IoT-Sustainability Protection:Water Level MonitoringWith Micro Leak Detection and AutomaticWater Restoration

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***Abstract*—Efficient water resource management stands as a linchpin for sustainable development initiatives worldwide. To this end, this work endeavours to pioneer a comprehensive water level monitoring system with a focus on leak detection and automatic water restoration. Tailored with specialized sensors with cutting-edge automation technology to monitor water levels against predefined thresholds, promptly triggering restoration processes when necessary and identifying leaks in real-time. Central idea of the design is the incorporation of a dedicated rain sensor module, bolstering the micro leak detection capabilities while an ultrasonic sensor ensures precise measurement of water levels in tanks. In the event of a detected leak, rain sensor promptly initiates a signal, process by the main board which also known as the "brain" of the system and triggers an automatic cessation of water input to prevent wastage. Moreover, the system ensures seamless data logging by uploading pertinent information to a dedicated IoT cloud database, facilitating comprehensive monitoring and analysis. This innovative solution underscores not only its viability but also its practical efficacy, showcasing its potential to optimize water utilization and conservation efforts. Specifically, it excels in detecting micro droplets indicative of leaks in the tank. This work aims to spearhead the development of an advanced water level monitoring system, leveraging state-of-the-art of Arduino hardware and a diverse array of sensors, including ultrasonic and rain sensors as well as presenting a holistic framework poised to revolutionize water management practices.**

***Keywords*— water level monitoring system; NodeMCU ESP8266; Internet-of-Things**

I. Introduction

In line with Industrial Revolution 4.0 (IR4.0) and revolution of wireless technology, Internet of Things can address the limitations of traditional water monitoring methods, which presents a promising solution. According to IBM, the Internet of Things (IoT) is a collection of network of devices, vehicles or appliances that are equipped with sensors, software, and network connectivity, allowing them to collect and exchange data [1]. With IoT revolving around the world, any smart devices such as smartphones can be used to create a wide interconnected network between devices which can perform various tasks autonomously such as monitoring environmental conditions in farms, managing traffic patterns with smart cars and other smart automotive devices, controlling machines and processes in factories and tracking inventory and shipments in warehouses [1].

In the context of water management, IoT devices can offer real-time monitoring of water levels, usage, and quality across different sectors. These devices come in various forms, including smart sensors, meters, and actuators, which can be deployed in residential, agricultural, and industrial settings. Smart meters, for instance, can accurately measure water usage and transmit data wirelessly, enabling timely insights into consumption patterns and potential leaks. Additionally, IoT-enabled actuators can automate responses to detected issues, such as adjusting water flow or alerting maintenance teams. With the incorporation of IoT, it can enhance people's productivity as it can provide an analytical and statistical report which can be accessed anywhere regardless of their location. This work proposes a system that focuses on monitoring water depth in a tank that has a capability of detecting micro leaks and restoring water automatically. This system uses specialized sensors: ultrasonic and rain module. Integrated with cloud computing technology to provide system's insights and dynamic data that are changes over time.

This paper is arranged as follows: Section I outlines the concept and purpose of the water level monitoring system. Section II anchors on the study and implementation of existing water level monitoring systems. Section III explains the proposed system. Section IV presents the results of the proposed system. Lastly, section V summarizes and concludes this paper.

II. Literature Review

A. *Statistic of IoT Connected Devices Worldwide*

It has been roughly three decades since the first IoT technology was introduced. Several sectors have implemented IoT systems to enhance their productivity and economic growth. Figure 1 below shows the numbers of connected devices gathered from 2022 to 2024 in which IoT has become a need in today's life especially in water management. Tranforma Insights predicted that in the later years reaching 2030, there should be around 40 billion devices embedded in IoT frameworks.

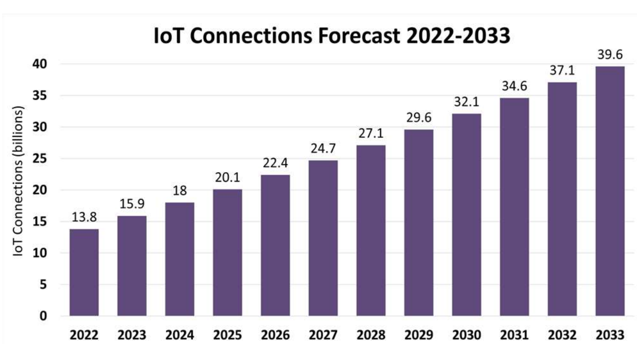

Fig. 1. Prediction of IoT connections from year 2022 to 2033 [2].

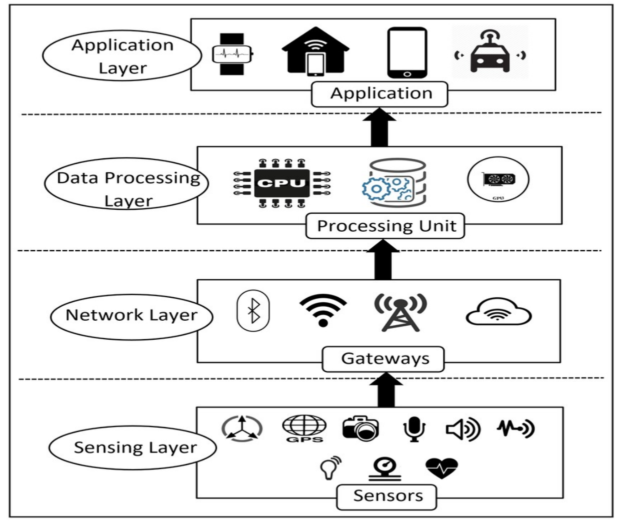

Fig. 2. IoT Architecture and Components [3].

B. *IoT Architecture and Component*

Predominantly, IoT connected device can be described as a device that consists of hardware, software, network connectivity and actuators. By this mean, it comprises four considerable layers which are sensing, network, data processing and application layers (as shown in Figure 2).

1) Sensing layer

This layer typically involves sensors which are used to monitor various systems. It offers sensing environmental changes, patterns and system performance. There are various kind of sensing technology available: humidity, temperature, turbidity, pH level, light intensity, and sound sensors. All these sensors are usually integrated through sensor hubs. Sensor hub is commonly known as connection point for multiple sensors that gather and transmit data acquired from sensors to the central processing unit of a device [3]. A sensor hub offers several mechanisms (Inter-Integrated Circuit (I2C) or Serial Peripheral Interface (SPI)) for data flow between sensors and applications [3].

2) Network layer

Network layer is essential in IoT technology where it handles the communication process whenever connections are established by transmitting packets back and forth between two different networks. In IoT devices, the network layer is implemented by using diverse communication technologies (e.g., Wi-Fi, Bluetooth, Zigbee, Z-Wave, LoRa, cellular network, etc.) to allow data transmitted between other devices within the same network [3]. Not only limited to private networks, it has the capability to extend its connectivity by integrating with some others mechanisms such as centralized server and hosted to the public network. Thus, allowing users to monitor and keep track of changes and data received from the sensors remotely.

3) Data processing layer

The processing layer is responsible for transforming the data so that it can be stored in the correct data model. Transforming data streams need to have a robust mechanism to process data in real time and much more efficiently. That is where it comes to cloud computing. Cloud computing offers greater flexibility and scalability, enabling a variety of services for IoT systems including information storage options, software analysis tools and the core infrastructure as well as the suitable platform for the development [4].

4) Application layer

Application layer refers to the highest level of the IoT protocol stack. This layer is responsible for enabling communication between IoT devices and applications or services that utilize the data generated by these devices. Inside the IoT world, current developed applications are first focused on monitoring the environment and acting as an information panel in which the user can read in real time, the values of the different sensors of the system, such as the inside temperature, power usage, and outside luminosity [5].

C. Cloud Computing Technology

Cloud computing is a model for delivering and consuming computing resources over the internet on an on-demand basis. Instead of owning physical hardware and managing software applications locally, cloud computing allows users to access and utilize resources such as servers, storage, databases, networking, software, and other computing services from cloud service providers. Cloud computing is a method that incorporate computing services such as servers, storage, databases, networks, software, and processing intelligence over the internet as depicted in Figure 3. It preserves the need for individuals to manage physical resources themselves and requiring them to only pay for what they need to use [6]. Cloud architecture majorly participate in the backend process which comprises various cloud services models, generally like: Infrastructure-as-Service (IaaS), Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS). IaaS is a traditional cloud computing model where a cloud provider supplies all necessary components including servers, network hardware, storage and virtualization technologies within data center [7]. For SaaS, it is a model where software applications hosted by third-party provider ensuring maintenance and updates as well as made available to clients over the internet [7]. Similar to SaaS, PaaS allows developers to focus on building and deploying applications while benefiting from scalable resources, automated updates, and integrated development tools [7]. This enables the creation and deployment of customised applications, databases and business services which can all be integrated into one platform for any SME and large enterprises.

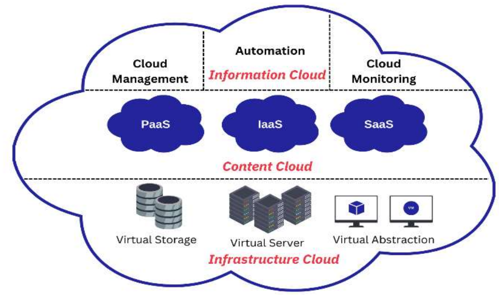

Fig. 3. General Architecture of Cloud Web Services [7].

D. Microcontrollers

Microcontroller is a hardware (integrated circuit) designed to govern a specific operation in an embedded system. The way of microcontroller operates is by receiving data and information from I/O interfaces, processing it in the CPU, and then transmitting signals to control the device. Table 2 list several types of microcontrollers that are commonly used in IoT development.

III. Methodology

The development of this work fused the concept of IoT technology, software engineering and electronic engineering resulting a resolute innovation of water level monitoring. In conjunction to the utilization of IoT technology, it revolutionized conventional water level monitoring practices, pioneering to elevate efficacity of both user and the flow of the system. The development of IoT prototype shows paramount significance in lining up the procedures of monitoring water level and detecting water leakage.

TABLE I. Types of Microcontrollers

Microcontroller	Description	Benefits
Arduino UNO	The Arduino Uno is a microcontroller board that utilizes the ATmega328P (datasheet). It features 14 digital input/output pins (with 6 capable of functioning as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header, and a reset button.	1. Cost-effective 2. Beginner friendly 3. Have community support 4. Not supporting Wi-Fi capability
Raspberry Pi	Raspberry Pi is a mini-sized computer that can be operated in Linux Operating System. Raspberry Pi provides a range of General-Purpose Input/Output (GPIO) pins, enabling users to connect and manage various devices and peripherals. Its versatility makes it a popular choice for IoT projects, as it can accommodate a wide range of applications and projects.	1. Deployed in LinuxOS 2. High learning curve 3. Expensive
Particle The Photon 2	The Photon 2 is a Wi-Fi module designed for development purposes, featuring a built-in microcontroller and Wi-Fi networking capabilities.	1. Supports 2.4 GHz and 5GHz Wi-Fi 2. Large RAM 3. High efficiency for

		large processing
NodeMCU ESP8266/32	The NodeMCU ESP8266 is an open-source development board widely employed in Internet of Things (IoT) projects. It can be programmed using the Arduino IDE, making it accessible to a broad range of developers.	1. Affordable 2. Offers Wi-Fi connectivity 3. Available with GPIO pins

IoT prototype allows to test new ideas and concepts in a real-world environment, paving the way for innovation by exploring new methods to connect devices, acquire data and automate processes. The integration of IoT components and devices simplifies the ability to keep track, monitor and gather data instantaneously. This prototype offers two features: a water depth monitoring system and a leakage detection system. The adoption of IoT technology facilitates the ability to measure water depth, elevating maintainability as well as offering preventive measures by leakage detection system unconditionally. Shown below (Figure 4) the flow of the system's algorithm. Fig. 4. shows the system include a few major components: NodeMCU Lua V3 ESP8266 WIFI, Rain Sensor Module and 3V-5.5V SR04P Ultrasonic Ranging Module. NodeMCU module act as the "brain" of the system where it processes all information received from the sensors (ultrasonic).

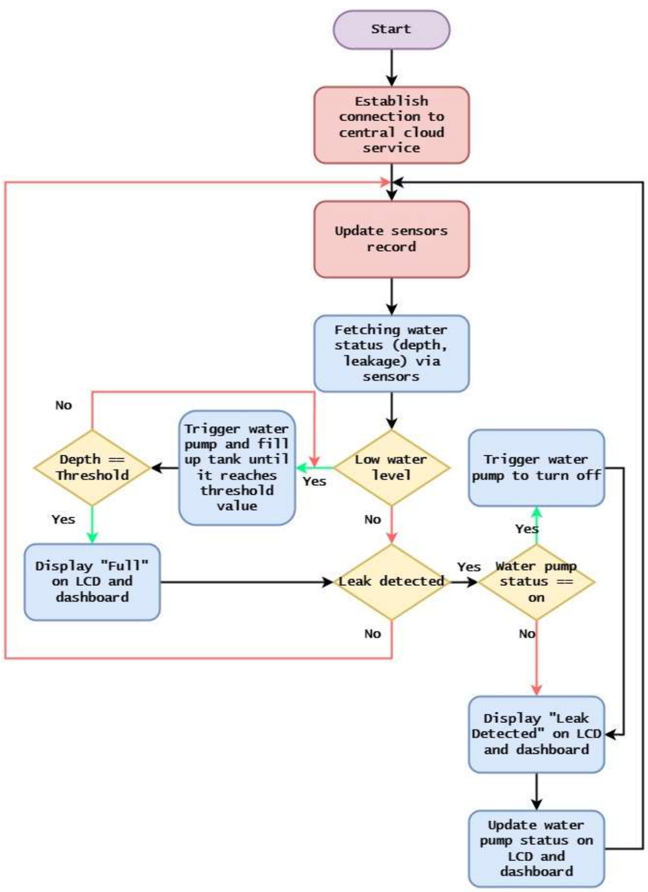

Fig. 4. System Flowchart.

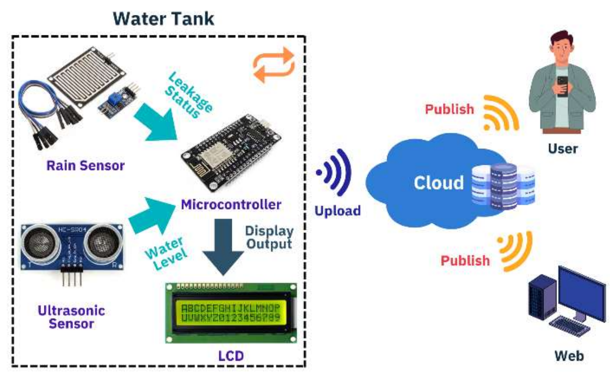

Fig. 5. System Block Diagram

and rain module) and translate the analog signal which then will be encapsulated into digital format. NodeMCU module is one of the available microcontroller where it is the core element where it contains a processor core (integrated CPU), memory (small amount of RAM and/or program memory) and programmable peripherals that handle input and output of the system [8]. Ultrasonic sensor, key component of the system, where it functions to sense the depth of the water inside the tank by resonating frequencies back and forth to the surface of the water and send the signal to the central processor to be processed. Ultrasonic transceiver generates ultrasonic pulses (high-frequency sound waves) and propagate through air which then it determines the water surface's depth based on total Time of Flight (TOF) measurement of the reflected wave [9].

LCD panel outputs the status of the system: current water depth and the tank condition via rain module sensor. The system begins by establishing a connection between the centralized IoT module and the central cloud service. This is a crucial step in the IoT framework as it ensures the transmission and exchange of data between the MCU module and the cloud, keeping the sensor records updated in real-time. Once the connection is successfully established, the sensors (ultrasonic and rain modules) simultaneously fetch data on water depth and leakage as well as displaying output onto LCD and dashboard.

IV. Results and Discussions

A. Design of Experiment

Figure 6 shows the experimental design of water level monitoring with micro leak detection capability. This design uses 1L container as a tank to analyze the behavior of the system based on water level.

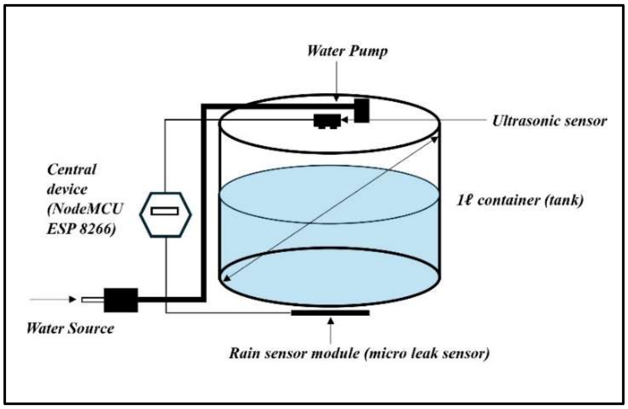

Fig. 6. Design of Experiment Using 1L Container.

TABLE II. WATER PUMP CUTOFF UNDER NORMAL AND LEAK CONDITION

Water Level (ℓ)	Water Pump Status		Water Pump Status (Leakage Based)			
			Detected		*No Leakage*	
	On	***Off***	***On***	***Off***	***On***	***Off***
0.0	/			/	/	
0.2	/			/	/	
0.4	/			/	/	
0.6		/		/		/
0.8		/		/		/
1.0		/		/		/

Table II describes the behavior of the system based on water depth measured in (ℓ). Water pump status shows that under normal condition (without leaking event), the water pump will remains on until the water level reaches 0.4ℓ which is approximately 50% of the tank capacity. Consequently, 50% is the cutoff value (threshold) of the system. Under leaking condition, the system's behavior changes dynamically. The system will thereby automatically stop water input regardless of water depth upon detecting micro droplets on the rain module sensor.

B. AutoDesk Fusion

AutoDesk Fusion is a computer-aided designing software that offers capability in 3D-modelling, PCB designing, and industrial designing. This software was used to design a case of the system to encapsulate all the main components like NodeMCU, battery holder, LCD and relay. Fig. 6 has shown the dimensions of the case. For Fig. 7, the designs of the cap are displayed.

C. Development of Prototype

The prototype of the monitoring system are demonstrated in Fig. 8. Fig. 8A presented the exterior view, meanwhile Fig. 8B displayed the interior of the prototype. The sensors: ultrasonic, rain module located outside of the case to monitor the depth of the water and detect any leakage present.

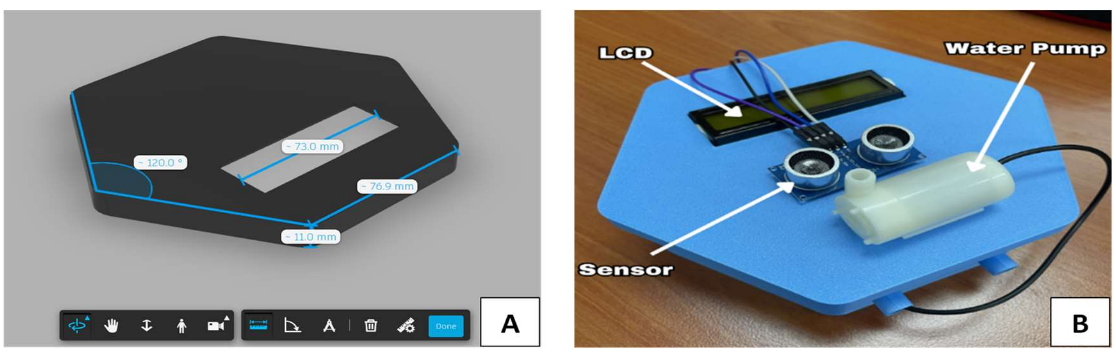

Fig. 7. (A) Structure and Measurement of Case Design (B) Top View of Case Design.

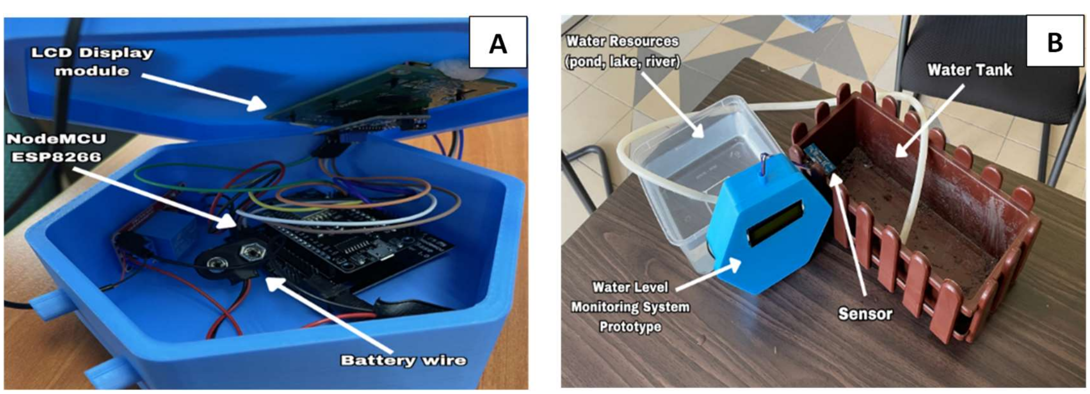

Fig. 8. (A) Exterior and Interior of the Prototype (B) Design of Experiment of the Prototype.

When the rain module senses any droplet of water (indicates leakage) it will trigger the water pump to stop the pumping process immediately if the system is currently restoring water into a tank. LCD will display the condition of the system including water pump status: On, Off as well as water level: High, Medium, Low, Very Low.

D. Programming

C language has been chosen as the basis for developing the system as it offers many libraries that can be utilized based on requirements which enables the ability of customization to realize the expected outputs. The example of coding were presented in Fig. 9 which signifies a written code sample for water level monitoring.

```
if (Level1 <= distance) {
  lcd.setCursor(8, 0);
  lcd.print("Very Low");
  lcd.print(" ");
  if (raindrops() == "No Leak Detected.") {
    digitalWrite(relay, LOW);
    lcd.setCursor(0, 1);
    lcd.print("Pump is ON ");
    Blynk.virtualWrite(V3, HIGH);
    lcd.print("                ");
    delay(1500);
    lcd.setCursor(0, 1);
    lcd.print(raindrops());
    lcd.print("                ");
    delay(1500);
  } else if (raindrops() == "Leak Detected!") {
    digitalWrite(relay, HIGH);
    lcd.setCursor(0, 1);
    lcd.print("Pump is OFF ");
    Blynk.virtualWrite(V3, LOW);
    lcd.print("                ");
    delay(1500);
    lcd.setCursor(0, 1);
    lcd.print(raindrops());
    lcd.print("                ");
    delay(1500);
  }
}
```

Fig. 9 Sample of C Code for Water Level.

This work success serves as a catalyst for promoting the Sustainable Development Goals (SDGs), with advantages on both global and individual scale. By embracing the SDGs, it raises global living standards while encouraging sustainable practices, increasing resource efficiency, boosting job creation, and developing different business opportunities, all while adhering to the essence of the 8th SDG (Decent Work and Economic Growth). Though, the system is not necessarily focus on monitoring water tank, the pattern or algorithm of this system may be implemented at several areas that holds a large capacity or volume of water for example like water dam. With that, this work contribution to Early Warning and Disaster Prevention is in line with SDG 13 (Climate Action), since it provides timely alerts on rising water levels to decrease flood risks in susceptible areas. Furthermore, it strengthens Water Supply Management, a critical step towards achieving SDG 6 (Clean Water & Sanitation) by ensuring continuous supply of clean water to consumers. Moreover, its capacity to detect tank and pipeline issues speeds up repairs, reduces costs, and supports robust infrastructure planning, aligning with SDGs 9 and 11.

V. CONCLUSION

With the existence of the Internet of Things, it enables the innovation of new ideas, especially in water level monitoring, by providing real-time data collection, remote access, and automated alerts, thereby enhancing efficiency and accuracy in managing water resources and preventing wastage. Cloud computing makes the record easy to store, manage, and process large amounts of data, offering scalable resources, enhanced collaboration, and reduced costs for businesses and individuals alike. Automated mechanism facilitates better management as well as increase user's productivity and saving cost by utilizing IoT components

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REFERENCES

[1] "What is the Internet of Things (IoT)? | IBM." Accessed: Apr. 19, 2024. [Online]. Available: https://www.ibm.com/topics/internet-of-things

[2] "Current IoT Forecast Highlights - Transforma Insights." Accessed: May 01, 2024. [Online]. Available: https://transformainsights.com/research/forecast/highlights

[3] A. K. Sikder, G. Petracca, H. Aksu, T. Jaeger, and A. S. Uluagac, "A Survey on Sensor-based Threats to Internet-of-Things (IoT) Devices and Applications." arXiv, Feb. 06, 2018. Accessed: May 01, 2024. [Online]. Available: http://arxiv.org/abs/1802.02041

[4] N. M. Kumar and P. K. Mallick, "The Internet of Things: Insights into the building blocks, component interactions, and architecture layers," *Procedia Comput. Sci.*, vol. 132, pp. 109–117, 2018, doi: 10.1016/j.procs.2018.05.170.

[5] D. Sembroiz, S. Ricciardi, and D. Careglio, "A Novel Cloud-Based IoT Architecture for Smart Building Automation," in *Security and Resilience in Intelligent Data-Centric Systems and Communication Networks*, Elsevier, 2018, pp. 215–233. doi: 10.1016/B978-0-12-811373-8.00010-0.

[6] "What is Cloud Computing?," Google Cloud. Accessed: May 02, 2024. [Online]. Available: https://cloud.google.com/learn/what-is-cloud-computing

[7] G. A. Oguntala and R. A. Abd-Alhameed, "Systematic Analysis of Enterprise Perception towards Cloud Adoption in the African States: The Nigerian Perspective," vol. 9, no. 4.

[8] Faculty of Electrical Engineering, Universiti Teknologi Mara, Cawangan Johor, Kampus Pasir Gudang, Johor, Malaysia and E. Al. Hasan, "Development of university public transport monitoring system with mobile communication application," *Int. J. Adv. Appl. Sci.*, vol. 4, no. 7, pp. 141–146, Jul. 2017, doi: 10.21833/ijaas.2017.07.021.

[9] E. Prayetno, T. Nadapdap, A. S. Susanti, and D. Miranda, "PLTD Engine Tank Oil Volume Monitoring System using HC-SR04 Ultrasonic Sensor Based on Internet of Things (IoT)," *Int. J. Electr. Energy Power Syst. Eng.*, vol. 4, no. 1, pp. 134–138, Feb. 2021, doi: 10.31258/ijeepse.4.1.134-138.