Leakage Detection in Water Distribution Pipes Using Wireless Sensor Network

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***Abstract*—Leakage is one of the crucial issues to be dealt with in order to improve the efficiency and effectiveness of water supply services. So it clearly shows the necessity for continuous, automatic monitoring systems that can provide early detection and early warning of defects, such as Leaks, before they reach the magnitude of a major disaster. The proposed work deals with the detection of water leaks by using vibration monitoring techniques. The long-term objective is the development of a system for the automatic detection of burst leaks in water pipes. These leaks can be avoided by Implementing Wireless Sensor Network. The proposed work deals with deploying wireless sensor network (contains MEMS Sensor) that monitors the water distribution pipes and indicates the leakage which can enable rapid and immediate action towards it. The smooth functioning of the system will be enhanced by using different transform methods. FFT and DWT are used for data analysis and the comparison of both FFT and DWT will be done based on data analysis. The above shall be accomplished by hardware implementation (prototype). The monitoring will be done by RF technology. The complete study would be based on Ahmedabad municipal water project System.**

***Index Terms*—: Leakage monitoring system; wireless sensor network; MEMS sensor; FFT and DWT transform; prototype structure; RF technology**

1. INTRODUCTION

The wireless sensor networks (WSNs) are penetrating more and more in our daily life. Their application started from military but they have now entered every zone of civil life from security to facilitation causing immense aid to the society. The diversity of their application is remarkable -environment monitoring, target tracking, pipeline (water, oil, gas, drainage) monitoring, structural health monitoring, precision agriculture, health care, supply chain management, active volcano monitoring, transportation, human activity monitoring and underground mining, to name a few.

A wireless sensor network (WSN) is a multi-hop network. It is also self-organizing distributed network system consisting of a large number of low power consumption sensor nodes through wireless communications. The nodes in the network collaboratively monitor, perceive and acquire information of their outer surrounding environment and also monitor the objectives in real time and process and provide them to users who need them.
WSN has very obvious advantages:
(1) With small power, much larger area is covered through ad-hoc communication.

(2) High level of redundancy is a 'built-in feature'.

(3) Wide ranging or high-precision surveys are carried out via extensive sensors distributed in surveyed regions.

(4) Communications networks are self-organized with network topology who have tendency to adapt the various situation of environments.

While many sensors connect to controllers and processing stations like local area network directly, so as increasing number of sensors collect the data and communicate with wirelessly to a centralized processing station. This is very important since many network applications require hundreds or thousands of sensor nodes and which are often deployed in remote and Inaccessible areas. Therefore, a wireless sensor has not only act as a sensing component, but also gives on-board processing, communication, and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network analysis, correlation, and fusion of its own sensor data and data from other sensor nodes. When many sensors collectively monitor large physical environments, they form a wireless sensor network (WSN). Sensor nodes communicate with each other but also with a base station (BS) using their wireless radios and allowing them to distribute their sensor data for remote

processing, visualization, analysis, and storage systems.

2. OBJECTIVES AND WORK PLAN

2.1Need of the System

Since 'world' heading towards 'smart cities', automation, data networking and analysis in utmost important.

For any state wishing to progress in efficient public administration water network management is a matter of concern. Problems of traditional water distribution networks lie only in their lack of maintenance which has its roots in inability to monitor it after being constructed. So insufficiency in operation and maintenance of water supply schemes is another important challenge for imperfect drinking water supply. An accountable problem in water distribution system is the variations in water supply and the leakages in the distribution water pipeline network are main management related challenges. Also other issue is power fluctuations, which make water supply schemes sub-optimal.

Leakages in the water distribution pipes cause the disparity in distribution reducing the actual quantity of drinking water supplied. In urban areas major factor of reducing the water quality is the leakages in the water. but precise information on the quantity of water lost in distribution network in the state is not available. The leakage occurs mainly due to corrosion of pipes, damages of the pipes during road widening and repair works and also use of poor quality pipes in majority of household connections.

So efficient leak detection in water distributed network is essential for reducing the water waste. So we proposed the system for this leakage detection. If the monitoring of the water distribution network becomes possible then these issues will be correctly addressed. So we propose the scheme of a wireless sensor network that is in line with the water distribution network of the study area.

2.2Objective

- Prototype development
- Development of efficient node that senses and converts real world signals to digital signals that consists vibration MEMS sensors.
- Manipulation of the number of nodes required and node positioning.
- Development of two vibration sensor node and one master node.
- Interconnection of nodes and determination of master and sensor nodes.
- Communication between the nodes using RF technology for leakage detection and required action.
- Real time data collection and analysis at Ahmedabad Municipal Corporation, East zone.
- Analysis model made by AMC, east zone.
- Data analysis done using different transform like FFT and DWT.
- Comparison of both transform will be done based on data analysis.
- Manipulation of the data and compatibility with study sites.
- GUI development using MATLAB.

2.3 Study Area

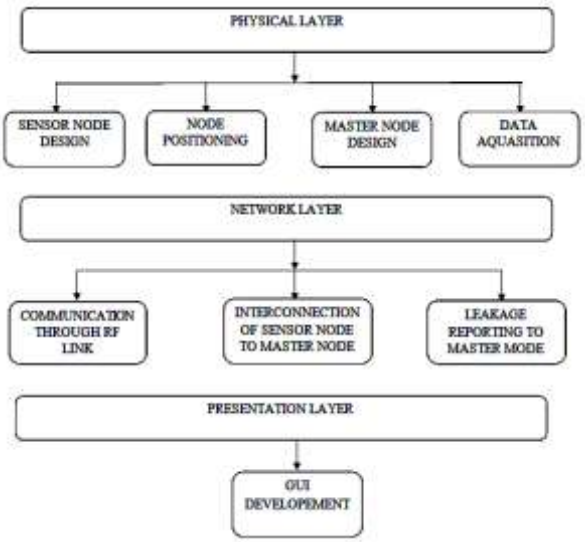
Ahmedabad stands as one of the rapidly urbanizing economies in India. There are five distribution zones, overlapping with the five administrative zones. The following table shows the east zone coverage of water supply. The distribution network of 2584 km caters to the entire city. There are 90 distribution stations in the entire city.
From all five zone we have choose east zone for site analysis and data collection. In table1 all information related to east zone is given.

Table 1 East Zone Coverage Water Supply

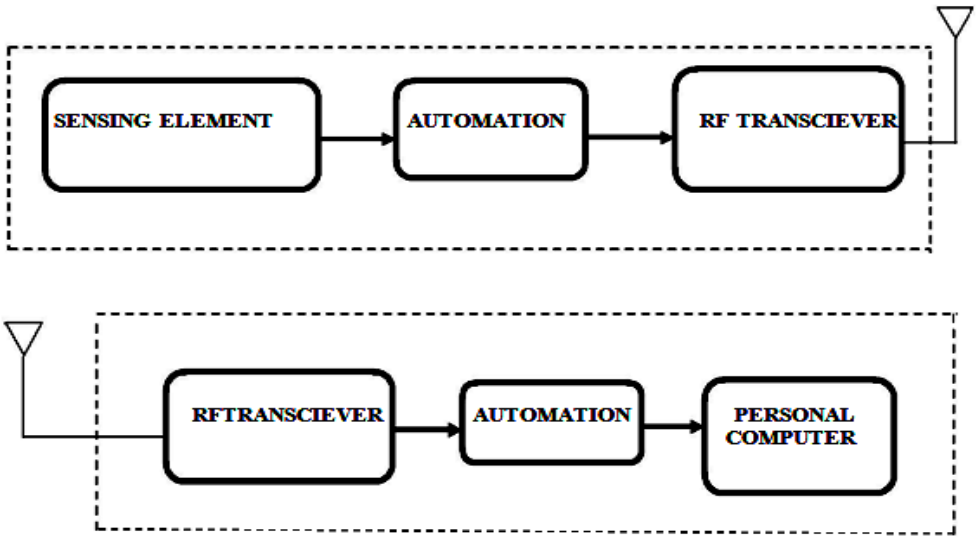
Parameters East Zone	**East Zone**
No of wards Catered	9
Total area of the zone (sqkm)	27.51
Total population of the zone	783107
Total area covered by piped water supply (%)	80
Total water supply capacity(MLD)	108
Water Supply Pipelines length(km)	605

Figure1 Water Distribution Map of Naroda Gam, Ahmedabad (Source: AMC, Naroda Ward)

2.4 Layer Wise Specification



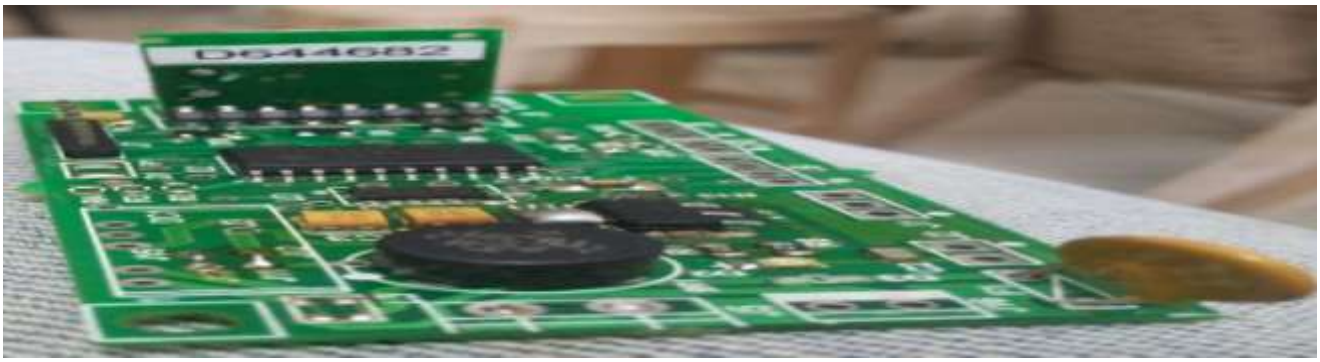
2.5 Block Diagram



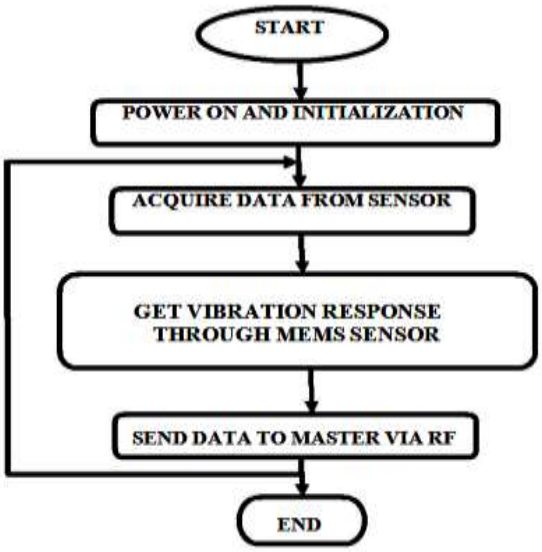
2.6 HARDWARE DESIGN

Sensor Node Design

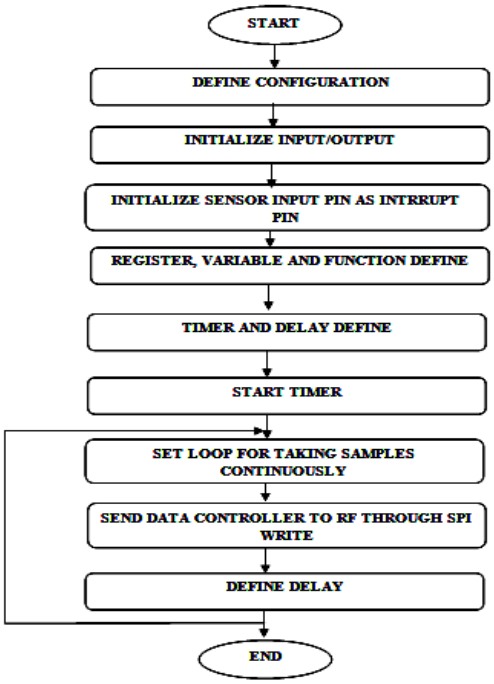
The sensor node and the master node have been designed. The figure shows the module of the sensor node.



The flow chart of the sensor node is as follows:

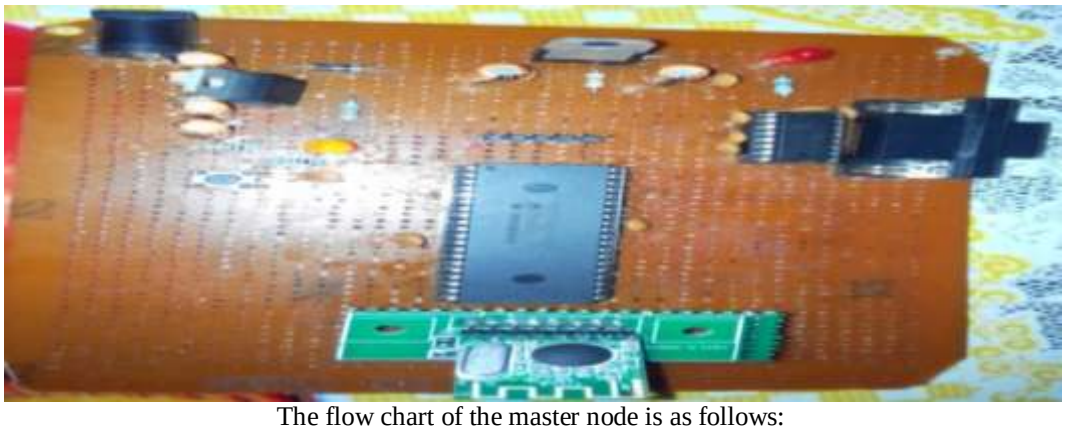


Steps of programming using mplab of sensor node:

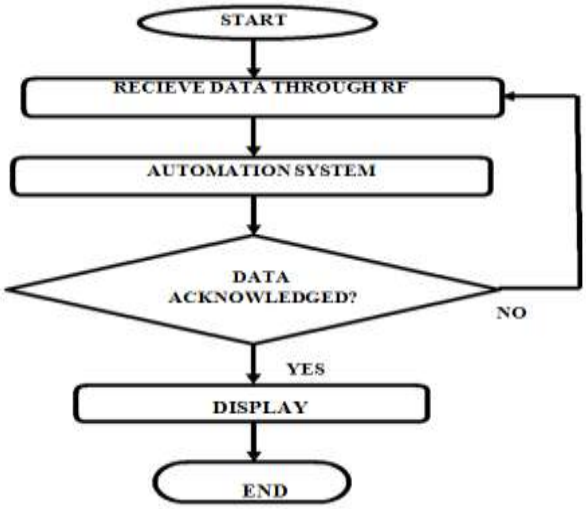


Master Node Design

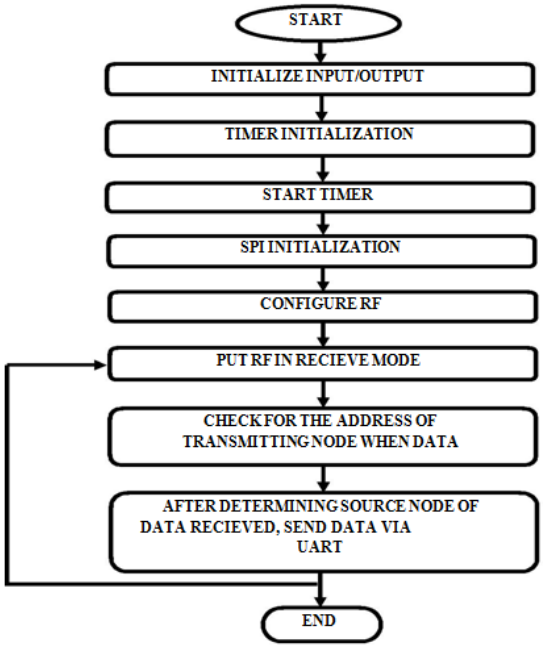
The figure shows the module of the master node.



The flow chart of the master node is as follows:



Steps of programming using mplab of master node:



3 EXPERIMENTAL SETUP & RESULT

Testing of the nodes is a very important facet and the same was done using artificial experimental set ups shown below to test the sensor nodes to ascertain that they would work successfully in the proposed prototype too.

Figure 2 Testbed for Real Data Analysis at AMC, EAST Zone, Naroda

In figure 2 shows the sensor placement on joint of the pipe. The water force given from the main storage tank of the water. Here two sensor nodes are placed on the pipe. This all experiment taken at AMC word naroda in suggestion of site engineer of AMC waterworks. Now after setting the testbed we have put sensor in different direction and take the reading and whichever the best result we get and used it for further analysis.

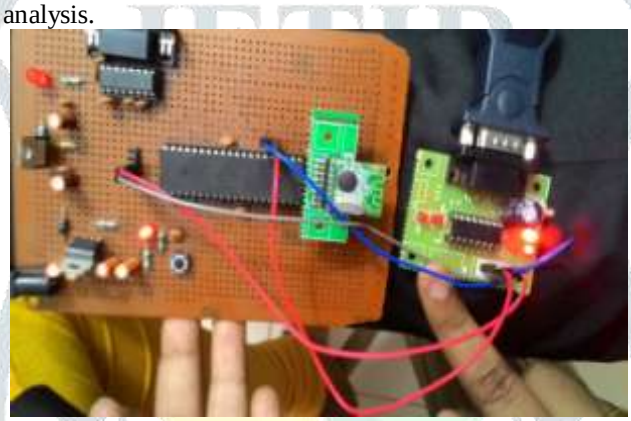


Figure 3 Runtime Situation of Hardware

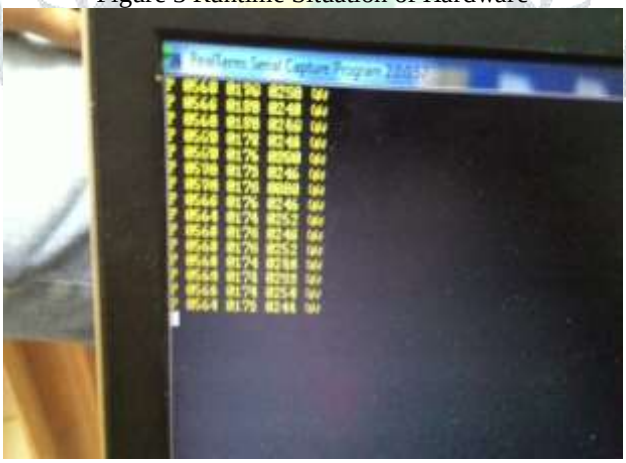


Figure 4 Real Data Receiving In Real Term Serial Capture Program

4 RESULT0

The Graphical User Interface is developed using software MATLAB. After storing the data into the text file the data can be open into the MATLAB via GUI. The data that is acquired from the real environment cannot be continuously displayed. Instead of it is stored in text file as a reference data and leakage data .and then these files can be opened into the GUI and different analysis can be performed.

Here three analyses can be made:

1) Time domain
2) Fast Fourier Transform
3) Discrete Wavelet Transform

In the first analysis time domain graph of data we can get in condition 1.we have to select time domain box in GUI.

In second analysis we get FFT of data and graph according it. Which is shown in condition 2 and we have to select FFT box option for that in GUI.

In third analysis DWT graph for data we get in condition 3 and we have to select DWT box option in GUI.

If we click only one box then we get only one analysis graph and if we select all box then we get all analysis graphs for data

So whenever any critical condition is invoked message for the same can be displayed in the central server/control room. This warning message can alert the concerned water system officer for prompt action.

Here as the prototype is tested in outdoor environment the programming is done by setting appropriate thresholds in DWT.

The reference data file have range between 0 to 5000 in normal condition and the leakage data have maximum value range above 5000.

For any particular file the threshold for sensor can be manipulated as follows:

a) If X< 5000,Y<5000 and Z<2000 for P type sensor and if X<3000,Y<5000 and Z<3000 for G type sensor, that is the value is lower than expected, condition (3.1) prevails;

b) If above value is higher than expected, then it check the both sensors threshold value and gives the following ;

- If P sensor has a higher value then threshold and G sensor has a lower value then threshould then, condition (3.2) prevails;
- If G sensor has a higher value then threshold and P sensor has a lower value then threshold then, condition (3.3) prevails;
- If both sensor have lower value then threshold then, condition (3.4) prevails;

These different conditions are displayed on GUI whenever any condition is reported.

Different conditions as displayed on GUI screen:

Condition 1: Time Domain Analysis

First we compute the time domain analysis of data. Here two sensor are used .two address are given P and G to the both sensor data. Here each sensor represents the three directions of vibration data. In figure 6 time domain analysis graph can be shown.

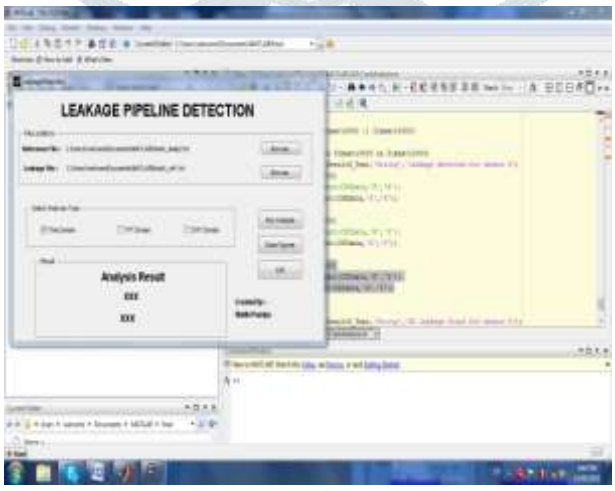


Figure 5 Time Domain Analysis in GUI

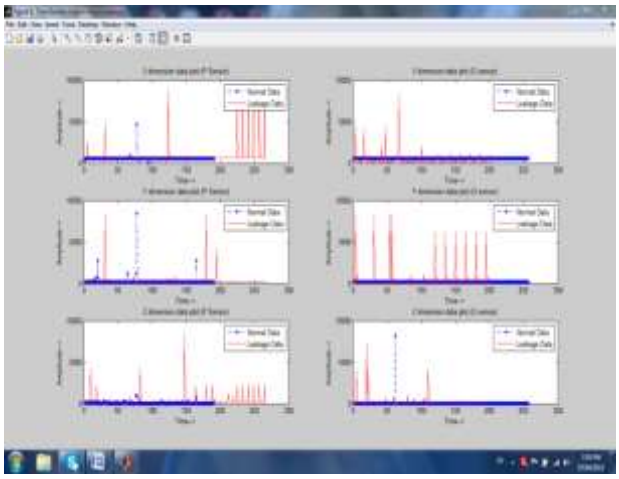


Figure 6 Time Domain Analysis of Data

Condition 2: Fast Fourier Transform Analysis

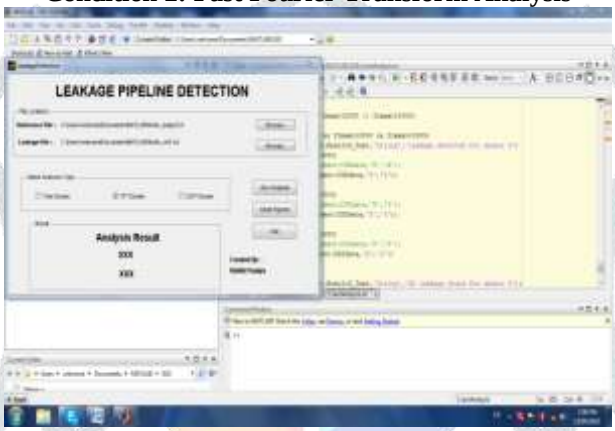


Figure 7 FFT Domain Analysis of Sensor Node in GUI

Now after time domain analysis and FFT analysis we have seen that X and Y direction gives the better result than the Z direction .So we have only consider X and Y direction for leakage detection. Respected graph of FFT can be shown in figure 8

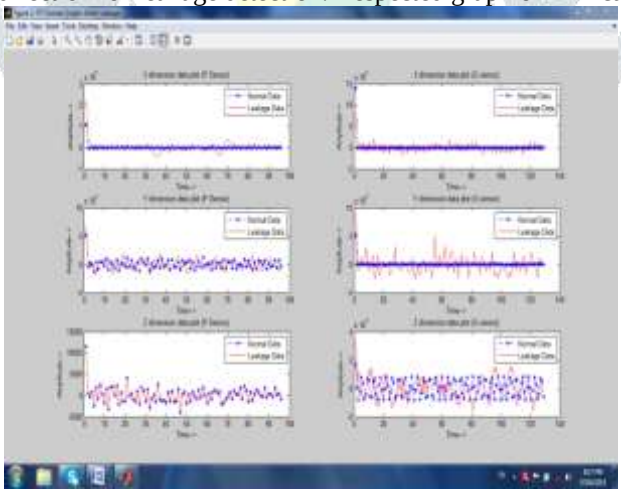


Figure 8 FFT Domain Analysis of Sensor Node

Condition 3: Discrete Wavelet Transform Analysis

In this section we analyze the data in DWT .In DWT we filter the data into four levels up to and we get better result. In some case we get good result in first, second or third level of filtering.

Also we have only plot the leakage data and perform DWT on that and this data will be plotted on the threshold condition .After analyze time domain leakage data of both sensor we select the level of the threshold at which the data cross the level of leakage and we get leakage detected message. If data has a lower value than the leakage then we get no leakage detection message. Here three conditions for both the sensor based on threshold for leakage can be as follow:

Condition 3.1: No Leakage (Threshold Value<Max Reference Data Value)

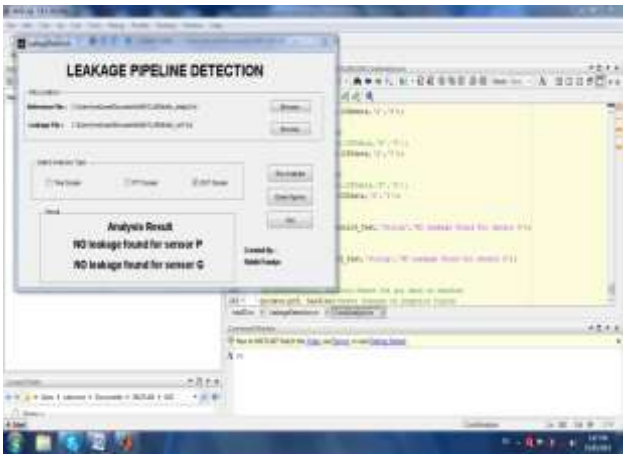


Figure 9 GUI Condition 3.1

Here in this case we noted that if there is no leakage detected in any of the sensor then we cannot get the DWT graph. We just get the message on GUI for no leakage detection for particular sensor.

Condition 3.2: Leakage Detection in P Sensor and No Leakage in G Sensor

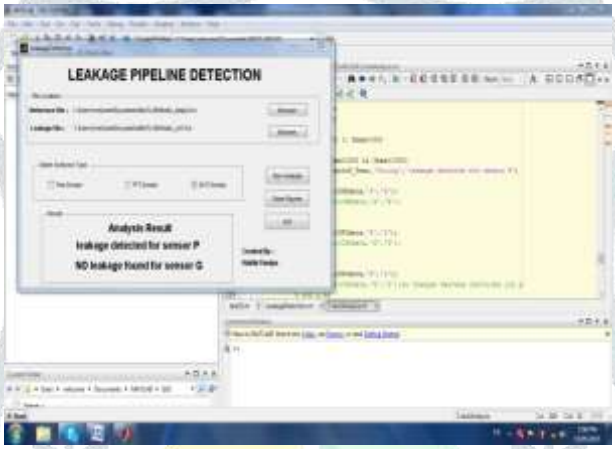


Figure 10 GUI Condition 3.2

As in this case only P sensor has detect the leakage so we can get only DWT graph of sensor P and we cannot get any graph in sensor G as it cannot detect any leakage.

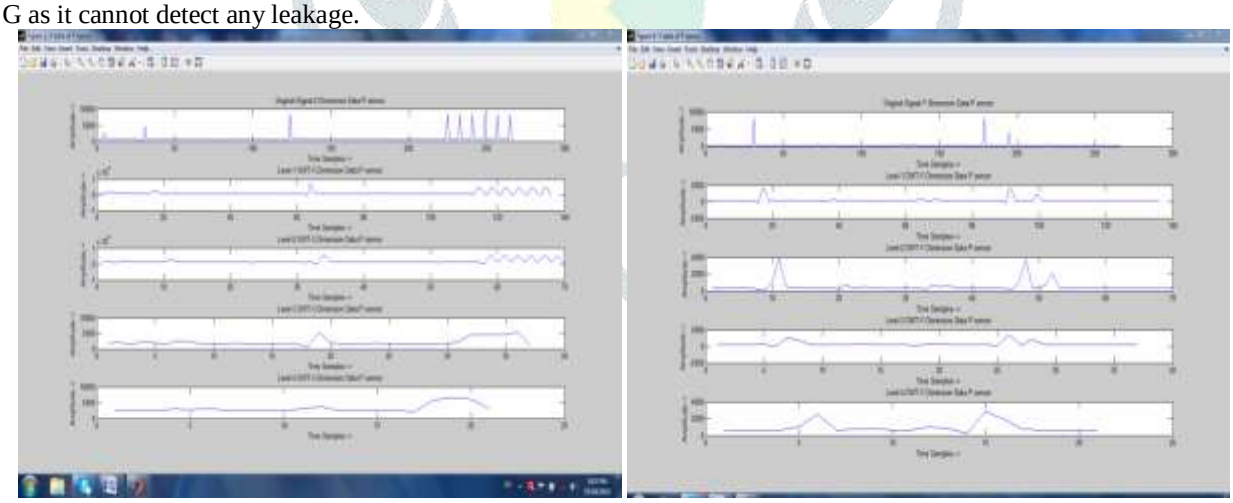


Figure 11 DWT of Leakage Data of Sensor P

Condition 3.3: Leakage Detection in G Sensor and No Leakage in P Sensor

As in this case only G sensor has detect the leakage so we can get only DWT graph of sensor G and we cannot get any graph in sensor P as it cannot detect any leakage.

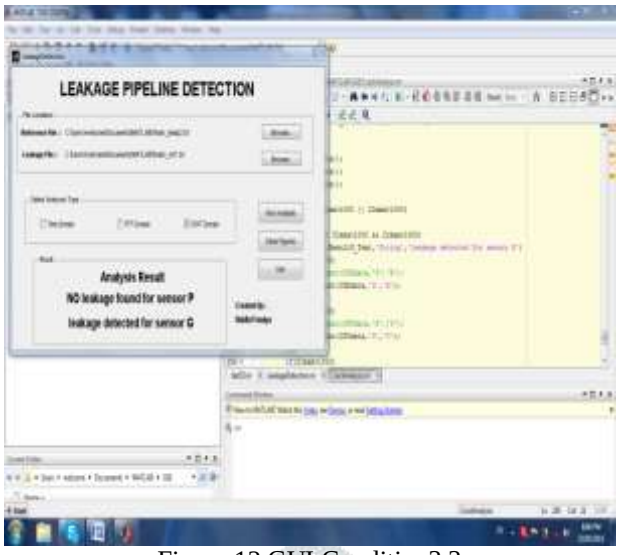


Figure 12 GUI Condition3.3

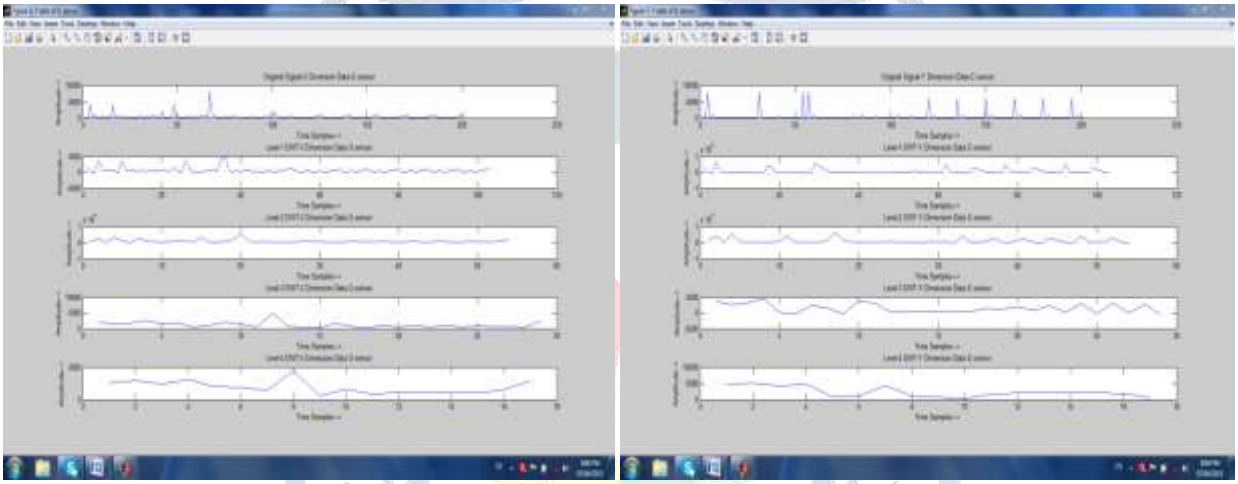


Figure 13 DWT Leakage Data Analysis for Sensor G

Condition 3.4: Leakage Detection in G Sensor and P Sensor

Here both sensors can detect leakages so we can get both sensors DWT graph same as in figure 10 and figure 12

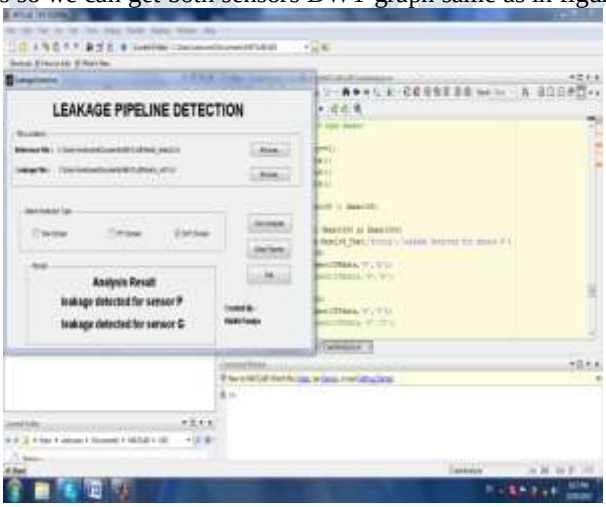


Figure 14 GUI Condition 3.4

5 SIZE AND PACKAGING OF SENSOR NODE

When the sensor nodes that shall consist of vibration sensor will be designed using assembly components the size of the node will reduce to that of our palm. The sensor node should be packed in tough plastic box or anti corrosive metal boxes designed to protect the node from external forces when mounted onto the joints of the pipe. The packaging of the sensor node should be such that sensor should not affect by the water flow when leakage will occur. Also waterproofing spray spread on hardware to protect it.The cover of the node should protect the circuit of the node from any kind of external force and should be easily open able for

maintenance or failure. Keeping these issues in mind a tough plastic box that is easy to open is preferable.

Figure 15 packaging of sensor

5.1 Estimated Cost Of The Deployment Of WSN

Here for the purpose of self designed hardware and assembly designing was done. So if the nodes are designed using assembly hardware in bulk the estimated cost of each sensor node turns out to be of approximately of Rs 2000/-. In an area of 1 km according to the RF range 20 nodes are needed, so the onetime cost of deploying sensor nodes in 1 km stretch is approximately Rs. 40,000/- which is affordable compared to LEAKAGE pipeline cost ranging from Rs. 20,000,00 to Rs. 30,000,00lakhs per zone. And in Ahmedabad total five zone so overall cost is 1 crore above. As we choose naroda zone which have different size pipelines ranging from 75 mm diameter to 750 mm diameter respectively.

6 CONCLUSION

An efficient water distribution system is an unavoidable infrastructure and a primary engineering measure leading any state towards accurate public administration. In a developing country like India, where urban construction is blooming there is a better scope of digitizing the water distribution systems in the upcoming areas.

An appropriate technology that suites the Ahmadabad water system and a proposed model based on wireless sensor network using RF technology have been suggested for localized area, NARODA. A system can thus be established based on the proposed prototype using WSN. The system has the advantage of providing real time data of the leakage in water pipes through vibration sensors. The system thus proves a decision support system for local government to tackle leakage issues which further avoids the health problems prevalent due to leakage in drinking water pipes.

The implementation of this prototype in newly developing areas of EAST Zone of Ahmadabad shall not only be easy but also preferable for efficient public administration.

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