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Water Pipeline Monitoring System Using Flow Sensor Based on the Internet of Things

Dedy Wahyu Herdiyanto[1*], Triwahju Hardianto[2], Dimas Ardiansyah[3]
Immawan Wicaksono[4], Widya Cahyadi[5], Catur Suko Sarwono[6]
[1,2,3,4,5,6)] Department of Electrical Engineering, Universitas Jember, Jember, Indonesia
e-mail: dedy.wahyu@unej.ac.id[1)], triwahju.teknik@unej.ac.id[2)], dimasardian347@gmail.com[3)]
immawanw@unej.ac.id[4)], cahyadi@unej.ac.id[5)], catur.teknik@unej.ac.id[6)]

Abstract

Pipe leakage is one of the most common problems in agriculture. Especially if the agricultural land is quite large, it will be challenging to determine the location if a leak occurs. Active sensors are not recommended because they do not follow the green computing concept (energy-efficient computing). This study is proposed to use a passive type sensor that is more energy efficient. This study will use a water flow sensor placed at several points in the irrigation pipe network. The water flow sensor was chosen because this sensor works passively and is very accurate in detecting changes in water flow, especially in flowing water. The sensor reading results will be sent using the Internet of Things with a Wi-Fi connection. The collected data results are processed on the server and displayed in an interface that makes it easy for users to monitor water flow through smartphones. The results of the tests that have been carried out show that the designed system has worked as expected. The system can detect the location of the leaking pipe flow and indicate the leaking pipe.

***Keywords* — Internet of Things, Leakage, Monitoring, Sensor.**

I. INTRODUCTION

The pipeline network is vital fluid transportation, one of which is water. The most common problem is a leak in the water pipe [1,2,3]. Leaks in water pipes are also one of the factors causing the depletion of clean water, which is the most common problem in life. This problem causes good financial losses for farmers, affecting the quality and quantity of the harvest. Water pipe leaks are usually identified only manually, namely by looking directly at the condition of the leaking water pipe. This is very ineffective because it will require considerable time and effort, especially if the water pipe is in the ground [4]. Monitoring underground water pipelines is more complex than monitoring above-ground water pipelines or networks. A disturbance in the water pipe, such as a leak, will be a permanent loss [5]. Leaks in pipes consist of two types, namely non-physical and physical leaks. The factors that cause leakage are the age of the pipe, rust, and natural factors. These factors can also cause problems with water quality [6,7].

Various monitoring systems are now widely used as an alternative way to monitor the situation in real-time at a distance and are grouped according to the infrastructure they use [8,9]. One of them is an IoT (internet of Things) system that does not need to use much additional infrastructure because it can use the existing backbone network. This monitoring system model will significantly save time and effort because users must check through the interface without changing locations. However, this monitoring system is still not widely applied in the agro-industry, especially agriculture. IoT in this monitoring system will make monitoring of water pipe leaks manually turn into monitoring automatically and save time.

For this reason, it is necessary to have a monitoring and detection system for leaks in the water pipe distribution media to suppress the high level of water loss. By monitoring the water discharge in the water pipe, users can find the condition of the leaking water pipe even though the water pipe is underground. This system also requires a user interface that is easy to use by its users.

From the aspect of data communication, the concept of telemetry needs to be applied to the system. Telemetry is an automated communication process that collects measurement data where data obtained from remote or rugged locations, even the location, cannot be accessed directly. The data needs to be transmitted to the receiving equipment for monitoring. Telemetry is a technology that enables remote measurement and transmission of information to system designers or operators. Several options, such as wireless sensor networks and the Internet of Things, can be used.

The first reference, the research on behalf of Khulief et al., focuses on leak detection by depending on external factors, namely the acoustic sound produced by the flow of water in the pipeline [10]. The disadvantage of this method is that the sound produced from the flow of water is primarily determined by the size and material of the pipe used. This result is because the sound echoes will bounce off the pipe wall. Moreover, some pipe materials can absorb the sound of water movement produced.

The second reference is the vibration sensor method to detect vibrations in the pipe [11,12]. Vibration is assumed to be a sign of flowing water. However, this method has drawbacks. The detected vibrations could be coming from an external source. So that even if the water does not flow, if the pipe is hit or given a similar action, it will still produce vibrations.

In the third reference, it has been explained that the research was carried out using a water level sensor placed in a water reservoir or on a pipe [13]. This method can detect a leak by monitoring the water in the reservoir or pipe. However, the problem with this method is that the leak's location cannot be detected correctly. This result is because the system only detects the amount of water. So, the location of the leak cannot be known directly.

The fourth reference explains the detection system uses an ultrasonic sensor [14]. This system will continuously shoot ultrasonic waves into the pipes and tanks and consider the resulting reflections. This system can detect the exact location of the leak, but the continuous use of ultrasonic sensors will consume more energy.

Several other references also found problems related to the communication used. In this reference, the observation process cannot be carried out remotely using a portable device. One source has mentioned that the sensor still has to be connected using a cable on the laptop [15]. This method becomes impractical, considering that each sensor location must use a laptop as an intermediary.

Some of the references obtained can be written down as the main problems that must be solved. The main problem is the detection of leaks and the leakage level. In this study, a water flow sensor will be used to determine the water flow in the pipe. The water discharge level will indicate a leak in the pipe. If the water that flows is getting smaller, it can be ascertained that there is a leak. This is because the leak will cause the water flow to be divided, which causes the water discharge in the pipe to be divided.

The second problem is knowing the location of the leak. In this problem, the solution that can be done is to add the number of water flow sensors used. The different sensors will be used to compare at various points on the water line. With this method, it will be easy to know the leak's location by comparing the presence or absence of a decrease in the value of the water discharge. The third problem is the communication model used. The most appropriate solution to the problem is to apply the IoT concept to the system. In the last 2-3 years, IoT technology has developed rapidly. IoT is a concept where an object can transfer or send data over the internet network. The Internet of Things has two main parts: the Internet, which regulates connectivity, and Things, which means connected objects or devices where Things can collect, store, process, and transmit data to the Internet. Connectivity is essential and fundamental in the IoT system because connecting between the devices requires connectivity. The connectivity used is a good and stable internet network. The provider's backbone and cellular networks are the most stable and affordable.

This study describes the development of an IoT-based water pipe leak detection and monitoring system. The monitoring and detection system for water pipe leaks was designed to be used or operated via a smartphone using the concept of reading the water flow on the sensor using the internet. The sensor reading results will be displayed on the smartphone via the Blynk application so that water pipe leakage information can be monitored at any time.

The remainder of this paper is as follows: In Section II presents more detail about the system design and research method of this study. Section III presents the result and discussion of this system and system trial in real conditions. And the last section, Section IV, present the conclusion from this system and future work that needs to be done.

II. Design and Method

This research began by collecting and studying the published literature and available information. Learning the basic theory and datasheet of the components used to support this research's implementation is also carried out as references. The work on hardware and software design is done after studying the literature and collecting components that will be used. System performance testing and analysis were conducted as the final part of the research.

A. Overall System Design

Monitoring the leak in the water pipe is to check the water discharge, which will be measured by the water flow sensor and displayed on the flash. If there is a leak in the water pipe, the water discharge value measured by the sensor will get smaller. This result happened because the speed and amount of water flowing through the sensor decreased. The value of the change in water discharge will be displayed on the block application as a gauge display.

The water faucet simulates the magnitude of the leak in the network or water pipeline. So, there will be a difference in the value of water discharge measured by the sensor when a leak occurs. In the system, a buzzer is also used as an indicator. The buzzer will become active if there is a decrease in water flow or less than the set water discharge value so that users can find out that there is a big leak in the water pipe and immediately fix it.

In Figure 1, it is shown that the source of the water pump comes from the 220V AC electricity, which is used to power the pump so that water can flow into the pipe. In comparison, the source for the NodeMCU Esp8266 microcontroller comes from an adapter that converts 220V AC voltage to 5V DC. The water flow sensor will measure the flow of water flowing in the water pipe with output data in the form of digital data.

Figure 1. System diagram

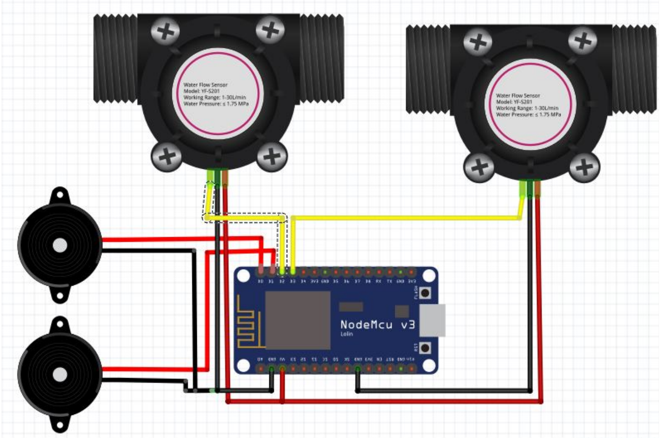
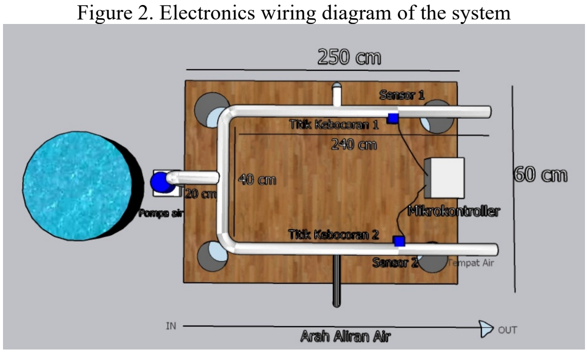
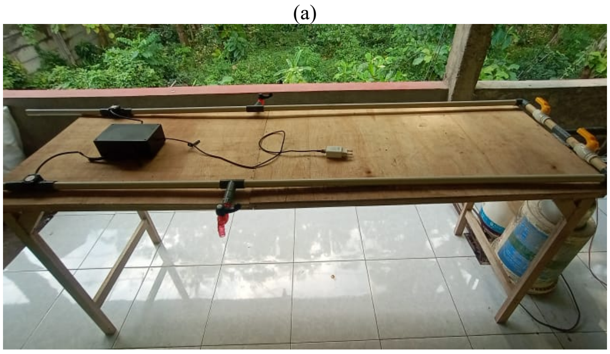


Figure 2. Electronics wiring diagram of the system



(a)



(b)

Figure 3. a) Device design, b) Device appearance

The NodeMCU Esp8266 will process the data from the water flow sensor to obtain the water discharge data. Then, the processed data is sent to the Blynk application installed on the smartphone and connected to NodeMCU Esp8266. The output of the NodeMCU Esp8266 displayed on the Blynk application is a gauge of the measured water discharge value.

Figure 2 shows a series of Monitoring and Detection Systems for Leaks in Water Pipes Based on the Internet of Things. Several components are used in the circuit above: the NodeMCU Esp8266 microcontroller, two flowmeter sensors, and two buzzers. The input of the above circuit is two flowmeter sensors connected to the GPIO pins D2 and D3. The system's output displays the results of measuring the water discharge volume from the flowmeter, which will be displayed on the Blynk application installed on the smartphone and connected to the NodeMCU Esp8266 in the form of a gauge.

In the circuit, there is also a buzzer connected to the NodeMCU Esp8266, where the GND buzzer pins 1 and 2 are connected to the GND pin of the Esp8266 NodeMCU. The VCC pin of buzzer one is connected to pin D0, while the VCC pin of buzzer two is connected to pin D1 of NodeMCU Esp8266. Two buzzers in the circuit are used as indicators of a significant decrease in the volume of water discharge caused by a leak. Buzzer one is used as an indicator for sensor one, and buzzer two is used as an indicator for sensor 2. Figure 3 shows the design of the pipe leak detection system and device.

B. *Research Method*

The working principle of this leak detection system is to compare the water discharge conditions monitored in real time with the specified initial set point. The set point is determined as a reference for the standard conditions of flowing water. When a leak occurs, it is assumed that the amount of water discharge will decrease according to the level of damage to the pipe. The more severe the damage, the lower the water discharge will be even more significant. The set point is 18 L/min, which can be adjusted according to the pipe size.

The water faucet in the Internet of Things-Based Water Pipe Monitoring and Detection System is used to simulate the magnitude of the leak in the water pipe network or channel so that there is a difference in the water discharge value measured by the sensor when a leak occurs and before a leak occurs. In the system, a buzzer is also used to indicate that if there is a significant decrease in water discharge or exceeds the water discharge value set, the buzzer will activate automatically. The leak in the water pipe can be found and immediately fix it.

The test combines several networks, as shown in the figure to obtain a more complex network. The testing process is a procedure that must be carried out to obtain supporting data. Testing this system consists of testing each sensor component and the whole. The sensor testing process is carried out to determine the percent error value of the water flow sensor when making measurements by comparing the measurement value of the tool or sensor with other measuring instruments in the form of a measuring tube. Sensor testing was carried out with three trials for each sensor one and sensor 2, where the volume of water from the three experiments was different, namely 1000ml, 1500ml, and 2000ml. Overall, tool testing aims to determine if the system has been running according to the desired set of points in testing the overall tool, which includes the condition of the buzzer on changes in water flow as measured by the flow meter sensor and the accuracy of reading the water discharge value which will be displayed on the Blynk application. The microcontroller will display the data received and processed through the Blynk application. The data is about the state or discharge of water flowing in the pipe. Figure 4 shows the flowchart of the pipe leak detection system and device.

III. Result and Discussion

A. System Evaluation Results

The testing process is carried out to obtain performance data on the prototype system that has been designed. There are three testing stages: the water flow sensor, the connectivity, and the overall system.

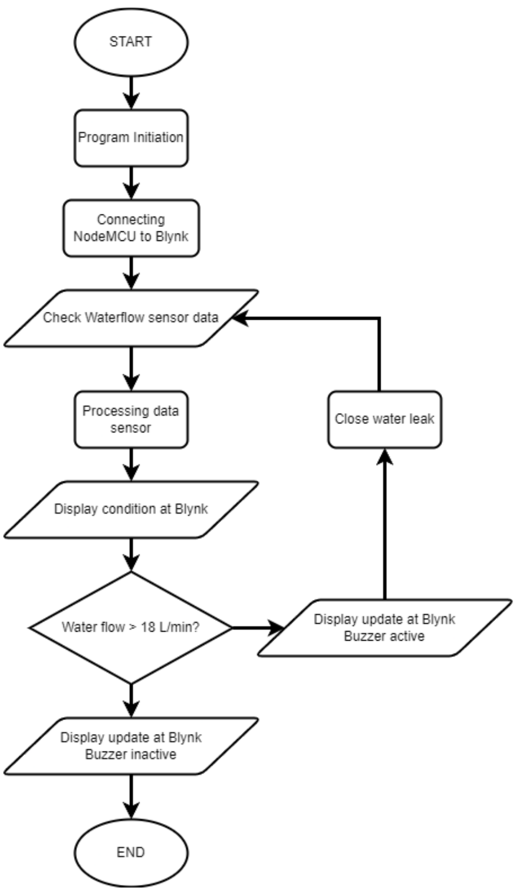


Figure 4. Flowchart of the pipe leak detection system and device

1) *Water Flow Sensor Evaluation*:

In testing the water flow sensor, it is carried out to determine the percent error value of the water flow sensor when making measurements by comparing the measurement value of the tool or sensor with other measuring instruments in the form of a measuring tube. The water will be measured using a measuring tube, then the measured water will be placed in a water reservoir (bucket), and then the water will be flowed by the pump to the water pipe. Then the volume of water measured by the sensor will be obtained by multiplying the value of the water discharge read by the sensor by the length of time when draining water from the reservoir. Furthermore, the volume of the sensor measurement results will be compared with the value of the volume of water measured using a measuring tube to obtain the percent error value. When testing this sensor, one of the pipes is closed using a stop faucet so that water will flow into one of the sensors being tested. Sensor testing was carried out with two trials for each sensor where the volume of water from the

TABLE 1
WATER FLOW SENSOR AT PIPELINE 1 RESULTS

Water Volume (L)	Sensor 1 Reading (L)	Sensor Measurement 1		Difference (L)	Error (%)
		Water Discharge (L/min)	Time (minute)		
10	10,4	26	0,4	0,4	4 %
10	10,25	25	0,41	0,25	2,5%
20	19	26	0,73	1	5 %
20	19	25	0,76	1	5%
30	29,25	25	1,17	0,25	2,5%
30	29,5	25	1,18	0,5	1,6%
40	38,22	26	1,47	1,78	4,4%
40	38,46	26	1,48	1,54	3,8%

TABLE 2
WATER FLOW SENSOR AT PIPELINE 2 RESULTS

Water Volume (L)	Sensor 1 Reading (L)	Sensor Measurement 2		Difference (L)	Error (%)
		Water Discharge (L/min)	Time (minute)		
10	10,26	27	0,38	0,26	2,6%
10	10,4	26	0,4	0,4	4%
20	20,25	27	0,75	0,25	1,25 %
20	20,28	26	0,78	0,28	1,4%
30	29,38	26	1,13	0,62	2,1%
30	29,12	26	1,12	0,88	2,9%
40	39	26	1,5	1	2,5%
40	39,52	26	1,52	0,48	1,2%

three experiments was different, namely by 10 L and 20 L. The test results are shown in Tables 1 and 2.

2) Connectivity Evaluation:

Connectivity testing aims to determine the connection distance and the length of time the device connects to the Blynk application. This testing process includes the Blynk application installed on the smartphone and the NodeMCU Esp8266. This test uses an internet connection from a smartphone, namely through the Hotspot, which is used to connect the device with the Blynk application. From the connection test data, it will be known the distance limit that can be reached by the tool when using a hotspot connection and the length of time it takes the tool to be able to connect to the Blynk application. The test results are shown in Table 3.

TABLE 3
CONNECTIVITY TEST RESULTS

Distance (meter)	Connection Time	Status	
		Connected	Not Connected
5	4	✓	×
10	3	✓	×
15	3	✓	×
20	3	✓	×
25	3	✓	×
30	3	✓	×
35	4	✓	×
40	3	✓	×
45	-	×	✓
Average Connection Time	3,25		

3) System Overall Evaluation:

The overall tool testing aims to find out if the system has been running according to the desired set point in testing the overall tool, which includes the condition of the buzzer on changes in water flow as measured by the flow meter sensor and the accuracy of reading the water discharge value which will be displayed on the Blynk application. The microcontroller will display the data received and processed through the Blynk application. The data is about the state of the water discharge flowing in the water pipe channel. The leakage rate is set in three levels, namely mild (35° opening angle), moderate (60° opening angle), and severe (90° opening angle). Leakage simulations are carried out alternately to determine the tool's overall performance. This simulation's water discharge set point is 18 L/min, so the buzzer will sound when the water discharge flow is below the threshold. The test results are shown in Table 4.

TABLE 4
SYSTEM OVERALL TEST RESULTS

Water Discharge Measurement (L/min)		Faucet Condition		Buzzer Condition	
Sensor 1	Sensor 2	Faucet 1	Faucet 2	Buzzer 1	Buzzer 2
18,8	18,2	Close	Close	×	×
16,4	19,1	Open (35°)	Close	✓	×
12,9	18,2	Open (60°)	Close	✓	×
10,5	18,2	Open (90°)	Close	✓	×
18,6	17,3	Close	Open (35°)	×	✓
18,6	12,5	Close	Open (60°)	×	✓
18,4	10,9	Close	Open (90°)	×	✓
16,7	9,6	Open (35°)	Open (90°)	✓	✓

B. Results Analysis

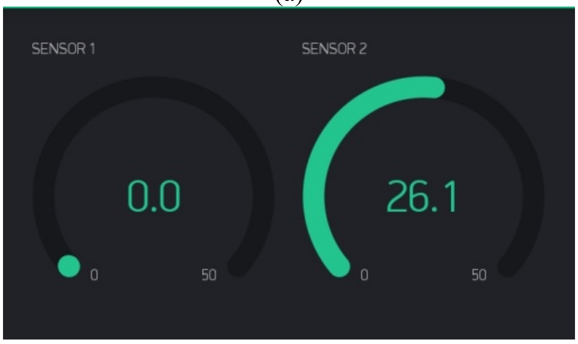
1) *Water Flow Sensor Result Discussion*:

Testing the water flow sensor is done to determine the percent error value of the water flow sensor when making measurements by comparing the value of the volume of water measured by the sensor with other measuring instruments in the form of a measuring tube. To obtain the value of the water volume read by the sensor, multiply the value of the water discharge measured by the sensor by the measurement time length, using the equation $V = Q \times t$.

In Tables 1 and 2, the water flow sensor test above can be seen. The experiment was carried out eight times with the volume of water used starting from 10L, 20L, 30L, and 40L, where the experiment was repeated once for each volume of water used. The data shows that the average value of the water discharge measured by sensor 1 is 25 L/min, whereas the most significant value measured by sensor 1 is 26 L/min. The average percent error on sensor 1 is 3.6%, whereas the most significant error in testing sensor 1 is 5% which occurred in experiments 3 and 4 with a volume of 20 L of water.

While on sensor 2, the average value of the measured water discharge is 26 L/min, whereas the most considerable value of water flow measured in sensor two testings is 27%. The average percent error in sensor2 testing is 2.2%, whereas the most significant error is 4% which occurred in the 2nd experiment with a volume of 10 L of water. From the data obtained in Tables 1 and 2, it can be concluded that the sensor can work well by the expected output.

(a)



(b)

Figure 3. Water Gauge Display at Blynk a) Pipeline 1, b) Pipeline 2

2) Connectivity Result Discussion:

This testing process includes the Blynk application installed on the smartphone and the NodeMCU Esp8266. This test uses an internet connection from a smartphone, namely through a hotspot, to connect the device to the Blynk application. From the connection test data, it will be known the distance limit that can be reached by the tool when using a hotspot connection and the length of time it takes the tool to be able to connect to the Blynk application. Data retrieval is carried out outdoors without any obstacles or barriers.

From Table 3 on the connection testing of the tool above, it can be seen that the average time required by the device to connect to the Blynk application is about 3.25 seconds. The longest time for the device to be connected to Blynk is 4 seconds, and the fastest is 3 seconds. In the connection distance test, the device is placed outdoors without obstructing it. The first test is carried out at a distance of 5 meters and continues to increase the interval by 5 meters in each test. The test was carried out nine times, whereas in the 9th experiment, with a distance of 45 meters, the device could no longer be connected to the Blynk application. So, from this test, it can be seen that the maximum distance of the device connected with the Blynk application using a hotspot network is 40 meters. When the distance exceeds 40 meters, the device cannot be connected to the Blynk application.

3) Overall Result Discussion:

From the evaluation, it can be concluded that there is a small leak at leak point 1 and a large leak at leak point 2. This can be proven by looking at the water discharge values read by sensors 1 and 2, where the average value of the measured water discharge by sensor 1 is greater than the average water discharge measured by sensor 2. However, the reading value of the two sensors is less than 18 L/min which is the setpoint value of the tool. It can be interpreted that there is a leak at leak points 1 and 2. Furthermore, it is also marked with the condition of the buzzers 1 and 2 in functional condition.

The value of the water discharge when a leak occurs that can be detected is from 1-17 L/min. When a leak occurs, the buzzer will activate until the measured water discharge value is more than equal to 18 L/min, where buzzer one is an indicator for sensor one and buzzer two is an indicator for sensor 2. The value of the water discharge measured by the sensor, which is located near the leak point, will be smaller than the normal discharge. The value of water discharge from sensor measurements far from the leak point will also decrease following the previous decrease. The final sensor point will have a minor water discharge reading if several leaks are in one pipeline.

IV. Conclusion

Based on the research results, it can be concluded that the system has worked as expected. This result indicates by the detection results shown on the user interface according to the simulated leak level. The water discharge value when there is a leak that can be detected is from 1-17 L/min, and when a leak occurs, it will make the buzzer active until the measured water discharge value is more than equal to 18 L/min. Where buzzer one functions as an indicator of sensor one and buzzer two as a sensor indicator. The water discharge value from the sensor measurement, located near the leak point, will be smaller, while the water discharge value from the sensor measurement, located far from the leak point, will also decrease. However, the measured water discharge value is greater than the sensor value close to the leak point. Connectivity between components has also been tested, where sensor measurement data can be sent to the Blynk application installed on a smartphone via an internal internet connection and represented as a gauge value of water discharge.

References

[1] G. Gupta, A., Mishra, S., Bokde, N., Kulat, K.. "Need of smart water systems in India". Int.J. Appl. Eng. Res.11(4), 2216–2223 (2016).

[2] Chen Yuanyuan; Zhang Zuozhuang. "Research and Design of Intelligent Water-saving Irrigation Control System Based on WSN". 2020 IEEE International Conference on Artificial Intelligence and Computer Applications (ICAICA). DOI: 10.1109/ICAICA50127.2020.9181897. Dalian, China.

[3] Nahom Aron; Bereket Yemane; Temesgen Mikael; Reem Salem; Fatna Belqasmi. "A WUSN-based Smart System for Water Flow Control". 2020 12th Annual Undergraduate Research Conference on Applied Computing (URC). DOI: 10.1109/URC49805.2020.9099183. Dubai, United Arab Emirates.

[4] Mohamed Afifi; Mohamed F. Abdelkader; Atef Ghoneim. "An IoT system for continuous monitoring and burst detection in intermittent water distribution networks". 2018 International Conference on

Innovative Trends in Computer Engineering (ITCE). DOI: 10.1109/ITCE.2018.8316632. Aswan, Egypt.

[5] S. Mohamed Rabeek; Han Beibei; Kevin T.C Chai. “Design of Wireless IoT Sensor Node & Platform for Water Pipeline Leak Detection”. 2019 IEEE Asia-Pacific Microwave Conference (APMC). DOI: 10.1109/APMC46564.2019.9038809. Singapore.

[6] Achyutprasad Annigeri; Sujatha B. “Optimized Domestic Water Quality and Consumption Monitoring System Based on IoT”. 2021 IEEE Mysore Sub Section International Conference (MysuruCon). DOI: 10.1109/MysuruCon52639.2021.9641667. Hassan, India.

[7] Simitha K.M.; Subodh Raj M.S. “IoT and WSN Based Water Quality Monitoring System”. 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA)”. DOI: 10.1109/ICECA.2019.8821859. Coimbatore, India

[8] Vasantrao, K. S., & Rajbhoj, S. M. (2017). WSN Based Water Pipeline Leakage Detection. 2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA)

[9] Ding Qiong and Peng Hao. “Design and Implementation of Irrigation Water Saving Control System Based on WSN”. 2021 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS). DOI: 10.1109/ICITBS53129.2021.00027. Xi’an, China.

[10] Khulief, Y. A., A. Khalifa , R. Ben Mansour , and M. A. Habib. "Acoustic Detection of Leaks in Water Pipelines Using Measurements inside Pipe". Journal of Pipeline Systems Engineering and Practice May 2012 DOI: 10.1061/(ASCE)PS.1949-1204.0000089.

[11] Jihoon Choi, Joonho Shin, Choonggeun Song, Suyong Han and Doo I Park. "Leak Detection and Location of Water Pipes Using Vibration Sensors and Modified ML Prefilter". Sensors, 17(9), 2104; https://doi.org/10.3390/s17092104, 2017.

[12] Daniel C. Ferino, et al. “Development of Leak Detection System for PVC Pipeline Through Vibro-Acoustic Emission”. TENCON 2018 - 2018 IEEE Region 10 Conference. DOI: 10.1109/TENCON.2018.8650536. Jeju, Korea (South).

[13] Saraswathi V, Rohit A, Sakthivel S, Sandheep T J. "Water Leakage System Using IoT". International Journal of Innovative Research in Engineering & Management ISSN: 2350-0557, Volume-5, Issue-2, March-2018.

[14] Thilagaraj.M dkk. "Water Leakage Detection and Management System Using IOT". International Journal of Advanced Science and Technology. Vol. 29 No. 9s (2020): Vol. 29 No. 9s (2020) Special Issue.

[15] Udin, Muhammad Arman dkk. "Leakage Detection in Water Pipeline Using Microcontroller". 1st International Conference on Advances in Science, Engineering and Robotics Technology 2019 (ICASERT 2019). 978-1-7281-3445-1/19 ©2019 IEEE.