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Water Pipeline Monitoring on Cloud & Leakage Detection with a Portable Device

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Abstract— **Water is without a doubt the most precious resource in the world. It is said that if there is any chance of third world war then it will be only due to scarcity of water all over the world. To avoid such situation water pipeline monitoring becomes necessary and an effective way to avoid enormous water wastage. Due to considerable amount of water loss due to tampering of pipeline almost all Municipal Corporations has appointed manual surveillance over the pipeline network. But due to unavoidable manual errors water loss continues which finally ends up in water supply shortage and hence regular water cuts with low pressure water supply. This project suggests simple and economical way of monitoring the pipelines. It just not provides the monitoring over the leakage but also informs concerned staff member about the approximate location of leakage in order to avoid digging up the road all over the pipeline in search of crack over the pipeline. Observatory kit which consists of flow, pressure and turbidity sensor are considered as a Node and are placed all over the pipeline which update output of sensors on cloud network and if level of any of the sensor goes down email is sent to concerned staff. To pinpoint the exact place of leakage on the pipeline, acoustic sensor is used which would be mounted in portable unit.**

Keywords- Internet of Things, leakage detection, flow sensor, pressure sensor, turbidity sensor, microphone.

I. INTRODUCTION

Future water scarcity is been always neglected and hence hardly any municipal corporation has implemented water pipeline monitoring. To provide economical and effective monitoring this project uses of ARM cortex M4F processor which is extremely user friendly and reasonable.

Pressure sensor will keep measuring pressure at every node and will be updated on cloud. Flow sensor will measure the flow rate of water and will give the output in the form of pulses. So it is number of pulses per liter which is given to microcontroller. Benefit of this senor is we need not to use any ADC since output is in the form of pulses itself. Microcontroller counts the pulses and using mathematical conversion formula result can be viewed on cloud where pressure in terms of Liter per Minute.

Turbidity sensor keeps check on the quality of the water. It is been observed that due to cracks on pipeline just not water leaks through these cracks but sometimes outside contaminated water also enters through these cracks under certain pressure conditions. Microcontroller keeps comparing turbidity of current water flow with predefined turbidity value and mail the value to the concerned staff along with microcontroller kit unique code if quality is detoriated as well as update the value on cloud.

The most important part of the project is portable kit which can determine crack on the pipeline by catching the sound of water leaking through the crack. This would help concerned staff to know exact location of leakage without digging up the whole road over the pipeline. Also once sound of leaked water is captured, remedial action can be taken well before occurrence of huge amount of water wastage.

II. OVERVIEW OF VARIOUS TECHNIQUES

Many different techniques and platforms have been discovered for pipeline monitoring. In this paper [1] a time domain reflectometry (TDR)-based system for the non-invasive detection of leaks in underground metal pipes is presented. The leak-detection system proposed herein, the sensing element consists of the underground metal pipe (which is used as one of two electrodes) and of a metallic wire (which is laid down on the road surface, in correspondence of and parallel to the pipe, and acts as the second electrode). The reflectometric signal propagates along the transmission line that is formed between the pipe and the metallic wire; as a result, the soil becomes the propagation medium. [2] This paper simply takes images of pipes, scans them and then compares them using cross correlation algorithm. [3] proposes a system which consists of three main components: the mobile sensor, also called the transmitter, the gateway and the backend server. The mobile sensor, or the transmitter, is a free floating sensor (hydrophone) that flows with the fluid inside the underground pipe. Sensor keeps receiving the sound of water flowing through pipe. Any changes in frequency of sound will only indicate leakage. [4] suggests the water pipeline leak detection device (WPLDD) which continuously monitors the condition of the water pipe. When a leak occurs, WPLDDs on the same pipe will detect abnormal sound changes in the pipeline and send the recorded sound to a cloud server for further analysis. Device consists of microcontroller ARM M4 with 3G communication model. [5] uses Ground Penetrating Radar (GPR), which can pass through objects in this case pipelines. The reflecting waves are recorded and digitized, and then, the B-scan images are formed. [6] The proposed method employs a modified maximum-likelihood (ML) prefilter with a regularisation factor. It derives a theoretical variance of the time difference estimation error through summation in the discrete-frequency domain, and find

the optimal regularisation factor that minimizes the theoretical variance in practical water pipe channels. [7] Another work suggests a leak detection method based on magnetic flux for pipeline inspection. The node prototype is implemented on Altera Cyclone FPGA [8] For instance, the authors propose a FPGA system for data acquisition. This FPGA is employed as co-processor with a DSP for leak detection and localization using acoustic sensors. The system is composed of a FPGA, DSP, acoustic sensors, a LCD, a wireless module and an ADC. [9] This paper focuses on the problem of detecting and locating the position of water leaks in water distribution Medium Density Polyethylene (MDPE) pipes using passive acoustic detection methods. This leak noise comprises vibration and acoustic signals, which can be detected using non-invasive accelerometers and invasive hydrophone sensors respectively. In order to locate leak with good accuracy in MDPE pipes, correlation process relies on estimation of the speed of sound in water/pipe and the time delay between leak signals measured at two locations across the pipes [10] This paper aims to use VAE (Vibro-Acoustic Emission) monitoring to investigate signal processing techniques that qualify leak flow rate. A strong correlation between the leak flow rate and signal RMS (Root Mean square), peak in magnitude of power spectral density was found which allowed for the development of a flow prediction model. Different techniques and platforms have been discovered for pipeline monitoring.

III. PROPOSED METHOD FOR LEAKAGE DETECTION IN PIPELINE

A. Proposed Block Diagram

Due to widespread length of pipeline, manual monitoring becomes very tedious. Proposed block diagram suggests automatic leakage detection which is known due to drop in water pressure and flow rate as well as rise in impurity level of water detected by quality sensor along with Microcontroller which will be located at each node A, B, C etc (Fig 1). All these nodes are situated all over the pipeline which consist of observatory kit as shown in Fig 1. Each observatory kit rather microcontroller in it has a very unique code assigned to it. Flow sensor counts number of pulses per minute which is equivalent to flow of water in liters per minute. These pulses are counted by microcontroller and equivalent reading is uploaded on cloud. Pressure sensor also senses the pressure between two nodes. Any change in pressure, will be reflected by graphs on cloud network. Sensed data is given to a processor which compares the sensor output with expected pressure of water. This comparison has to be executed continuously in order to maintain the required pressure in the pipeline. Flow of input feeder pipeline should be equal to summation of flows of output distributive pipeline. This live data (sensor output) is continuously updated on cloud network by microcontroller. Due to this, manual supervision at the very remote places can be avoided.

Due to slight crack on pipeline and especially when pipeline is surrounded by sewage pipeline or contaminated water puddles pure filtered water gets mixed with impure water. That maintains the pressure of pipeline as earlier. To shed a light on this water quality sensor value uploads turbidity count of water on cloud. That indicates clearly that if turbidity value has increased but pressure sensor output remains constant, water is contaminated due to crack on the pipeline.

ThingSpeak is a cloud network which has a support from MATLAB software initiated by MathWork which can collect data from private channels like individual sensors. It can share the data with public channels using IoT platform.

Identified Leakage will be informed to staff via email by Microcontroller with its unique code. Staff will already have a database in which location of observatory kit and its unique code is listed. Since alert email specifies this unique code, staff will be able to identify the location where readings of sensors are not up to the mark. But to identify exact location of leakage (between any two observatory kits) without digging the road portable and handy kit is rolled down manually. This kit would consist of the sensor which will predict exact location of the crack on the pipeline as shown in Fig 3.

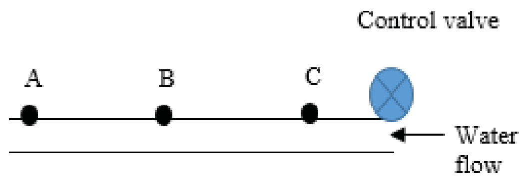

Fig. 1. Test bed layout of observatory kits all over the pipeline.

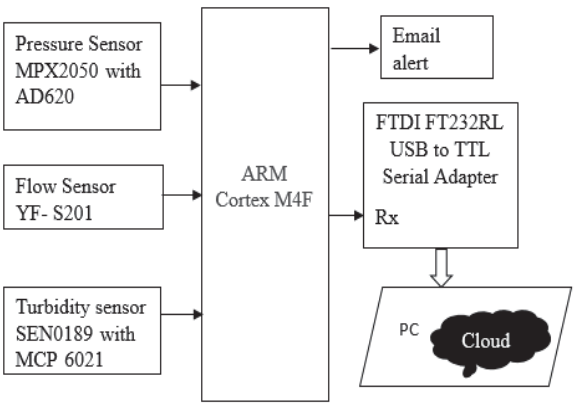

Fig. 2. Block Diagram of observatory kit at every node for e.g. node A

B. Working of Proposed block diagram

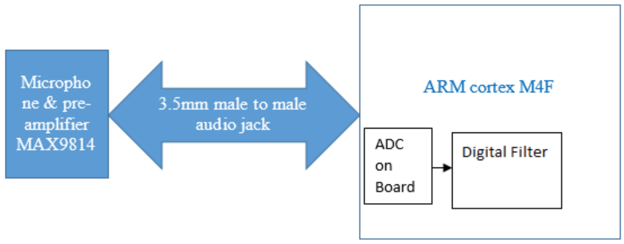

Fig. 3. Final Physical Implementation with microphone sensor for portable kit

To pinpoint the exact location of crack portable unit is designed which will be rolling down over the ground. Acoustic sensor can be used to detect the crack between the two points estimated by observatory kit. Portable kit with acoustic sensor will capture the sound of leaked water and leakage can be identified. If acoustic sensor can also be fixed along with observatory kit, then captured sound will be compared and if it lies in the band of frequencies, it will update the concerned staff accordingly.

IV. RESULT

Pressure, flow and turbidity sensors are fixed and suspended in water pipeline as shown in Fig. 8. Water pressure sensor used for 4 inch or 2 inch pipeline are very expensive. So here pressure sensor is tested where pressure is applied by BP machine, which measures the pressure in mmHg. BP machine can apply maximum input of 300mmHg or 40KPasal. We have to use ADC to convert pressure into equivalent digital and then it is given to microcontroller as can be seen in Table 4. Presence of turbidity sensor at every node determines quality of water between each of the node. So decrease in voltage due to increase in turbulence can be seen on cloud will indicate detoriated quality of water which can be seen in Table 3. Readings of different types of minerals like salt, rock salt, as well as dissolvable and nondissolvable soil has been mixed to know how it affects on output voltage which can be seen in Table 2 & 3. Flow of Feeder pipeline should be equal to summation of flow of Distributive pipeline as shown in Table1. If microcontroller finds outputs of sensors are not as per the predetermined value, mail will be sent to concerned staff as shown in Fig. 6. For portable device condenser microphone is selected. Output of microphone has to be amplified and then it can be passed through filters to get exact frequency of sound of leaked water. Various recordings of leaked water were recorded. Few sites are shown in Fig. 9 & 10 where sound of leaked water was recorded. Recording was also done at artificially generated leakage on pipe with diameter 1.25 inch and 4 inch as shown in Fig 7. Then they were filtered on Audacity to know exact range of frequency of leaked water from pipes with various diameters like 1/2 inch, 1.25 inch, and 4inch with leakage size of 1mm. Recording of live water leakages were also studied where frequency of sound of water leakage found in the range of 3KHz to 6KHz. Audio signal is captured by microphone and then given to microcontroller, which will compare incoming audio signal with 3KHz to 6KHz. Result can be seen in Fig. 5. Frequency range of sound of escaped air through the crack also lies in the range specified above.

TABLE I. READINGS BY FLOW SENSOR

Flow Input f1	Flow of Leak f2	Flow Output f3
1.6	0	1.6
1.7	0	1.7
2.1	0.4	1.1
2.4	0.4	1.7
2.5	0.4	1.9

TABLE II. UNDISSOLVABLE SOIL MIXED IN PURE WATER

Quantity of water	Position of soil	O/p voltage(v)
1 glass of water	Soil mixed	2.58
	Soil at rest	0.5
1 ½ glass of water	Soil mixed	2.64
	Soil at rest	1.47
2 glass of water	Soil mixed	2.68
	Soil at rest	2.14
2 ½ glass of water	Soil mixed	2.78
	Soil at rest	2.48
3 glass of water	Soil mixed	2.83
	Soil at rest	2.65

TABLE III. DISSOLVABLE SOIL MIXED IN PURE WATER

Quantity of soil	½spoon soil	1 spoon soil	½spoon rock salt	1 spoon rock salt
Quantity of water	Output at encoder(v)	Output at encoder(v)	Output at encoder(v)	Output at encoder(v)
1	1.97	1.70	2.22	2.52
1½	1.83	1.40	2.05	2.23
1	1.73	1.34	1.99	2.22
2 ½	1.5	1.20	1.96	1.27
3	1.4	1.15	1.15	1.25

TABLE IV. READINGS BY PRESSURE SENSOR

Output voltage by microcontroller(v)	Pressure by BP machine in mmHg	Output voltage by microcontroller(v)	Pressure by BP machine in mmHg
0.2v	23	1.2v	136
0.3v	34	1.3v	148
0.4v	45	1.4v	159
0.5v	57	1.5v	170
0.6v	69	1.6v	180
0.7v	81	1.7v	193
0.8v	91	1.8v	204
0.9v	102	1.9v	218
1.0v	114	2.0v	227
1.1v	125	2.1v	230
		2.2v	250

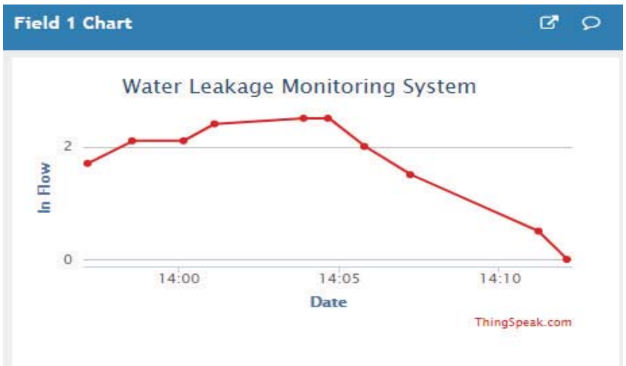

Fig. 4. Sensors output on cloud

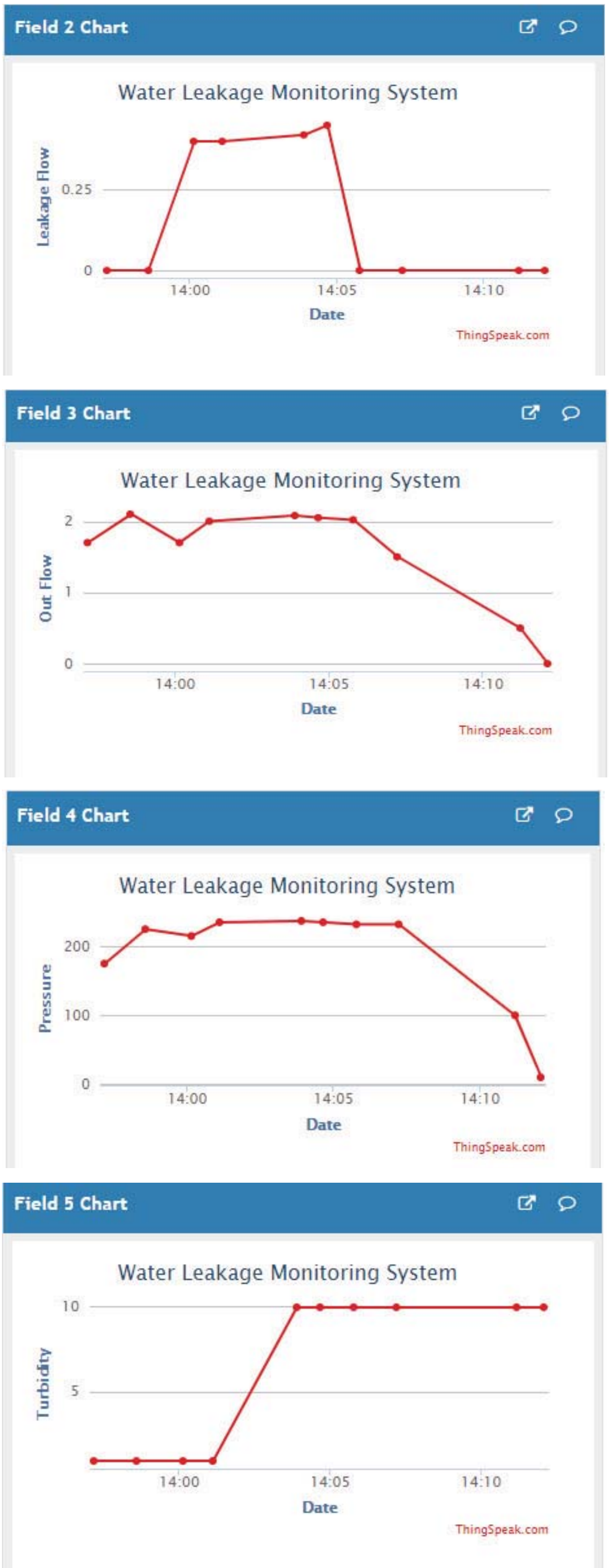

Fig. 5. Sensors output on cloud

Fig. 6. Microphone reading on microcontroller

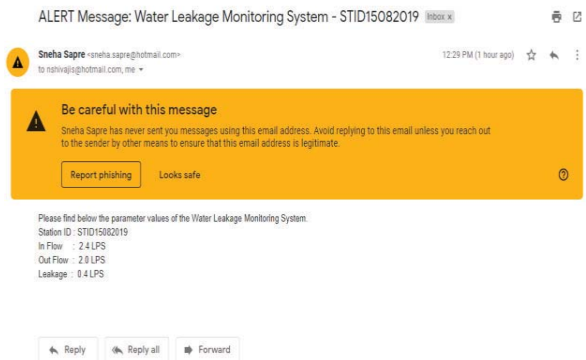

Fig. 7. Test mail

Fig. 8. Test result on pipe for water leakage sound recording

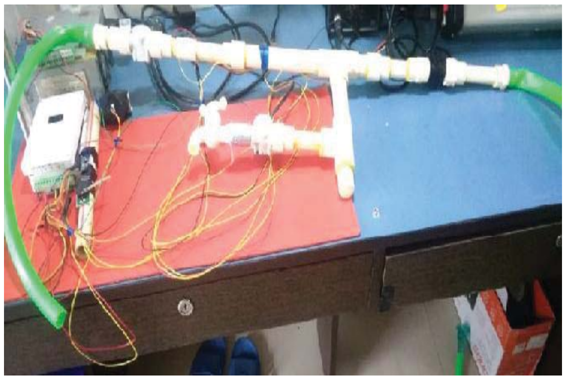

Fig. 9. Test pipe where sensors are mounted

Fig. 10. Live recording of water leakage with large diameter pipeline

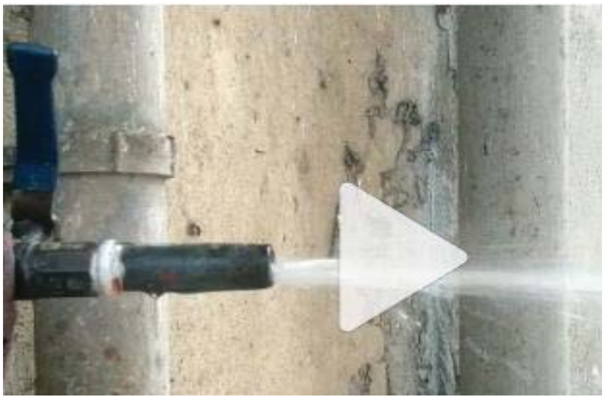

Fig. 11. Live recording of water leakage with small diameter pipeline

V. CONCLUSION

When pressure sensor or turbidity sensor output drops below certain value email with microcontroller code will be sent to concerned staff. Microcontroller keeps updating cloud with all sensors outputs from all the nodes. Due to the presence of turbidity sensor quality of potable water can be monitored continuously. If contaminated water enters through the crack over the pipeline, turbidity graph on cloud will instantly show the detoriated quality of water which also indicates the presence of crack on the pipeline. To know exact location of leakage between two observatory kits one portable device is designed, so that without digging the ground crack or leakage can be determined. Flexible programming takes care of all time changing, area wise schedule of water distribution; in this case no water flows through the pipeline at all. In empty pipeline air is always present. So just before water supply is resumed back, air escapes through the crack present on the pipeline. If this sound of air leak can be captured by portable kit, exact location of crack can be determined, hence any further water loss can be avoided.

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