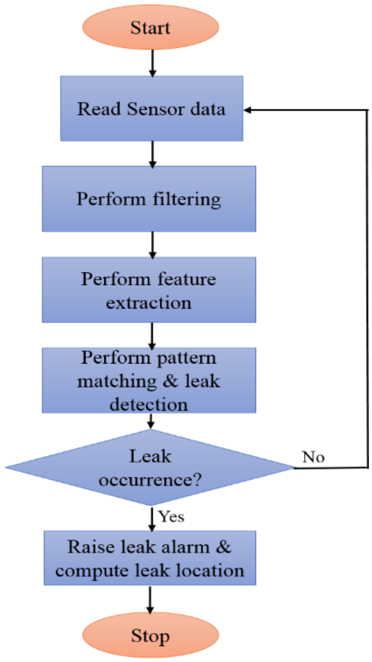

Figure 4: Proposed leakage detection and localisation flow chart

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Kazeem Adedeji received his M.Eng and M.Tech in 2015 and 2016 respectively. He is currently doing his doctorate degree at Tshwane University of Technology, Pretoria, South Africa. His research area include data communication and network security, broadband communication and sensor networks.