Iraqi Journal of Information and Communications Technology(**IJICT**)
Vol. 6, Issue 1, April 2023
www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

OIL AND GAS PIPELINES MONITORING USING IOT PLATFORM

Ahmed K. Yas[1], **Ammar Al Qassab**[2]
[1,2] College of Information Engineering, Al-Nahrain University, Baghdad, Iraq
ahmedkannan@yahoo.com[1], ammar.algassab@nahrainuniv.edu.iq[2]
Corresponding Author: Ammar Al Qassab
Received:28/02/2022; Revised: 10/05/2022; Accepted:20/06/2022
DOI:**10.31987/ijict.6.1.209**

Abstract- **The early detection of pipeline breaches in the pipeline monitoring system is a crucial concern for oil management firms. Diverse technologies have been created to identify pipeline leaks. However, they need development as the current systems take a long time to detect leaks. As a result, it can contribute to oil waste and natural disasters. This paper provides a system for detecting pipeline leaks using pressure, water-flow, Accelerometer, and voltage sensors coupled to an Arduino mega microcontroller with BLYNK IoT platform real-time monitoring. It is obvious from the data that the Oil Pipe Monitoring System is capable of displaying pipeline flowrates, pressures, and acceleration. When a leak occurs or an event occurs during operation, a message is delivered to the responsible technical individual indicating which pipe is leaking. This project successfully established an Internet of Things (IoT) platform to monitor pipeline events in real-time.**

keywords: **Wireless Sensor Network (WSN), Internet of things (IoT), Arduino Mega, Monitoring and Communication Unit (MCU).**

I. Introduction

Pipelines are vital for the transfer of many different types of fluids in industries, as well as for the transmission of natural gas and water for use in residential and commercial constructions. Pipeline leaks and ruptures occur as a result of aging and external damage, resulting in the loss of valuable water [1]. Depending on the severity of the damage produced by these leaks, there may be major consequences and disasters, as well as high maintenance and cleaning costs and potential danger to human life. Numerous automated pipeline monitoring systems (PMS) have been developed for industrial application to limit the negative consequences of leak damage and to notify maintenance authorities as soon as feasible. These monitoring solutions differ in a variety of ways, including the pipeline's material [2], its surroundings, the size and shape of the monitoring network [3], the type of application being monitored, and the various types of leak detection devices, including sensors, and monitoring procedures used.

Because of their greater strength and flexibility, plastic pipes are the most often utilized pipe material [4], low weight, simplicity of deployment across large regions, corrosion resistance, and resistance to bursts produced by hydraulic variations and seismic waves are all advantages. Numerous factors, including pipe material, length, diameter, mounting type, the existence of bends and loops in the pipe, and overground or subterranean pipe installation, all affectthe monitoring system utilized [5]. The most common sensing technique is a network of pressure and flow sensors. The most common sensing technique is a network of pressure and flow sensors. Vibration sensors, on the other hand, use less power and provide a much-needed extension to the sensor nodes' operational life [6].

In recent years, the introduction of MEMS sensors has made Wireless Sensor Network (WSN) a more dependable alternative for monitoring, because the MEMS system offers compact size, cheap cost, and ease of operation [7]. A wireless

ISSN:2222-758X
e-ISSN: 2789-7362

sensor network is a collection of sensors that can transport information acquired from a monitored field across wireless networks, and it is used to gather and analyze data. The data is routed across a large number of nodes and connected to other networks, such as wireless Ethernet, through the use of a gateway a WSN is a network that is comprised of base stations and a number of nodes (wireless sensors). These networks are used to monitor physical or environmental variables such as sound, pressure, and temperature, and to collaboratively communicate data to a centralized point over the network. Because WSNs comprise solely static nodes, they are often referred to as static networks. The WSN will collect, integrate, and process data from on-site sensor nodes in this scenario. The IoT provides us with the ability to alter how we perceive and interact with our physical surroundings in a variety of ways. By linking physical items to the information network, it will improve the efficiency, intelligence, and accuracy of applications in the future. It also provides a potential solution for a variety of current industrial systems, such as water transportation systems and production systems [8]. WSNs are critical in this technology because they operate as a bridge between humans and their real surroundings. WSN applications are now gaining traction in business and academia [9][10][11].

Oil and gas pipeline monitoring is one of the most essential uses of WSN due to the significance of this strategic asset. Representing accurately this multi-parameter dependence of pipeline behavior in a dynamical model is especially challenging, because pipelines are defined by a plethora of characteristics that affect flow and leakage. To provide a reliable monitoring system and precise leak detection in the face of this sophisticated pipeline dynamic behavior, a data-driven solution is preferred to a model-based one. Machine learning models are frequently constructed and fed data from several sensing nodes to identify numerous scenarios relevant to the work at hand.

While alternative wired systems based on fiber optics or copper are used, they are constrained by high installation and maintenance costs, difficulty detecting and repairing faults, inflexibility in tough terrain, and the danger of being compromised by the third-party intervention [12]. Additionally, monitoring can be accomplished by the use of supervisory control and data acquisition system (SCADA) that analyzes their pressure, volume, and temperature via sensor and communication networks [13]. Despite its popularity as a legacy monitoring technology, SCADA is defined by its high cost, significant delays, and inflexibility to protocol modifications [12], [14], [15]. All of these characteristics are in direct conflict with pipeline operators' fundamental monitoring system requirements, which include sensitivity, accuracy, and affordability [16]. The inadequacy of the aforementioned monitoring methods is underscored further by the loss of 11000 barrels of crude oil per day from Shell Nigeria's pipeline network in 2018, an increase of almost 550 percent over the previous year [17]. Additionally, it is critical to have a system in place that can monitor pipeline operations in real-time in order to detect any developing anomalies swiftly. The design of a pipeline monitoring system has become a popular issue in recent years, with numerous research groups focusing on different components of the monitoring process in different parts of the country.

Numerous studies have been undertaken in this subject in order to develop methods for pipeline leak detection and localization. The vast majority of them deal with software-related issues, such as leak detection techniques and communication protocols. Others are more interested in physical components like sensors and WSN platforms [18]. There are a number of objectives and contributions to this study, including initially examining the differences in vibrations experienced between

www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

pipeline stands, as well as recording the influence on flow meters and pressure differences. These sensors are positioned strategically along the pipeline to compare and analyze reading differences in order to ensure the safety of the pipeline. A second use of the recorded differences is to determine the most likely location of the leak in the pipeline and to assist the pipeline engineer in placing sensor nodes at a few critical locations in order to find the leak in two ways: first, sensor readings from the specific leaking section of the pipeline were used, and then sensor data from other sections of the pipeline were used as well.

II. Related Work

Pipelines include a wide range of characteristics that affect flow and leakage, which makes it challenging to adequately predict pipeline behavior in a dynamical model. Because of the complex dynamical behavior of pipelines and the need for accurate leak detection, a data-based technique is recommended over a model-based one. To do this, machine learning models are commonly created and fed data from a large number of sensing nodes to recognize various situations relevant to the task at hand. Using an Arduino Mega 2560 microcontroller, a Global System for Mobile (GSM) module, a solenoid valve, and a water sensor, a previous study was conducted to detect water leaks and operate the water pump [19]. The Android application notifies users when a leak occurs, which is one of the system's benefits. Other than that, the application can only be signed by an authorized individual. The absence of a real-time monitoring system is one of the system's disadvantages.

Additional research has been conducted to monitor and detect pipeline leaks utilizing GSM, Liquid Crystal Display (LCD), Arduino Uno, ESP8266 Wi-Fi module, and a water flow sensor [20]. If there is no difference in flow rate between the inlet and outlet sensors, no leakage is detected. A leak is detected if there is a variation in the flow rate. One of the benefits of using this system is that it can automatically turn off the water pump if there is a leak in the pipeline and then notify the person using the system. However, one of the drawbacks of this project is that it is not possible to perform real-time monitoring of leakage, nor can it be accessed from any location. Because of this, it is challenging for the user to detect a leakage in real-time, and the user must instead rely on the LCD to monitor the leakage.

Past research utilized a geophone detector to identify the presence of leakage in water[21]. The sensor was tested with both a cracked and a non-cracked pipe. Arduino Mega 2560 received leakage data and transmitted it to SIM900 GSM if leakage happened. As this was an urgent notice, the data would be forwarded as an SMS alert to the appropriate authorities. The geophone is a sensor that measures seismic activity by transforming ground motion into voltage. It cannot be used to identify a leak since any ground movement, such as that caused by natural catastrophes or construction, would cause the leak to be detected even if there is no real leak.

Previous research using Arduino Uno, an Internet of Things module, a solenoid valve, a pH sensor, and a flow sensor was carried out to detect leakage and measure the quality of the water [22]. The fact that the system utilizes the IoT system is one of its many benefits. The solenoid valve can be turned on or off by using a mobile application that is connected to the MQTT server. However, some of the drawbacks of the system include the fact that it does not have a Graphical User Interface (GUI) interface and that it must monitor the flow rate using the serial monitor that is included with the Arduino software.

Using autonomous robots, research was undertaken to discover a leak in the pipeline[23]. Using gyroscope and accelerometer sensors, radial pressure gradients in the vicinity of the leak were detected. The technology could identify a small breach, but it could not operate when water poured through the pipeline since the robot was not waterproof. In addition, two Arduino Nano were employed as microcontrollers. It was inefficient due to its reliance on a single microprocessor, which was insufficient to save battery life and money. In addition, the coordinates of the leak and the robot could not be recognized because the system lacked GPS.

Along with [24] proposes an In-Situ Pipeline Monitoring System based on WSN for vibration monitoring. The sensing approach employs a triple-axis vibration sensor, the ADXL345, to determine acceleration. Each node's data is filtered and processed locally in real-time by two neighboring nodes. The estimated values are subsequently communicated to the base-station supervisor. The system's disadvantages include the lack of a graphical user interface (GUI), the need to monitor the flow rate using the serial monitor included in the raspberry pi, and the absence of a notification message to alert the remote admin room or the concerned individual.

Each of the authors above has worked on one or two sensors that monitor oil, gas, and occasionally water pipelines. Five sensors have been included to improve the dependability of this monitoring. We relied on the most frequently utilized sensors in this instance. The length of the pipeline makes it more difficult to conduct reliable monitoring while simultaneously reporting on time to remote control rooms. This is because the pipeline carries oil and gas. In this paper, we investigate and propose a solution for monitoring oil and gas pipelines that are based on wireless sensor networks, with a focus on the reliability of leakage sensing and wireless data communication. Additionally, the Internet of Things platform was employed to give the necessary flexibility and ease for this monitoring in terms of storing and presenting data, as well as sending notifications and emails in the event of a leak.

III. OIL PIPELINE SPECIFICATION AND NATURAL FREQUENCY

Social occasion lines, which are 10-30 cm in width and utilized for brief distances to convey gas or unrefined petroleum, and feeder lines, which are utilized to move gas or rough from capacity tanks and handling offices to transmission pipes, are the two fundamental sorts of pipelines. Flammable gas pipelines and fluid oil pipelines are two additional kinds of pipelines. Iraq has an enormous pipeline network that transports raw petroleum and flammable gas from oil sources to treatment facilities, stockpiling tanks, and oil trade stages in Basra (southwest Iraq) [25].

The pipeline utilized in the tests in this study is composed of polyvinyl chloride (PVC), and its diameter is 20 mm. The pipe's wall thickness is proportional to its outer and inner diameters Table I. The following are the descriptions of the tested pipes utilized in this experiment:

A. Determining the natural frequency of the pipeline

The first step in determining the dynamic behavior of a structure when subjected to an external body, surface, or boundary stress is to obtain information about its normal mode. Normal modes of vibration can be utilized to forecast how a structure will respond when loaded with force fields [8].

TABLE I
OIL PIPELINE SPECIFICATIONS.

Pipeline Product	Water
Ends Type	Plane
Type of Pipe	Polyvinyl chloride
Wall Thickness	2.9 mm
Pipe Diameter (OD)	26.7 mm
Inner Diameter (ID)	23.8 mm
Weight	0.3 kg/m
The interval between Each Supports	1700 mm

Any system has the same amount of degree of freedom as natural vibrational frequencies. As a result, any distributed parameter system can have an endless number of natural frequencies. At any given time, such a system normally vibrates at only one or a few frequencies of detectable amplitude [9]. To resolve the free vibration problem in any system, it is necessary to discover all natural frequencies and their associated mode shapes. In reality, it is typically sufficient to know a few natural frequencies. Typically, the lowest frequencies are more significant [9]. Before any external force is applied, the natural frequency of the tested pipeline may be computed using the following equation[26]:

$$\mathrm{F_n} = \frac{1}{2\pi} * 22.4 * \sqrt[2]{\frac{\mathrm{EI}}{\mathrm{ML}^4}} \tag{1}$$

Where: Fn: refers to the pipe's natural frequency (Hz) E: Elastomeric Young's modulus (2.4 G Pa or 0.348 M psi for PVC) I: an inertial moment of inertia of the fourth polar system (0.049*[OD4-ID4]). Where OD and ID refer to the Outside and Inside Diameters, respectively. M: pipe mass per unit length lbs. /inch or kg/m. L: is the length of the intervals between pipe support.

Using the data in Table I and Eq.1, In this experiment, the natural frequency of the examined pipe is around 40 Hz.

B. Establishing The Required Sampling Rate

According to the Shannon Sampling theorem, if a continuous-time signal contains no frequency components greater than W Hz, it may be entirely identified by taking uniform samples at a rate of fs samples per second

$$\mathrm{fs} \ \geq 2 \ \mathrm{W} \tag{2}$$

Alternatively, in terms of the sample period:

$$\mathrm{T} \leq 1/2 \ \mathrm{W} \tag{3}$$

A band-limited signal has no frequency components above a particular maximum frequency. The Nyquist rate is the smallest sampling rate permitted by the sampling theorem (fs = 2W). The sampling frequency must first be established before selecting an appropriate hardware component (Microprocessors, Sensors, and communication elements). Shannon's theorem

Iraqi Journal of Information and Communications Technology(**IJICT**)
Vol. 6, Issue 1, April 2023
www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

[27] states that "the lowest sampling rate equals two samples per period of the signal's highest frequency component," Equations. 2 and 3. As a result, the minimum sample rate required to acquire the specified pipe's inherent frequency is 40 Hz. As stated previously in Section, the sampling frequency used in this article is 110 Hz.

IV. CONCEPTION OF A SYSTEM

This section will outline our proposed method. The architecture of an IoT system will be demonstrated. The sensor node's software and hardware implementations will be discussed.

A. Structure Of The Proposed System

This technique is intended for use with tubes that work under pressure. Multiple layers comprise the proposed IoT architecture, which interacts and collaborate to detect pipeline problems. The components of various levels are depicted in Fig. 1. First layer: is the layer of the WSN that collects and pre-processes data at the local level (not in the Blynk server). Following the software implementation, subsection 4.2 undertakes an experimental investigation into the hardware components of the node in order to select and create the numerous components. The second layer: the network consists of networking, service, and storage layers. This layer is responsible for communication with nodes, gates, and the base station. When there is a leak, the data is collected at low pressure and low flow rate. Nodes transmit compressed and leak data to the gateway (router), which estimates the location of the leak, and eventually to the cloud. The final layer is the user interface layer that allows interaction with sensor data. Several analyzes are conducted at this stage and made available to the public. Users can get information about leaks, statistics, graphs, pipeline status, and network information using the software.

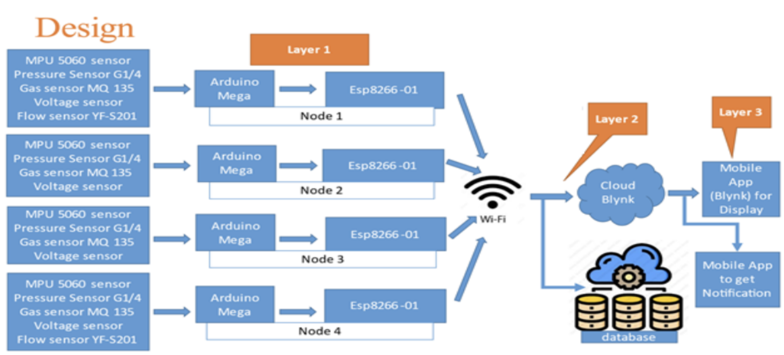

Figure 1: System design

B. Sensor Node Design

As seen in Fig. 2, the node design is divided into four subsystems: power supply, CPU, sensor, and communication. Due to their low cost, small size, long life, and large capacity, batteries, and solar panels are the most extensively used energy sources. As a result, the power unit is battery-operated. The processing subsystem is in charge of capturing and processing data streams via a microcontroller or microprocessor, and then storing them in memory. A suitable sensor detects and records any events occurring in the field of interest and converts them to an analog signal using the sensor's hardware architecture. An analog-to-digital converter (ADC) converts the analog signal to digital, which is then processed by the CPU. The communication subsystem completes the hardware configuration of the wireless sensor node. It is in charge of data transmission and reception via Wi-Fi.

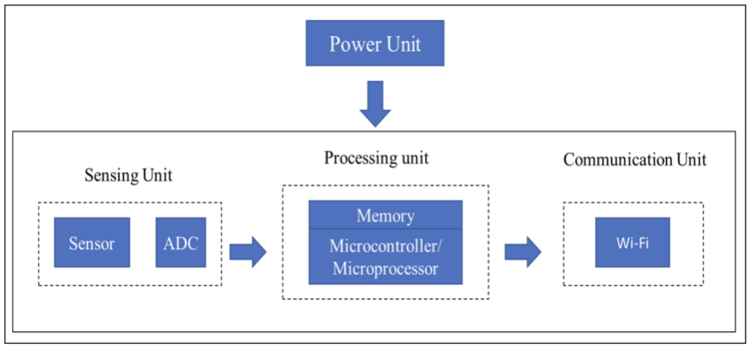

Figure 2: Wireless sensor node architecture

C. Sensors Selections

In this part, the proposed sensors will be discussed in further detail. Then after, compare them to other sensors.

1) Accelerometer Sensor: Accelerometers are utilized rather commonly for defect detection in a wide variety of different kinds of machinery as a result of their dependability, precision, and sensitivity shown in Fig. 3. They are electromechanical devices that transform mechanical signals, such as vibrations and stresses, into electrical impulses. MEMS (Micro-electro-mechanical sensors) accelerometers utilize less energy, have a smaller form factor, and weigh less than conventional vibration sensors. All of these characteristics, as well as the low cost, make the MEMS accelerometer a better fit for wireless system applications. In this study, a six-axis accelerometer is utilized to detect pipeline vibrations. The 6-axis MPU5060 MEMS accelerometer was chosen from among many commercially available options. Its operating conditions and specifications are also extensively documented the Table II can be seen below

The MPU-6050 [28], seen in Figure, is the world's first integrated 6-axis motion tracking device, integrating a 3-axis gyroscope, a 3-axis accelerometer, and a Digital Motion ProcessorTM (DMP) all in a small (4x4x0.9mm) package. With an independent I2C sensor bus. Additionally, the MPU-6050 is designed to communicate with a range of non-inertial digital sensors, including pressure sensors. Three 16-bit analog-to-digital converters (ADCs) are provided for digitizing gyroscope outputs and three 16-bit ADCs are provided for digitizing accelerometer outputs on the MPU-6050The components include a user-programmable gyroscope with full-scale ranges of $250, 500, 1000$, and $2000\%/\sec$ (DPS) for accurate tracking of both fast and slow motions, as well as a user-programmable accelerometer with full-scale ranges of $2\text{ g}, 4\text{ g}, 8\text{ g}$, and 16 g for precise tracking of both fast and slow motions. A 1024-byte on-chip FIFO buffer contributes to system power savings by allowing the system CPU to receive sensor data in bursts and then enter a lowpower mode while the MPU gathers additional data. Normal running accelerometer current is $500\mu\text{A}$, Low power accelerometer mode current is $10\mu\text{A}$,

TABLE II
Compares a number of accelerometer sensors

Technology	LDT0-028K [25]	Piezoelectric [25]	ADXL345 Accelerometer [25]	MPU 5060 Accelerometer
Reliability	Low	Low	High	High
Shock &vibration Resistance	Withstands High impact	Max. Pressure can apply 69 Bar	$10,000$ g shocks	$10,000$ g shocks
Temperature of Operation	$00 - 850\text{C max}$	-50 to 350°C	$-40°$C to $+85°$C	$-40°$C to $+85°$C
Resolution	Low	Low	Scalable	Scalable
Cost	$$$	$	$$	$$
Embedded Memory Management System	No	No	FIFO technology minimizes host processor load	1024 Byte FIFO buffer
Size	28μm thick polymer film, laminated to 0.125 mm polyester	$(18 \times 9 \times 0.21)$mm	Small and thin: $3 \times 5 \times 1)$mm LGA package	Small and thin: $4 \times 4 \times 0.9$ mm
The filter output is required.	Yes	Yes	Contain embedded digital filter	Contain embedded digital filter
Measurementrange (Data Rate)	1000 Hz maximum	from 20 Hz to 10kHz	From 10 Hz to 3200 Hz	From 1 Hz to 8000 Hz

Gyroscope operating current is 3.6μA, and Gyroscope standby current is 5μA. The supplied voltage ranges from 2.375 V to 3.46 V. As a result, it was chosen since it encompasses twice the natural frequency of the system suggested for this mission.

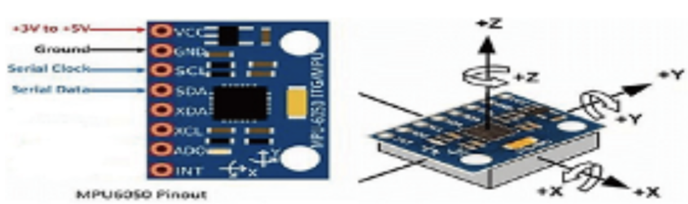

Figure 3: MPU6050 pinout and axis

The actual value from the average or offset of each axis to obtain the true reading. (Eq.4).

Iraqi Journal of Information and Communications Technology(**IJICT**)
Vol. 6, Issue 1, April 2023
www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

$$
\begin{aligned}
\mathrm{X-ACTUAL} &= \mathrm{X-MEAS-X0\ g} \\
\mathrm{Y-ACTUAL} &= \mathrm{Y-MEAS-Y0g} \\
\mathrm{Z\text{-}\ ACTUAL} &= \mathrm{Z-MEAS-Z0\ g}
\end{aligned}
\tag{4}
$$

Where: MEAS is sensor measurement

2) Pressure Sensor: Water Pressure Sensor G1/4 1.2Mpa [29] Fig. 4 illustrates Pressure point analysis is used to detect leaks because it compares current pressure data to historical pressure trends. Sensor specification:

TABLE III
Pressure sensor specification

Accuracy:	$\pm 1.5\%$
Application:	Industrial Automation
Maximum Pressure:	348.09 PSI (24 Bar)
Operating Pressure:	174.05 PSI (12 Bar)
Operating Temp:	$-20°C \sim 105°C$
Output:	$0.5\ V \sim 4.5\ V$
Package / Case:	Cylinder, Metal
Port Style:	Threaded
Pressure Type:	Gauge
Termination Style:	Screw Terminal
Voltage - Supply:	5 V

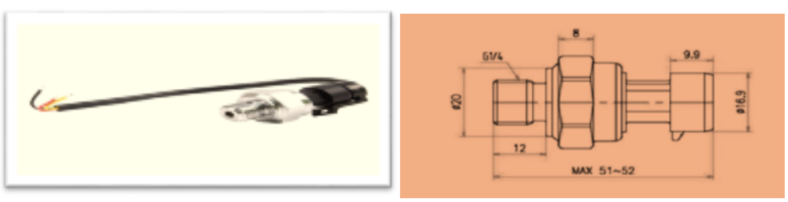

Figure 4: Water pressure sensor

3) Voltage Sensor: A voltage sensor is an accurate and low-cost voltage sensor. It is used to monitor, calculate, and determine the voltage source's voltage supply shown in Fig. 5. This sensor may be used to determine the alternating current or direct current voltage level [30]. The voltage may be used as the input to this sensor, while the switches, analog voltage signal, current signal, or audio signal can be used as the output. Sensor specification:

Voltage sensors make use of a voltage divider to perform their measurements.

www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

TABLE IV
Voltage sensor specification

Input Voltage	0 to 25 V
Voltage Detection Range	$0.02445 - 25$ V
Analog Voltage Resolution	0.00489 V
Needs external components	No
Simple to integrate with microcontrollers	Yes
Dimensions	$4 \times 3 \times 2$ cm

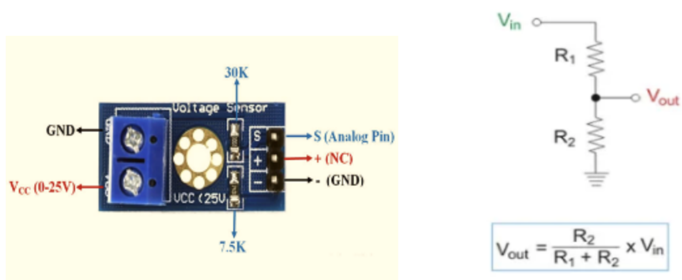

Figure 5: Voltage Sensor

4) Sensor For Water Flow: As depicted in Fig. 6, this sensor is used to detect changes in the flow rate of water in pipes [31]. The following components comprise a water flow sensor: a magnetic core, a spinning impeller, an exterior shell and sensor, and a hall-effect sensor. The magnetic core is triggered as water travels through the rotor, resulting in the switch action. The flow rate influences the speed at which the switch operates. Users may compute the flow rate by monitoring the pulses generated by the hall-effect sensor. Sensor specification:

TABLE V
Water flow sensor specification

Model	FS400A-G1
Flow Rate Range	$1 - 60$ L/min
Working Voltage	DC 5 V – 24 V
Max. Working Current	15 mA(DC5 V)
Mini. Working Voltage	DC 4.5 V
Water Pressure	≤ 2.0MPa
Operating Temperature	$\leq 80°$C
Liquid Temperature	$\leq 120°$C

ISSN:2222-758X
e-ISSN: 2789-7362

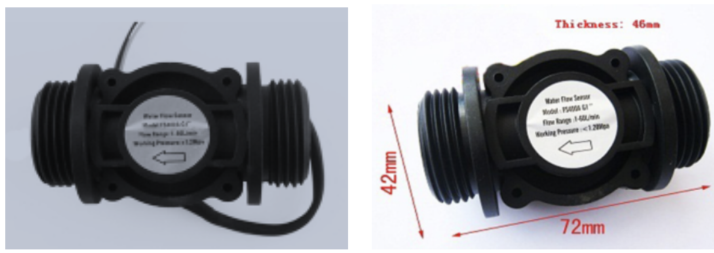

Figure 6: Water flow sensor

A proportional pulse is generated by the water flow sensor in proportion to the flow rate. To determine the volume of liquid that flowed through the sensor during this one-second interval, divide the flow rate in liters per minute by 60 and multiply by 1000 to convert it to milliliters. Flow MilliLitres = (flowrate / 60) * 1000.

D. Selection of Micro Controller

The WSN node's intelligence is provided by the processing unit. The application class has a big effect on which processing unit WSNs use [10]. When selecting a processor unit for a WSN node, the most critical thing to consider is establishing a balance between cost and processing speed. Other criteria include physical dimensions, required memory capacity, energy utilization, and peripheral support. Many companies, including Arduino, NodeMCU ESP8266, Microchip, and Texas Instruments, now provide off-the-shelf microcontroller/microprocessor boards for research and hobbyist users. Because it meets the design requirements described above, the Arduino board was deemed suitable for this purpose. Additionally, this board is compatible with a broad range of electronic components and benefits from a robust community support network, simplifying the development process.

"Arduino is a free and open-source electronics platform built on a foundation of simple hardware and software" [32]. The Arduino Mega [33], as seen in Fig. 7, the Arduino Mega 2560, is an ATmega2560-based microcontroller board table (6).

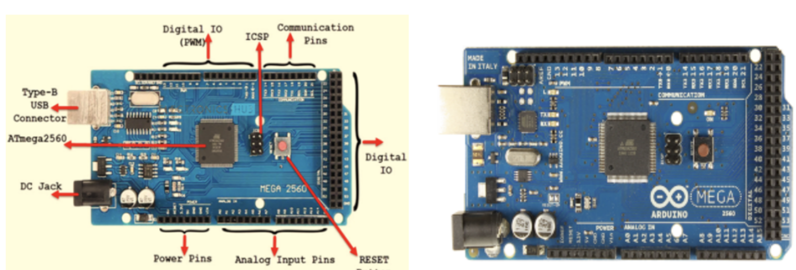

Figure 7: Arduino ATmega 2560 shape and pinout

Specification:

TABLE VI
Arduino ATmega 2560 specification

Microcontroller	ATmega 2560
Input Voltage (recommended)	7 – 12 V
Operating Voltage	5 V
Analog Input Pins	16
Digital I/O Pins	54
SRAM	8 KB
EEPROM	4 KB
Flash Memory	256 KB of which 8 KB used by bootloader

To allow any microcontroller to connect to your Wi-Fi network, the ESP-01 ESP8266 Serial Wi-Fi Wireless Transceiver Module contains an integrated TCP/IP protocol stack Fig. 8. With an ever-growing community, the ESP8266 module is one of the most affordable boards today [34]. The specifications are shown in Table VII. Specifications:

TABLE VII
ESP-01 ESP8266 specification

Module Model	ESP-01
QSPI flash memory	8 Mbit external (1MByte)
IO Port	2
Power Supply Voltage	3.30 V
Wi-Fi protocol	Wi-Fi b/g/n supported
Antenna	PCB antenna, 2dBi.
Operating Temperature	$-20°C \sim 85°C$
Size	$24.7 \times 14.4 \times 11.0$ mm

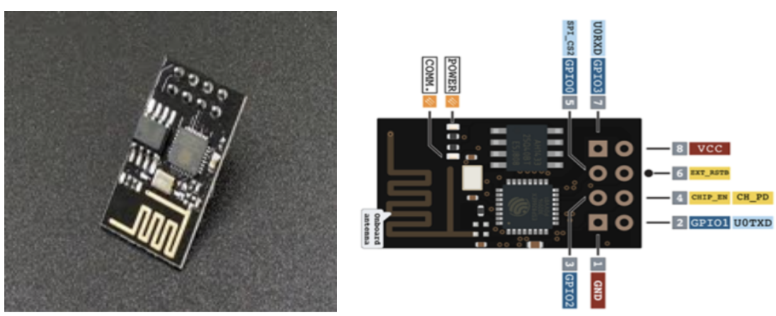

Figure 8: ESP-01 ESP8266 Wi-Fi shape and Pinout

V. SYSTEM SETUP

Fig. 9 depicts the suggested system. It is made up of four sensor nodes that are joined at the end of a 23-meter-long polyvinyl chloride (PVC) pipe with an exterior diameter of 26.7 mm. This type of pipe is popular due to its low cost, resistance to chemical and electrical corrosion, and lack of susceptibility to these corrosion processes. Additionally, the system incorporates two valves at the intake and exit points to enable pressure adjustment to meet the user's requirements.

Iraqi Journal of Information and Communications Technology(**IJICT**)
Vol. 6, Issue 1, April 2023
www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

As a water supply, a 1000 m3 reservoir is employed. Two flow meters are used to control the water entering and exiting the system. Since the pipes are designed at the same level and the water is transported along with them via an electrical pump, the jet pump motor may generate a pressure in the pipeline of approximately 3 bar when the output valve is closed and approximately 1.8 bar when it is entirely open. Finally, leaks are created using four garden taps. The suggested sensor node is tested using this demonstration. The Arduino board, the ESP-01 ESP8266, a flow sensor, an accelerometer, and a pressure sensor comprise the prototype. As illustrated in Fig. 9, the sensor of Node 1 is attached 1.5 meters from the right end of the pipe, while the sensor of Node 2 is attached to the opposite end at 21.5 meters. The sensors were mounted to the pipe in a variety of methods, including utilizing adhesive spray, drilling a hole in the pipe, and connecting directly to the pipe. To support the pipe, 13 concrete supports are built every 1.7m. Experiments were carried out on the site in a variety of scenarios:

First: conducted to compare sensor measurements without event on the pipe Fig. 14 (A).

Second: Make a lake five meters away from the beginning of the pipe from the side of the water compressor by opening the water tap located there. Fig. (14 (B)).

Third: Make a lake Fifteen meters away from the beginning of the pipe from the side of the water compressor by opening the water tap located there. Fig. (14 (C)).

The suggested system is primarily concerned with detecting the event. Each node captures live vibration measurements for a brief period (0.6 seconds) as a result of the activities that occur (Leak). The node analyzes the data locally before sending the activity detection to the cloud through a wireless connection (Wi-Fi). If any actions are abnormal, the node sends a notification via mobile notification and email. The result may be viewed in a mobile application (Blynk), and there is also the option of transferring data from the application to an email address for downloading, displaying, or analyzing, depending on the format of the data file (CSV file format). A CSV file is a simple text file that can be opened in a variety of applications, including any software that deals with plain text, such as the Notepad app. What distinguishes a CSV file from others is the way its contents are arranged.

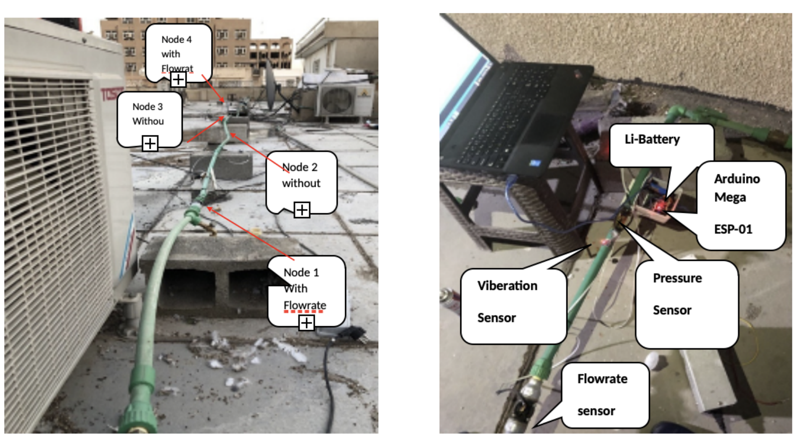

Figure 9: Nodes layout on pipeline

VI. RESULTS AND DISCUSSIONS

This section contains the results of various sensor statuses, as well as snapshots and graphs. If there is a change in the process, the pipeline monitoring node device will send a notification message to the user's mobile phone and email address. Fig. 10 shows the steps of system operations.

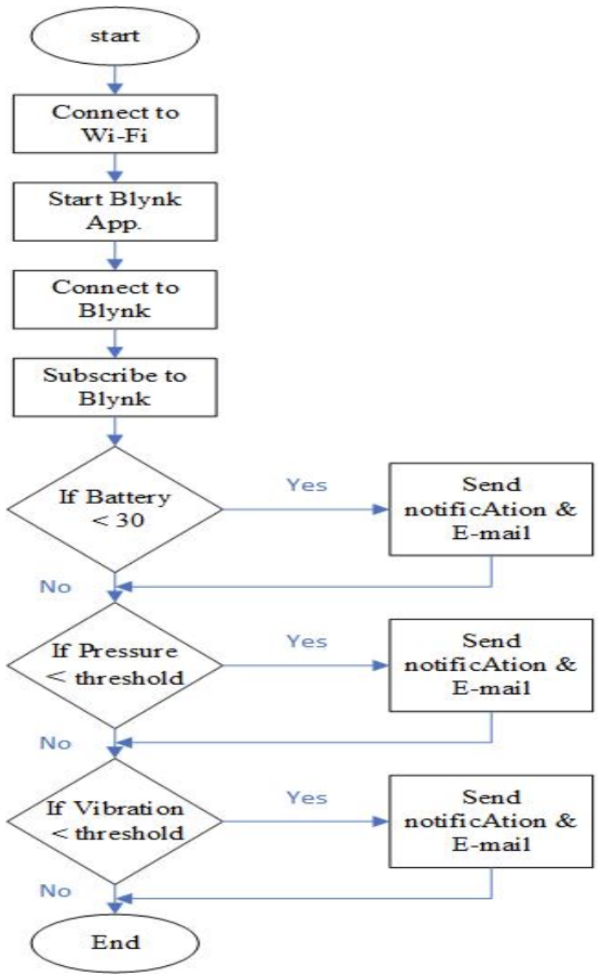

Figure 10: Shows the steps of operation

The whole system is depicted in Fig. 11, along with peripherals that are interfaced to perform a specific task. Automation is used to send and receive messages in a topic format using an iOS/Android application designed for engineers to monitor the status of the stations. This is accomplished by automatically subscribing to and posting on related topics.

www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

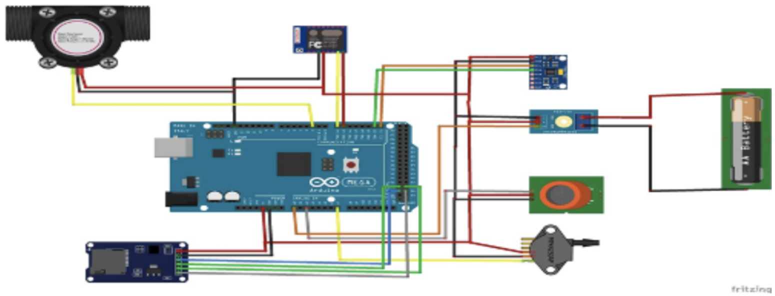

Figure 11: overall system with peripherals interfaced

When an app is executed with data connection enabled, the port is instantly directed to the Blynk server, which saves the node's processed data. Fig. 12 is a screenshot from a mobile application that shows the pressure, vibration, flow rate, and total liters in the pipe, as well as the notice that was sent owing to a vibration problem and a low battery level.

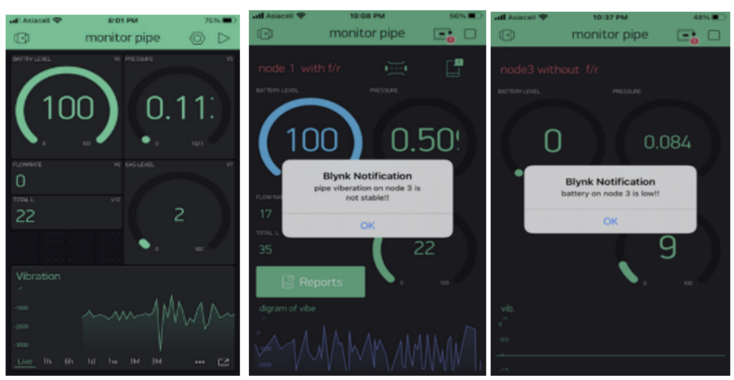

Figure 12: is a snapshot from a mobile app

Fig. 13 is a snapshot from the Blynk mobile application showing that if the node is on or off, this is noted by the color of the LED, where if the node is working, the LED color is green, but if the node is not working, the light is gray, and also noted below each point is the last date it was working.

ISSN:2222-758X
e-ISSN: 2789-7362

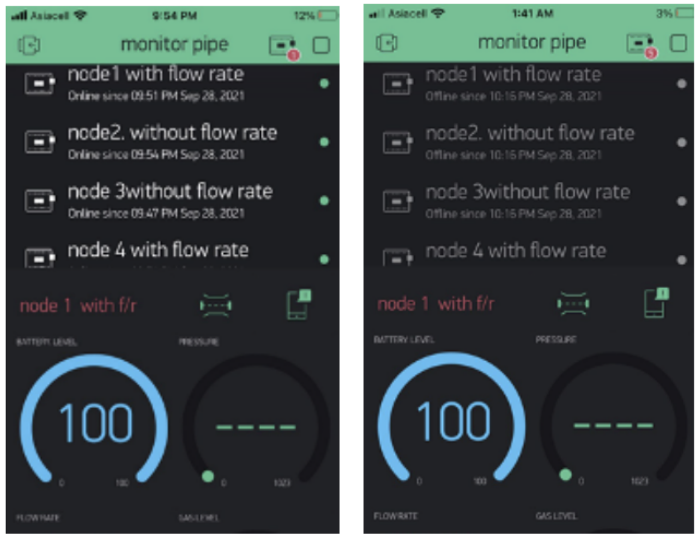

Figure 13: A snapshots from the mobile application showing if the node is on or off

A B C

Figure 14: A. sensor measurements without event on the pipe. B. a lake five meters away from the beginning of the pipe. C. a lake fifteen meters away from the beginning of the pipe.

Fig. 15 demonstrates that when there is a leak in an oil pipeline, there is an imbalance between the fluid flow and pressure within the pipelines. When there is a leak in an oil pipeline, the sensor will detect it at two different locations: the first location will be near the source, where the sensor will detect an increase inflow, and the second location will be on the opposite end of the pipe, where the sensor will detect a drop inflow. There is a drop in pressure at both locations, which may be seen in terms of the level of pressure.

Iraqi Journal of Information and Communications Technology(**IJICT**)
Vol. 6, Issue 1, April 2023
www.ijict.edu.iq
ISSN:2222-758X
e-ISSN: 2789-7362

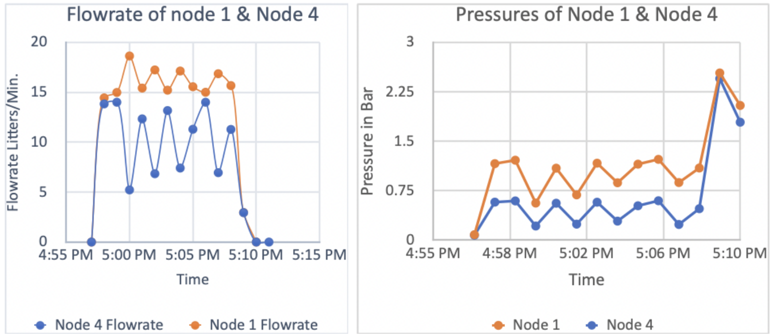

Figure 15: Comparison of Node 1 and Node

VII. Conclusion

This study has a number of objectives and contributions, including analyzing the changes in vibrations experienced between pipeline stands and documenting the effects on flow meters and pressure differentials. These sensors are strategically placed along the pipeline in order to evaluate and analyze reading variances in order to ensure the pipeline's safety. A second application of the recorded differences is to determine the most likely location of the pipeline leak and to assist the pipeline engineer in strategically placing sensor nodes at a few critical locations in order to locate the leak in two ways: first, sensor readings from the specific leaking section of the pipeline were used, and then sensor data from other sections of the pipeline was used as well. To conclude, the system investigated and proposed in this paper can be efficiently used in oil and gas pipeline monitoring solutions with a focus on sensing and wireless data communication. The developed system provides the capability of reporting reliable pipeline health-related statistics stretched over large geographical areas. Development in the domain of wireless sensor networks and communication technologies has created an industrial need to automate tasks and gain more control. Rapid advancement in data processing technologies, wireless communication, the evolution of business intelligence, process planning, and control has created room for improvement in all areas of industrial practices related to oil and gas processing. Wireless reliable monitoring for reporting the events that happen on oil and gas carrying pipelines to remote control rooms on timeis a bigger challenge due to its lengthy span. The findings from this study can be used to construct a reliable WSN-based pipeline monitoring system. All of the WSN systems developed in the present prototype have expanded capabilities and overcome the limitations of earlier data transfer solutions accessible between the master and node. Numerous enhancements are possible, including the following:

Hop-based node-to-node communication.

Carry out the localization algorithm.

In the event of a battery failure, backup energy is available.

In the event of a communication breakdown, onboard log storage is provided.

Funding

None

ACKNOLEDGEMENT

The author would like to thank the reviewers for their valuable contribution in the publication of this paper.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

REFERENCES

[1] Z. Almheiri, M. Meguid, and T. Zayed, "Intelligent Approaches for Predicting Failure of Water Mains," J. Pipeline Syst. Eng. Pract., vol. 11, no. 4, p. 04020044, Jul. 2020, doi: 10.1061/(ASCE)PS.1949-1204.0000485.
[2] H. Shukkla and K. R. Piratla, "Unsupervised classification of flow-induced vibration signals to detect leakages in water distribution pipelines," in Pipelines 2020: Planning and Design - Proceedings of Sessions of the Pipelines 2020 Conference, pp. 437444, 2020.
[3] M. I. M. Ismail, R. A. Dziyauddin, N. A. M. Salleh, R. Ahmad, M. Hadri Azmi, and H. M. Kaidi, "Analysis and procedures for water pipeline leakage using three-Axis accelerometer Sensors: ADXL335 and MMA7361," IEEE Access, vol. 6, no. c, pp. 71249-71261, 2018, doi: 10.1109/ACCESS.2018.2878862.
[4] H. Shukkla and K. Piratla, "Leakage detection in water pipelines using supervised classification of acceleration signals," Autom. Constr., vol. 117, 2020, doi: 10.1016/ j.autcon. 2020.103256.
[5] M. I. Mohd Ismail et al., "A review of vibration detection methods using accelerometer sensors for water pipeline leakage," IEEE Access, vol. 7, pp. 51965-51981, 2019, doi: 10.1109/ACCESS.2019.2896302.
[6] S. Xie, Y. Hu, and Y. Wang, "Weighted centroid localization for wireless sensor networks," Proc. 2014 IEEE Int. Conf. Consum. Electron. - China, ICCE-C 2014, pp. 1-4, 2015, doi: 10.1109/ICCE-China.2014.7029859.
[7] A. Rghioui and A. Oumnad, "Internet of things: Surveys for measuring human activities from everywhere," Int. J. Electr. Comput. Eng., vol. 7, no. 5, pp. 2474-2482, 2017, doi: 10.11591/ijece.v7i5.pp2474-2482.
[8] C. Chepken, E. Blake, and G. Marsden, "Day labour mobile electronic data capture and browsing system," ACM Int. Conf. Proceeding Ser., vol. 91, no. 8, pp. 69-76, 2011, doi: 10.1145/2072221.2072230.
[9] A. A. Jaber and R. Bicker, "Design of a Wireless Sensor Node for Vibration Monitoring of Industrial Machinery," Int. J. Electr. Comput. Eng., vol. 6, no. 2, p. 639, Apr. 2016, doi: $10.11591/ijece.v6i2.pp639-653$.
[10] H. Sayuti et al., "Smart home and ambient assisted living based on the internet of things," Int. J. Electr. Comput. Eng., vol. 7, no. 3, pp. 1480-1488, 2017.
[11] M. Y. Aalsalem, W. Z. Khan, W. Gharibi, M. K. Khan, and Q. Arshad, "Wireless Sensor Networks in oil and gas industry: Recent advances, taxonomy, requirements, and open challenges," J. Netw. Comput. Appl., vol. 113, pp. 87-97, 2018.
[12] Anshu Mittal, Andrew Slaughter, and Vivek Bansal, "The digital transformation in upstream oil and gas," Deloitte Insights, no. January, pp. 20-22, 2017.
[13] W. Z. Khan, M. Y. Aalsalem, M. K. Khan, M. S. Hossain, and M. Atiquzzaman, "A reliable Internet of Things based architecture for oil and gas industry," Int. Conf. Adv. Commun. Technol. ICACT, pp. 705-710, Mar. 2017, doi: 10.23919/ICACT.2017.7890184.
[14] S. Shoja and A. Jalali, "A study of the Internet of Things in the oil and gas industry," 2017 IEEE 4th Int. Conf. Knowledge-Based Eng. Innov. KBEI 2017, vol. 2018-Ianuaa, pp. 0230-0236, Mar. 2018, doi: 10.1109/KBEI.2017.8324979.
[15] P. Ostapkowicz, "Leak detection in liquid transmission pipelines using simplified pressure analysis techniques employing a minimum of standard and non-standard measuring devices," Eng. Struct., vol. 113, pp. 194-205, 2016, doi: 10.1016/ j.engstruct.2016.01.040.
[16] Shell, "Our activities in Nigeria - Shell Sustainability Report 2017," 2018. https:// reports.shell.com/sustainability-report/2017/managing-operations/our-activitiesin-nigeria.html (accessed Feb. 28, 2022).
[17] F. Karray, A. Garcia-Ortiz, M. W. Jmal, A. M. Obeid, and M. Abid, "EARNPIPE: A Testbed for Smart Water Pipeline Monitoring Using Wireless Sensor Network," Procedia Comput. Sci., vol. 96, pp. 285-294, 2016, doi: 10.1016/j.procs.2016.08.141.
[18] M. Daadoo, A. Eleyan, and D. Eleyan, "Optimization water leakage detection using wireless sensor networks (OWLD)," ACM Int. Conf. Proceeding Ser., vol. Part F130522, no. August, 2017, doi: 10.1145/3102304.3102309.
[19] P. Swetha Reddy, K. V. Chanakya, B. Eswari, and C. Bhupati, "Water leakage detection monitoring and controlling system using IOT," Int. J. Eng. Technol., vol. 7, no. 2, pp. $120-123$, 2018, doi: 10.14419/ijet.v7i2.7.10276.
[20] E. F. Rusli, I. A. Aziz, J. Jaafar, N. Haron, S. Qaiyum, and N. F. Ali, "Pipeline leakage alert system with water displacement detection," 2017 IEEE Conf. Wirel. Sensors, ICWiSe 2017, vol. 2018-January, pp. 12-17, 2018, doi: 10.1109/ICWISE.2017.8267154.
[21] M. M. Srihari, "Intelligent Water Distribution and Management System Using Internet of Things," Proc. Int. Conf. Inven. Res. Comput. Appl. ICIRCA 2018, no. IcirÃ§a, pp. 785789, 2018, doi: 10.1109/ICIRCA.2018.8597325.
[22] G. Dvajasvie, B. P. K. Farishha, S. N. Babu, K. P. Saheen, and N. C. Binoy, "Leak Detection in Water-Distribution Pipe System," Proc. 2nd Int. Conf. Intell. Comput. Control Syst. ICICCS 2018, no. Iciccs, pp. 1151-1154, 2019, doi: 10.1109/ICCONS.2018.8663193.
[23] A. H. Hadi and W. F. Shareef, "In-Situ Pipeline Monitoring System Design for Identifying and Locating Damaging Activities Based on Wireless Sensor Network," Iraqi J. Comput. Commun. Control Syst.. Eng., vol. 20, no. 2, pp. 33-46, 2020, doi: 10.33103 /uot.iiccce.20.2.5.
[24] "Here's The Map Of Iraq's Energy Infrastructure That Everyone Is Going To Want To Save | Business Insider India." https://www.businessinsider.in/heres-the-map-ofiraqs-energy-infrastructure-that-everyone-is-going-to-want-to-save/articleshow/ 36657956.cms (accessed Feb. 24, 2022).
[25] M. U. R. A. Virk, M. F. Mysorewala, L. Cheded, and I. M. Ali, "Leak detection using flowinduced vibrations in pressurized wall-mounted water pipelines," IEEE Access, vol. 8, pp. 188673-188687, 2020, doi: 10.1109/ACCESS.2020.3032319.
[26] R. J. Marks, Introduction to Shannon Sampling and Interpolation Theory. 1991.
[27] InvenSense, "MPU-6000 and MPU-6050 Product Specification Revision 3.4 MPU-6000/MPU-6050 Product Specification," 2013. Accessed: Jan. 24, 2022. [Online]. Available: https://www.invensense.com/wp-content/uploads/2015/02/ MPU-6000-Datasheet1.pdf.

[28] Seeed Technology, "Water Pressure Sensor G1/4 1.2Mpa - Datasheet," vol. 3, pp. 4-6, 2017, Accessed: Jan. 24, 2022. [Online]. Available: https://www.seedstudio.com/ Water-Pressure-Sensor-G1%2F4-1.2MPa-p-2887.html.
[29] "Voltage Sensor Module Pinout, Features, Specifications & Arduino Circuit." https:// components101.com/sensors/voltage-sensor-module (accessed Jan. 24, 2022).
[30] Seeedstudio, G3 / 4 Water Flow sensor, pp. 39, 2014,
[31] C. Chepken, E. Blake, and G. Marsden, "Day labour mobile electronic data capture and browsing system," ACM Int. Conf. Proceeding Ser., vol. 91, no. 8, pp. 69-76, 2011, doi: 10.1145/2072221.2072230.
[32] G. Dvajasvie, B. P. K. Farishha, S. N. Babu, K. P. Saheen, and N. C. Binoy, "Leak Detection in Water-Distribution Pipe System," Proc. 2nd Int. Conf. Intell. Comput. Control Syst. ICICCS 2018, no. Iciccs, pp. 1151-1154, 2019, doi: 10.1109/ICCONS.2018.8663193.
[33] https://www.arduino.cc/, "Arduino - Home," Hardware, 2016. https:// www.arduino.cc/ [Accessed Feb. 28, 2022].
[34] L. Vinet and A. Zhedanov, "A 'missing' family of classical orthogonal polynomials," Journal of Physics A: Mathematical and Theoretical, vol. 44, no. 8. p. 3, 2011, doi: 10.1088/1751-8113/44/8/085201.
[35] S. A. T. CO and LTD, "ESP-12E WiFi Module Version 1.0," Shenzhen Anxinke Technol. CO LTD, pp. 1-18, 2015, [Online]. Available: http://www.kloppenborg.net/images/blog/ esp8266/esp8266-esp12e-specs.pdf.