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Leakage Detection in Underground Pipes using Zigbee-Based Wireless Sensor Network

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Abstract— This paper presents the use of Zigbee-Based wireless sensor network (WSN) for leakage detection in underground water transporting pipelines. It has been implemented on a laboratory model of an underground pipeline having length of 20 metres. Sensor nodes configured in mesh topology were distributed over the length of the pipeline. The gateway node has been placed at some distance from the sensor nodes and was programmed to acquire data for soil-moisture, soil-temperature and GPS data at intervals of 5 seconds. The system has been programmed is such a way that when the change in soil temperature or soil moisture as read from any sensor exceeds a pre-set threshold an alarm or warning signal is generated so that the corrective action can be taken on time.

Keywords— Wireless Sensor Network, Zigbee, Monitoring, water leakage detection, Pipeline, Soil-moisture (SM), Soil-temperature (ST).

I. Introduction

Various pipeline systems such as underground, exposed and underwater are deployed for transporting water from one location to other. Mostly, underground water pipeline system is preferred for transporting and distributing water to the consumers ranging from few metres to several kilometres distance. Huge amount of water is being wasted on daily basis throughout the world because of leakages and ruptures. The underground water supply pipelines are not visible and easily accessible. Therefore, this problem is becoming worsened day-by-day due to lack of advanced water supply pipeline monitoring, leakage detection and leakage locating system. Because of harsh underground environmental conditions, existing leakage detection techniques does not work well in monitoring and detection of leakages in underground pipeline [1].

The paper has the following sections: Section 2, presents the proposed approach. Sections 3, the sensors used in the work have been introduced. Section 4, the wireless sensor used is presented while section 5 has been dedicated for gateway node used for the work. In section 6, of the paper, architecture of WSN has been explained. Section 7, presents the data acquired from the sensor nodes while data processing & decision making along with flowchart is reported in section 8. Finally, the conclusion obtained is presented in section 9 of the paper.

II. PROPOSED Approach

This paper proposes the use of Zigbee-based WSN along with GPS Sensor for detection and locating the leakages in underground Pipes. The earlier technology of detection and locating the leakages in underground pipes uses wired and manual inspection method and it was costly and time consuming. Such systems are very cumbersome and are not very satisfactory [2]. The new technology, which uses a wireless sensor network (WSN), has several advantages and hence real-time detection of leakages of underground pipes is possible.

III. Sensors Used

A. *Soil Moisture Sensor:*

At the location of water leakages in the pipeline especially in case of underground pipeline, the moisture content increases in the soil. Therefore, Soil-Moisture sensor can be used to sense the change in of moisture content in soil for the underground pipeline and hence leakage detection can be done easily. Soil sensing arrangement is used to measure the volumetric water content of soil. It consists of two sensing probe having dimension 60x30mm, which must be inserted in the soil, This soil moisture sensor is used to sense the presence of water in soil and gives some output voltage to the microcontroller to execute according to the instruction given by the user. The Soil-moisture sensor is shown in the Fig.1.

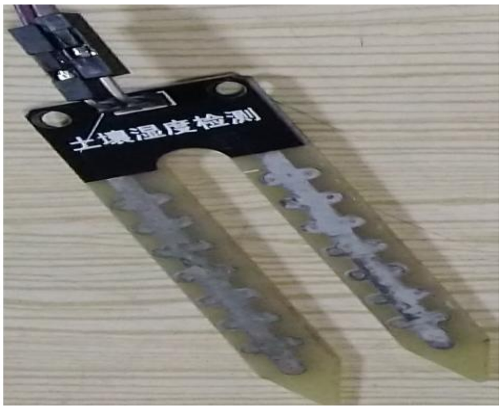


Fig1.Soil-Moisture Sensor

B. *Soil Temperature Sensor*

Soil-temperature is an important factor considered for the detection of leakages in the underground pipeline. In case of underground pipes, the soil-temperature at the location of leakage under the ground suddenly changes and falls low as compared to the normal soil-temperature.

The 100Kohm NTC thermistor is used as temperature sensor for measuring Soil-temperature. It is small in size, light weight and cheap. It has fastest response time with high accuracy and better stability. Because of its high resistance and high mechanical strength it withstands, it is very much usable in high-temperature and high moisture environments. The NTC thermistor temperature sensor is shown in the Fig.2.

Specifications:

Operating temperature range: -50∼+260°C

Resistance value: R (25°C) = 100k ± 1%

B value: 3950±1%

Insulation resistance: 50MΩ

Thermal time constant (T): T≤10∼17s (in still air)

Thermal dissipation constant (δ): 1.1∼1.6mW/°C (in still air)

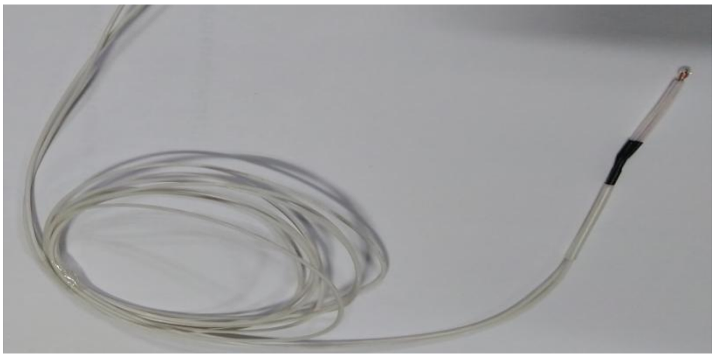


Fig.2 NTC thermistor temperature sensor

C. *GPS Sensor*

The GPS sensor (antenova M10382) is a single package that combines a full GPS engine and antenna on a small SMD module. The M10382 is a highly integrated GPS RF antenna module suitable for L1-band GPS and A-GPS systems. It combines the high performance u-blox 6 GPS position engine.M10382 also benefits from novel external that ensures easy tuning for each platform. The M10382 operates on 1.8V or 3.3 V positive supply with low power consumption. The M10382 is supported by u-blox stand-alone software and is compatible with UART, SPI, DDC, I^2C and USB host processor interfaces [4]. The GPS Sensor is shown in the Fig.3.

Fig.3 GPS Sensor

IV. WIRELESS SENSOR NODE USED

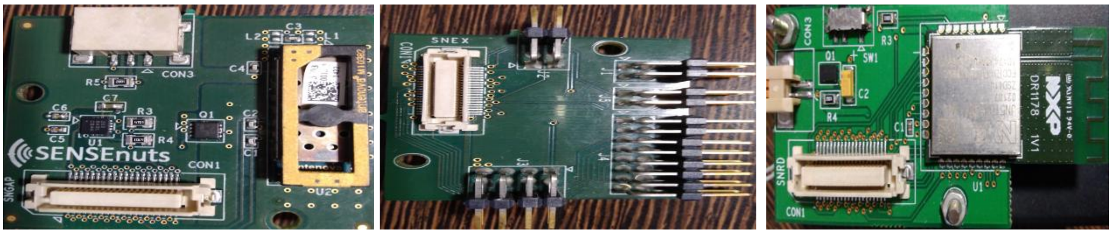
The Wireless Sensor Node used in this work consists of sensor module, extender module, radio module and power supply module.

The sensor module contains soil-moisture sensor, soil-temperature sensor as discussed above. The GPS module combines GPS transceiver with an integrated antenna, an accelerometer and an interface for a PIR sensor.

The extender module extends all the pins of the micro controller on a board and provides access to users to connect external sensors and other device. It is also used to debug hardware/checking output on DIOs. The soil-moisture and soil-temperature sensor as discussed above is connected to pin ADC 1 and ADC2 respectively of the extender.

The radio module comprises of 32-bit RISC JN 5168 microcontroller , 1.32 MHz clock speed, 256 KB flash memory, 32KB RAM and 4KB EEPROM.. It has 2.4 GHz IEEE 802.15.4 integrated transceiver with integrated PCB antenna [5].

The battery module contains 3V battery covered in a plastic casing to provide power supply to the node. The sensor nodes is programmed in such a way so as to give the values of soil-moisture in floating numbers in percentage and soil-temperature in floating numbers in degree Celsius (°C). The GPS module, extender module and radio module is shown in the Fig.4. and that of wireless sensor node is shown in Fig.5.



a) GPS module *b) Extender module* *c) Radio module*

Fig.4 *Top view of GPS module, Extender module and Radio module*

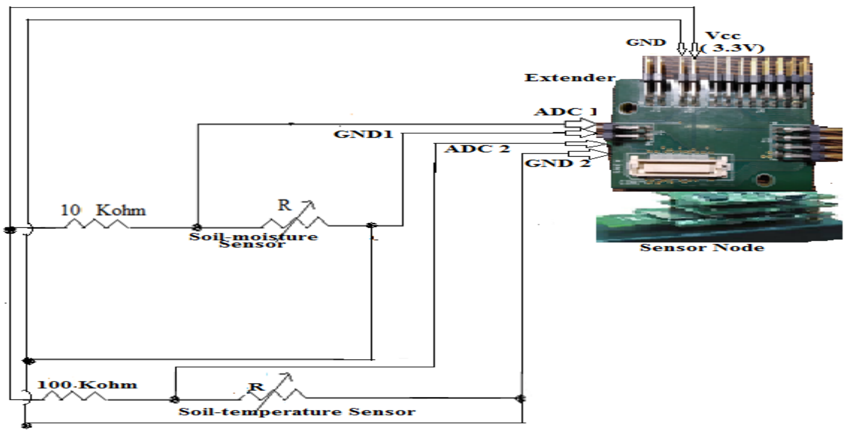


Fig.5 Wireless Sensor Node

V. GATEWAY NODE

The SENSEnuts USB gateway node is used to program the microcontroller and also acts as interface between the wireless sensor nodes and the PC via USB link for serial data transfer. It consists of three modules namely – radio module, USB-Zigbee Gateway module and battery module. It follows IEEE 802.15.4 standard and has integrated PCB antenna and operates in the 2.4 GHz ISM frequency band [6]. The USB gateway node is shown in Fig.6.

Fig.6 Gateway Node

VI. WIRELESS SENSOR NETWORK ARCHITECTURE

The architecture of wireless sensor network is shown in the fig.7. In WSN, the number of sensor nodes can be in the order of hundreds or even thousands and these nodes are evenly distributed in the area. A number of topologies are available for WSN configuration. In this application, leakage detection of underground water pipeline using Zigbee-based Wireless Sensor Network, the sensor node is configured in mesh network topology. Since there are generally multiple routing paths between the nodes, these networks are robust to failure of individual nodes or links. The gateway node also called as data collector, continuously collects the data from all these deployed wireless sensor nodes wirelessly and send to the Pc for further display, processing and storage. There is wired USB link between the data collector node and PC for serial data transfer

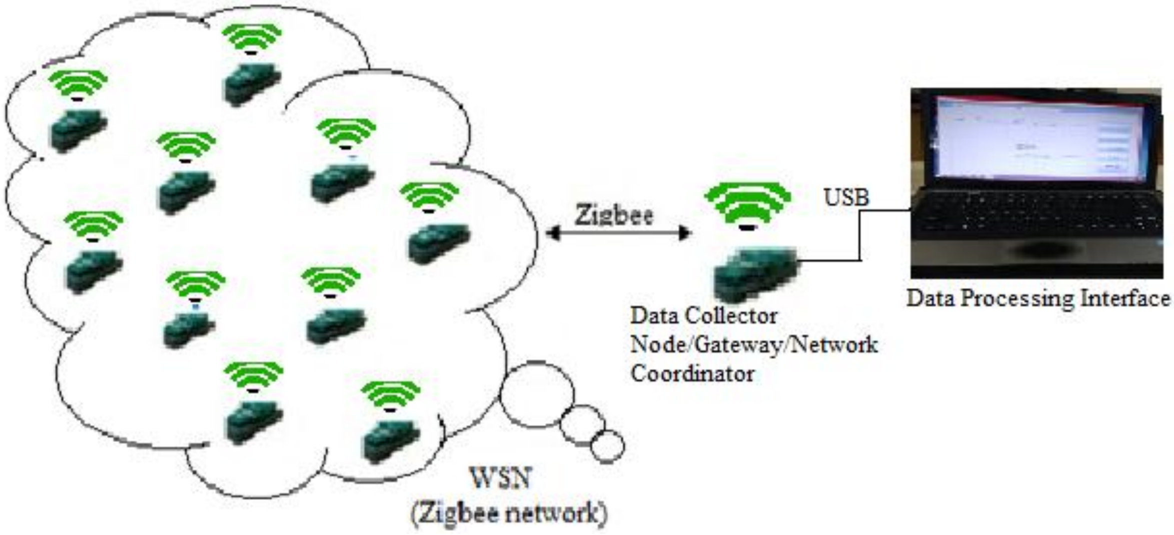


Fig.7 Wireless Sensor Network Architecture

VII. DATA ACQUISITION

The development has been carried out for a small laboratory model of an underground water transporting pipes as shown in the Fig.8. The length of the pipe in the deployment is 20 metres. Each sensor node having soil-moisture sensor, soil-temperature sensor and GPS sensor are evenly distributed throughout the length of the pipeline at a distance of 2 metres apart. The external soil-moisture and soil-temperature sensor is connected to ADC1 and ADC 2 respectively of the extender and GPS module is mounted on the same node. One of the node having radio module and gateway module also called as data collector node/Gateway node connected to PC via USB cable was programmed as PAN coordinator and rest of the sensor nodes were programmed as coordinator. It is programmed in such a way so as to acquire data of soil-moisture, soil-temperature from each sensor node at the interval of 5 seconds and find the exact location in case of the leakages using GPS sensor. The acquired data is then delivered to the PC for data processing, display and storage. The data acquired by the gateway node is displayed on the SenseLive GUI. Since the WSN is based on Zigbee protocols n and the range it supports is limited to only 100 metres, therefore, through multi-hopping, the range can be extended to many kilometres as per the requirements. The acquired data for soil-moisture and soil-temperature is shown in Fig.9.

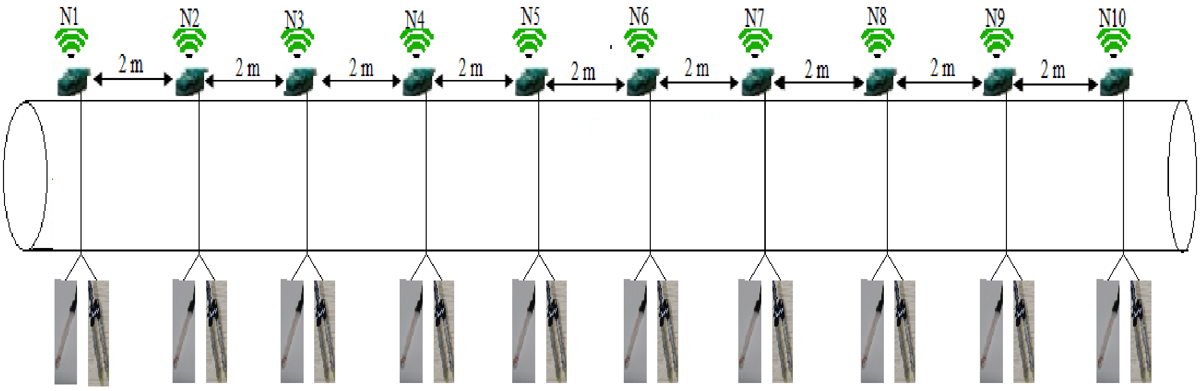


Fig.8 Laboratory model of Underground water transporting pipeline

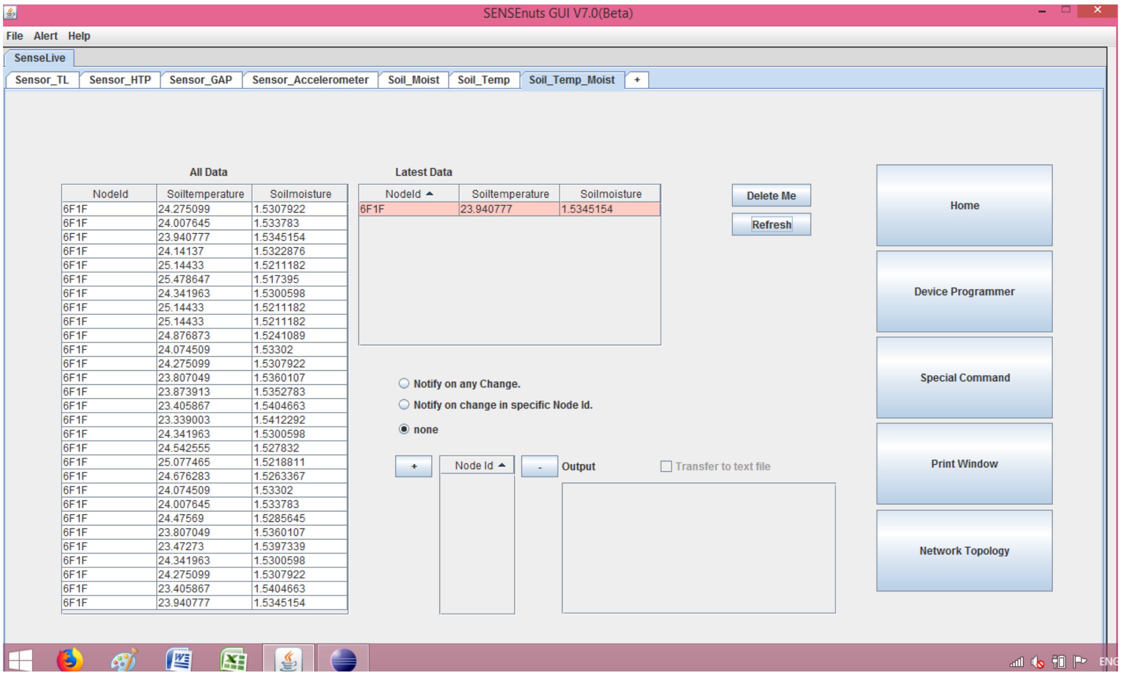


Fig.9 Data acquired from Sensor Node

VIII. DATA PROCESSING AND DECISION MAKING

The software flowchart for data processing & decision making is shown in Fig.10. To start with, the program selects the first WS node and acquires three sets of (SM and ST) data from it at intervals of 5 seconds as mentioned earlier. Their average values are calculated and stored as reference soil-moisture (SMR) and reference soil-temperature (STR). The software then reads latest values of SM and ST from SenseLive & calculates SM-SMR as the increase in soil-moisture with respect to reference value SMR and STR-ST as the fall in soil-temperature from the reference value STR. If the increase in soil-moisture is equal to or more than a pre-defined threshold value of M_2 or the fall in temperature is found to be more than a pre-defined threshold valueT_2, then an alarm signal is issued. If this check fails, then the program finds whether the changes are equal to or more than M_1or T_1 (which are the prefixed threshold for warning) then a warning signal is issued. In case, the check for alarm and warning signal passes, then the software proceeds to determine the location of WS node for which the signal has been issued. For this purpose, the program reads the GPS data from the WS node and displays its location to the operator. The location displayed is the location of the point at which water leakage is taken place If both the checks for alarm and warning fail for the selected node, then the next WS node is selected and the process is repeated.

Decision Making Program is as follows:

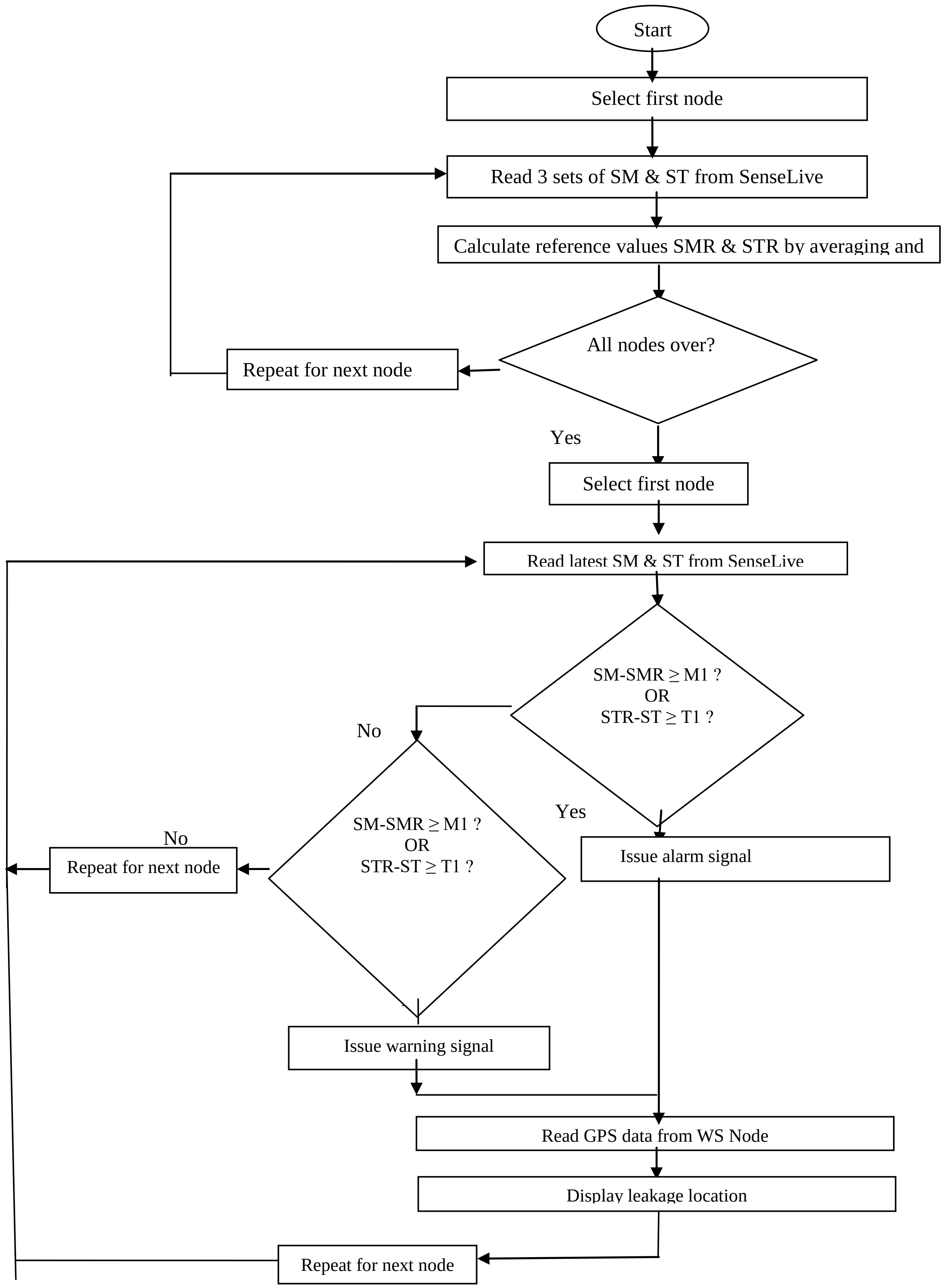


Fig.10. Flowchart for Data Processing and Decision Making Program

IX. CONCLUSIONS

In this paper a proposed solution, using Zigbee-based WSN along with GPS Sensor, for detecting and locating the leakages in underground pipes has been successfully implemented. The experiment was performed on laboratory model of underground water pipes of 20m length. This method has helped to overcome the drawbacks of earlier leakage detection and localization approaches which were based on caballed systems and required manual inspection. Therefore, WSN is an efficient technology and best suited for real time leakage detection system for underground pipes.

REFERENCES

[1] K. Abdullah, Abu. Adnan, T.Daniele and S. Riccardo, "Autonomous sensing for leakage detection in underground water pipelines", IEEE Palmerston North, New Zealand: IEEE, 2011, Fifth International Conference on Sensing Technology, pp. 639-643, Dec.2011.
[2] M. JayaLakshmi and V. Gomathi, "AN ENHANCED UNDERGROUND PIPELINE WATER LEAKAGE MONITORING AND DETECTION SYSTEM USING WIRELESS SENSOR NETWORK", Coimbatore, India, IEEE, 2015.
[4] GPS radionova RF antenna module product specification.
[4] SENSEnuts TM IOT sensation
[5] SENSEnuts WSN sensation quick start guide