The Application of IoT-based Water Pressure Monitoring System

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***Abstract*—The study was stimulated by local utilities to improve their reputation in the era of water supply in residential areas, particularly the issue of low water pressure. The current low water pressure situation is highly dependent on complaints from residents in the supply area. This resulted in an extended period of time to solve the problem. Therefore, an IoT-based water pressure measuremeter was proposed. The proposed measurement device was used to detect low water pressure at the residential area or internal area that is away from the water main. The proposed solution is developed based on the principle of IoT architecture which covers the perception layer, network layer and application layer. The perception layer is composed of Arduino as microcontroller, GSM and WiFi shield as communication and water pressure sensor as transducer. Wi-Fi and GSM shield provide communication services within the network layer. For the application layer, an IoT platform was chosen for data analysis and visualisation. The water pressure variation taken at two different places in urban areas. Two datasets were collected at Location 1 and four datasets were collected at Location 2. Each dataset has a 24-hour time frame. Preliminary findings were obtained and presented in this paper. The results showed the water pressure pattern within 24 hours. The study shows that real-time monitoring of water pressure contributes to a better standard of living for residents, as well as helping authorities find efficiencies and increase profits.**

***Index Terms*—Internet of Things, water pressure, piezoelectric pressure sensor, Arduino, GSM, WiFi connectivity.**

I. Introduction

Low water pressure often has an effect on human daily activities. Pipe failure is always the main cause of low water pressure due to severe water leak. The lack of a real-time monitoring system poses a challenge to water utility company. The existing solution depends on the report of the resident of the affected area. In June 2019, water utility company responded slowly to severe water leaks, which led to a drop in water pressure and affected more than 100,000 people [1]. This caused the water utility company a great loss on the money and reputation due to the water leak. Due to the issue, an IoT-based, affordable real-time monitoring system has been proposed to measure and monitor the water pressure level in the residential or internal area. The system is developed using the IoT architecture, which consists of three elements: perception layer, network layer and application layer. Arduino Uno is used as a microcontroller and connected through GSM and WiFi technology. An application is developed to gather and monitor the water pressure level in the selected urban housing area.

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II. Literature Review

A. Piezoelectric Pressure Sensor

Monocrystalline silicon is an internal component of the transducer. As monocrystalline silicon undergoes stresses, it induces an infinitesimal modification of the inner structure of the atom and an electron-level transition. Changes cause a major shift in resistivity and resistance. It is known as the Piezora effect [2].

A strain gauge shows the engineering technology work of the integrated circuit, based on piezoresistif effect. The production process involves doping, oxidation and orientation of the substrate towards the crystals. A diffuse silicon sensor is then produced, taking advantage of the elastic properties of the special silicon material and heterosexual micromachining of the same silicon material in different directions. This sensor is a mechanical-electrical energy-sensitive investigator. The Fig. 1 shows the structure of piezoelectric pressure sensor.

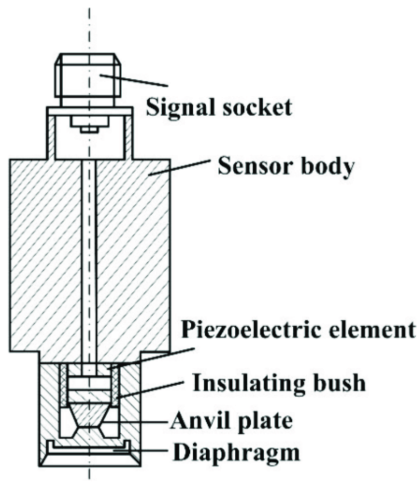

Fig. 1. Structure of piezoelectric pressure sensor [2].

B. Water Pressure Measurement

Pressure measurement is the analysis of a force applied by a medium (liquid or gas) to a surface. Pressure is usually measured in units of force per unit of surface area. Numerous techniques have been developed to measure pressure and vacuum. The following terminology is used to designate zero reference [3]:

- **Absolute pressure** measured by reference to zero. This is similar to how gas pressure transducers measure gas pressure in relation to a vacuum.
- **Gauge pressure** measures the pressure relative to the atmospheric pressure surrounding the sensor.
- **Differential pressure** reflects the difference between two bodies such as the two separate tanks or water pipes. This can be used to measure pressure drops across filters, or measure flow rates by measuring the difference in pressure across a restriction.

C. Water Pressure Sensor

Water pressure sensors are frequently used to measure the water level in a tank, or the rate of change in that level. The sensor is mounted to the top of an open-ended tube submerged in the container. When the water level increases, the air above the water in the tube is compressed, thereby increasing the pressure on the sensor. An analog-to-digital converter (ADC) is used to convert the sensor signal to a digital value [4]. The sensors can also be used to measure the pressure in pipes where water is flowing at the depth of a submerged object or underwater.

Water pressure sensors generally contain a physical diaphragm, often silicon, which bends when the pressure is applied. The diaphragm is a strain gauge that varies its electric resistance when the force is applied. This resistor will change the sensor output voltage.

Certain water pressure sensors provide zero-based outputs, where zero-pressure gives no output signal. For instance, their output can range from 0 to 5 V. While certain water pressure sensors shows a zero-pressure voltage, with a range like 1-5V. Fig. 2 shows the water pressure sensor specification graph in MPa vs the output voltage with equation (1). While Fig. 3 shows the water pressure sensor specification graph in bar vs the sensor value with equation (2).

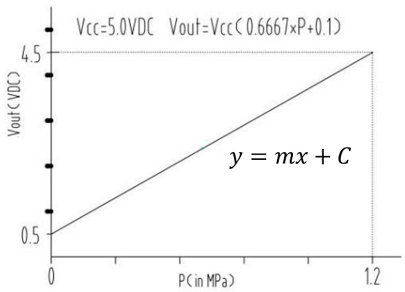

Fig. 2. Water Pressure Sensor Specification (in MPa) [5].

$$V_{out} = V_{cc}[0.6667P + 0.1] \quad (1)$$

$$Pressure, P = (sensorValue - 102)/68.5 \quad (2)$$

D. Water Measure Unit

There is water pressure measuring unit which can be used in various way. There is standard where the water company set for the water pressure. To achieve of the service standard,

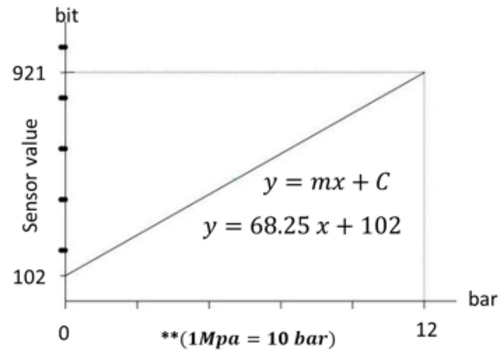

Fig. 3. Water Pressure Sensor Specification (in bar) [5].

water companies should maintain a minimum pressure of water in the communication pipe serving the premises supplied with water of 70 kPa (0.7 bar) [6].

E. IoT Architecture

With the rapidly growing IoT, the implementation of the IoT system is taking place. IoT architecture delivers efficient and reliable IoT solutions to the proposed system. The IoT may not just be something that pertains to the device connected to the Internet. It is a technology behind which builds the system that is capable of autonomous sensing and response of the real world without human intervention. The IoT architecture in this project comprises three layers (Fig. 4).

Perception layer: involves the use of sensors and actuators. The functionality of sensors and their ability to convert information gathered from real-world data analysis. This is an essential step in the treatment of the data submission. Network layer: data transmission between application layer and perception layer. The data sensors obtained readings of the aggregated device and converted it from analogue to digital for subsequent processing. Data aggregation and conversion functions carried out in data acquisition systems. Application layer: edged analytics of the IoT systems through machine learning and visualization technology [7].

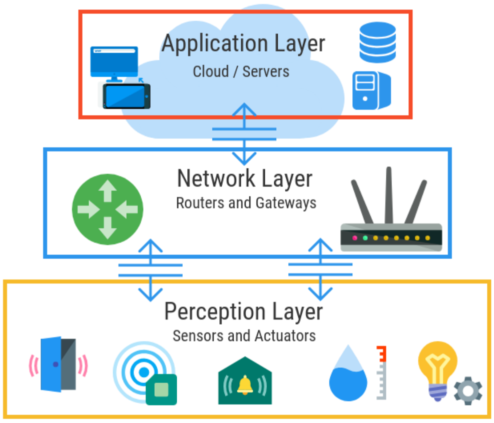

Fig. 4. The Fundamental Three Layer IoT Architecture [8].

III. Methodology

The proposed system is developed based on the IoT architecture, which comprises three components: a perception layer, a network layer and an application layer. Two types of prototypes using different communication technology are developed, GSM and Wi-Fi [9]. GSM was used to simulate the resident area without a WiFi connection. The details of the system development and data acquisition are presented and discussed.

A. System IoT Architecture

The proposed system's (Fig. 5) perception layer focuses primarily on the part of the device's hardware that includes design, components, circuit design and algorithms. IoT platform, Adafruit is used in the application layer for data visualisation after the acquisition process. The network layer acts as the connector between the perception layer and the application layer using GSM and NodeMCU communication technology along with their respective network protocol. The developed system concentrates on the condition of the water level where the water pressure is measured using the developed device.

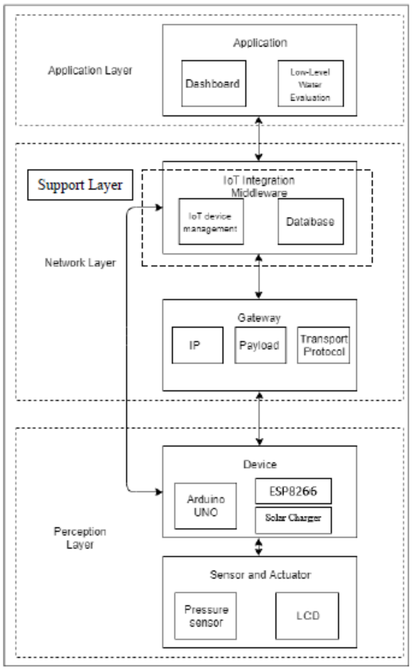

Fig. 5. Project Proposed System Architecture.

B. Perception Layer

Fig. 6 illustrates the prototype design with Arduino Uno. The Arduino Uno board is selected as the board is programmable and the price of the board is inexpensive. Arduino IDE provides easy programming via Type-B USB connector. The water pressure sensor G1/4 1.2MPa plays a role in measuring the water pressure. The sensor will measure the pressure value once the water flows through the attached pipe. GSM and NodeMCU served as communication technology. The collected data will then be transmitted and visualized on the IoT platform.

There is also an easy on-site view of the data via the liquid crystal display (LCD). A 16x2 Inter-Integrated Circuit (I2C) LCD was chosen on account of its compatibility with the Arduino board. The LCD component acts as the display for the reading gathered from the sensor. A stackable solar charger shield is used as an energy harvester for in-field charging in cooperation with solar panel and lithium-ion battery. The maximum current provided by the board can be up to 600mA. The prototype operates with 3.7V and 4.8AH lithium-ion batteries. The battery had a parallel connection. Parallel connectivity increases battery capacity from 4.8AH to 19.2AH.

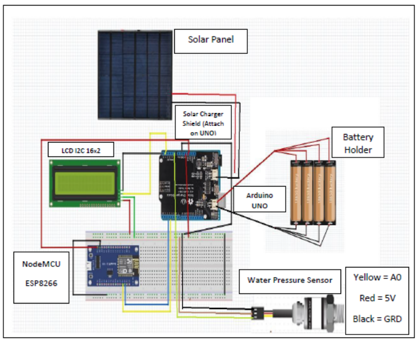

Fig. 6. Prototype Design.

C. Network Layer

The WiFi module is an important element in the developed IoT device. The Wi-Fi module, ESP8266 NodeMCU establishes communication with the current device in order to send the collected data to the IoT platform. This NodeMCU Wi-Fi has built-in Transmit/Internet Protocol (TCP/IP) protocol stacks that connect the microcontroller to the Wi-Fi network. Both components communicate using a Universal Asynchronous Receiver Transmitter (UART) method. NodeMCU acts as the Sender while the Arduino UNO is the Receiver. The data transfer to the application layer of this serial communication using Message Queuing Telemetry Transport (MQTT) communication protocol.

D. Application Layer

The application layer is developed using off-shelf IoT platform, Adafruit IO [10]. A lots of built-in features enable to real-time management, monitoring, storing and analyses on the data. As a cloud server, Adafruit IO provide useful feature such as dashboard user interface which enable the monitoring of the water pressure level.

Fig. 7. Application Dashboard.

IV. Result and Discussion

The study is still in the preliminary stage and yet this pilot test was conducted on data collection and analysis and therefore significant preliminary results were obtained.

A. Data Acquisition

The Fig. 8 shows the data acquisition process. The water pressure sensor was connected to the pipe to obtain the water pressure reading. An analog pressure gauge was also used to manually measure the data. The result is used for data validation to prove the reliability of the developed water pressure measurer. Both prototype and analog gauge show two different readings. The discussion will be discussed in the section below.

Fig. 8. Data Acquisition.

B. Result Reliability Testing

Fig. 9 shows the water pressure measurement obtained from the prototype and analog gauge. Both prototype and analog gauge showing 0 bar and 0.17 bar respectively during the measurement while there is not water in the pipeline. Three types of measured water pressure data were visualized in the graph: prototype data, analog gauge data and calibrated data. The graph shows that the data obtained from the prototype and the analogue gauge are about the same with an error range close to 0.1 bar. The results have shown the reliability of the prototype device.

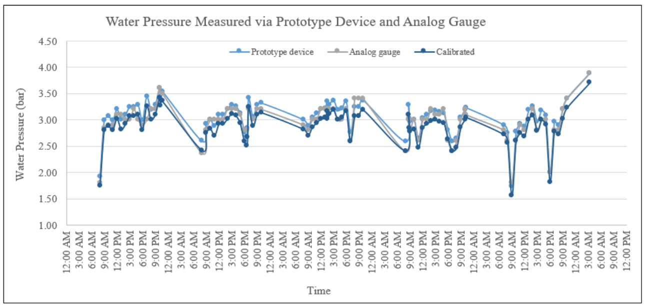

Fig. 9. Water Pressure Validation.

C. Water Pressure Pattern

Fig. 10 shows the water pressure variation taken at two different places in urban areas. Two datasets were collected from the first location, and four datasets were collected from the second location. Each data set is 24 hours in duration.

The graph visualized the drop in water pressure in the morning, before 9am and in the late evening, after 5pm. Water pressure increased after 10:00 in the morning and after 8:00 during the night. The first location reported the lowest water pressure level of 0.17 bar and the highest water pressure level of 1.12 bar. The second location reported the lowest water pressure level of 1.56 bar and the highest water pressure level of 3.24 bar. None of these areas experienced water shortage at these low water pressure levels.

Water pressure increases during the day, while most residents are at their worksite. It also shows an increment during bedtime. In conclusion, the day-to-day activities of residents affect the increase and decrease in water pressure.

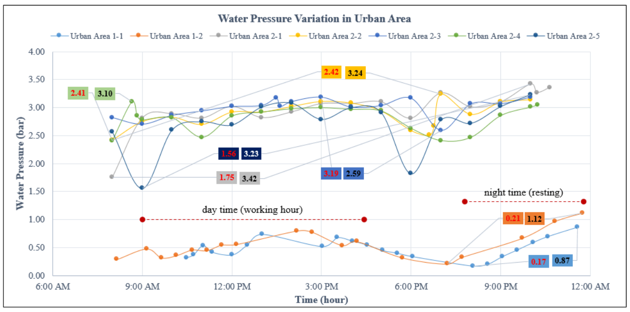

Fig. 10. Water Pressure Variation in Urban Area.

V. Conclusion

The study shows that with the application of IoT technology in local utilities, the residents' living standards can be improved. The IoT application provides real-time monitoring to enhance the water supply service. The duration of the utility issue will be addressed in a nutshell. Real-time monitoring of water pressure can help authorities find efficiencies and increase profits. The study will be continued to make the system more comprehensive.

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References

[1] Low water pressure hits high-rise residents hard. (2019, September 19). *TheStar*. https://www.thestar.com.my/metro/metro-news/2019/09/19/low-water-pressure-hits-high-rise-residents-hard

[2] Xu, F., & Ma, T. (2019). Modeling and Studying Acceleration-Induced Effects of Piezoelectric Pressure Sensors Using System Identification Theory. *Sensors*, 19(5), 1052.

[3] Ridley, A. M., & Burland, J. B. (1993). A new instrument for the measurement of soil moisture suction. *Geotechnique*, 43(2), 321-324.

[4] Rosli, N., Aziz, I. A., & Jaafar, N. S. M. (2018). Home Underground Pipeline Leakage Alert System Based on Water Pressure. *2018 IEEE Conference on Wireless Sensors (ICWiSe)*, pp. 12-16.

[5] Avnet Abacus (2021). *Pressure sensors: The design engineers guide*. Avnet Reach Further.

[6] Guidance Leafet (2010). Reducing water use-pressure, pipework and hoses. https://silo.tips/download/pressure-pipework-and-hoses. Accessed 20 Jun 2021.

[7] Saadeh, H., Almobaideen, W., & Sabri, K. E. (2017). Internet of Things: A review to support IoT architecture's design. *IEEE 2017 2nd International Conference on the Applications of Information Technology in Developing Renewable Energy Processes & Systems (IT-DREPS)*,pp. 1-7.

[8] Rahimi, H., Zibaeenejad, A., & Safavi, A. A. (2018). A novel IoT architecture based on 5G-IoT and next generation technologies. *2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)*, pp. 81-88.

[9] Horak, R. (2007). *Telecommunications and Data Communications Handbook*. John Wiley & Sons.

[10] Kodali, R. K., & Mahesh, K. S. (2016). A low cost implementation of MQTT using ESP8266.*IEEE 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I)*, pp. 404-408.