IoT Motion Detection Sensors for Monitoring in a Smart Campus

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***Abstract*—This paper presents the study of the monitoring of student attendance in a Smart Campus using the IoT Motion Detection Sensors, and the implementation of IoT technology in educational institutions. The proposed solution is far more secure than the existing RFID monitoring system. The IoT devices are embedded into the existing campus environment for data to be collected, transmitted through Wi-Fi using MQTT protocol and store data in local server. The collected data is then accessible to the management with real time insights and attendance pattern. The proposed solution was tested in a one UG course in real time over a period of 8 hours (9:00 – 13:00 and 14:00 -18:00).**

Keywords—Internet of Things (IoT), RFID, MQTT, classroom occupancy, smart campus.

I. Introduction

The recent growing advancements in technology and increase in computational power pose a serious threat to the security of user data. The Internet of Things can be implemented to eliminate cyber security risks to a certain level and also to make better use of the available resources to improve the quality of service. Universities are under pressure to make better use of their available resources due to the rising demand for higher education. Even though IoT system development and implementation are very popular in education institutions, there is a concern that security is still not given enough consideration. Universities are adopting creative solutions in today's rapidly evolving technology landscape to protect the security of data and replace traditional methods with more cost-effective IoT solutions.

As of 2025, more than 30 billion devices will be connected to the internet. While 5G rolls out at neck-breaking speed, the resulting evolution in communications will bring the world a faster, smarter future. By the estimation of 5G Americas and analyst firm Omdia, 5G is on track to hit 8 billion connections by 2028, at its ten-year mark—exceeding LTE's 10-year connection total by more than 2.5 billion.

With the help of the wide arrays of devices connected over the internet, IoT has greatly transformed sectors such as agriculture, healthcare, entertainment, and education [1]. As a result of the increased data connectivity, communication has reached a significant level, which has had enormous practical advantages. These devices can monitor and control their environment with the help of real-time data inputs from several other interconnected devices. The education sector has evolved from traditional blackboards to projectors and online presentation classes; similarly, IoT can catapult the evolution of the education sector. Even though IoTs are already being implemented in educational institutions, such as RFIDs to monitor attendance and provide access to the facility, the educational platform can still be improved by developing a smart environment to monitor and control certain tasks, which may increase security and make better use of resources. With the aid of IoT, academic staff may easily engage with remote students who are in different locations and control the instruction in smart classrooms using gestures, speech, and facial recognition. Additionally, they may automatically gather data from sensors, analyze analytics on student behaviors, interest, performance, and engagement, and collect feedback from students on their interests and the likeability of a teaching session [1]. Certain schools in China have already started using IoT devices to monitor and assess the emotions of the students, including their mood changes and their attention level. Which are processed and sent as feedback to the students and their caretakers. This method of using IoT to assess student's emotions and distress levels has been proven to improve their academic results. An Internet of Things (IoT) system enables data interchange across an extensive network and gives users management over connected as well as wireless devices. Through various communication interfaces, data may be gathered as input, stored in a computer system, processed, and utilized by other applications. Wirelessly linked devices provide users with the liberty to function over remote networks with more control, which improves overall productivity [2].

There are number of available approaches to count the number of students in a classroom, such as thermal imaging, ultrasound imaging, camera image processing, thermal imaging, and beam counters affixed to entryways [3], WiFi-based approach [4], and RFID-based attendance system [5]-[9]. Each approach has its own advantages and disadvantages across various dimensions such deployment, privacy, accuracy, cost, power, communications, and operations. For example, using camera-based image processing is computationally expensive, cameras endanger privacy, thermal and ultrasound imaging and WiFi data have low accuracy. Therefore, understanding both challenges and benefits of various approaches in order to adopt the most suitable methods is important for the real deployment of classroom occupancy monitoring system.

This paper describes our experiences in adopting Internet of Things (IoT) motion detection sensors to monitor the attendance of lectures in courses at our university campus in real time in a smart campus, process the data, present the processed data in a graphical format for easy interpretation, and compare the obtained result with the expected result. To determine its accuracy, the data will be collected over a period (2 x 4 hours) and then compared to the number of students enrolled in the classes. Section II. will describe the IoT system design and architecture. Some experimental results will be presented in Section III.

II. IoT System Design and Architecture

A. IoT System Architecture

The IoT based attendance system includes hardware selection and setup, software design, integration of IoT required components within the existing infrastructure, and testing the proposed solution in real time. By integrating IoT components, we have developed a smart automated attendance system. The aim of this paper is to propose an IoT-based solution that is more secure than the traditional RFID based system. The IoT solution is developed in a cost-effective way using the below required components:

TABLE I. Components Required

Software components	**Hardware Components**
Gateway	Handset
Docker and Docker containers	Raspberry Pi 5
Mosquito (MQTT broker) protocol	Raspberry Pi Pico W IoT node
Influx DB	Micro PIR Motion sensor
Grafana	Breadboard
Node Red	

B. IoT System Implementation

As mentioned earlier, we have integrated the Raspberry Pi Pico W and Micro pir motion sensors together to collect, process, share, and store data. The IoT system is equipped with motion sensors integrated into a Pico W on a single-piece breadboard such as shown in Fig.1. The sensors are used to capture measurements such as student's motion.
The first stage involves storing the student's details, such as their allotted seat number, student registration number, scheduled classroom, and course timetable. Once the students are in their allotted seats, the motion sensor reading gets triggered. The sensor readings are then sent to the MQTT broker and stored in the InfluxDB datastore. The data can then be sent to the institution's backend server. The architecture of the IoT system is shown in Figure 1. The sensor data is collected by the first Pico W and is constantly published under the topic "sensor_mo_data" using the MQTT protocol. In real time, multiple sensors will be employed to collect attendance from multiple students i.e. desks. All the collected data will be published under topics (one per IoT node) using the MQTT broker connected via gateway microprocessor.

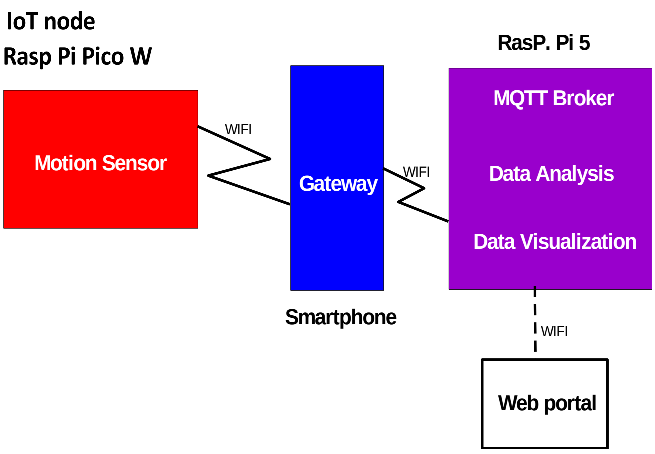


Figure 1. System architecture of monitoring

The sensor data must be sent to a MQTT broker for distribution to subscribers one of which is storing it in a database (InfluxDB). As mentioned earlier, we have used the MQTT protocol for communication as it allows publishing and subscription of topics over Wi-Fi. The MicroPython script mentioned above publishes the collected data under "sensor_mo_data". The MQTT (Eclipse Mosquitto) broker acts as a middleman to exchange the messages. It is responsible for streamlining the processing of incoming messages and sending them to appropriate receivers (subscribers). The sensor data is then transformed into a JSON string and marked with a timestamp and sensor ID using a MicroPython script that we created in order to standardise the data format.

We used the IoT Stack to build a Docker environment to install and run the tools required for the project including the MQTT broker (Mosquitto). The Docker environment is also used to host a database to store the collected data for further processing and visualisation. As mentioned earlier, we have used the InfluxDB database as it adds a timestamp to every entry, which is crucial when it comes to storing attendance data and provides us with a timeline for attendance. The IoT system setup shown in Figure 2. Includes handset (gateway), Rasp. Pi 5 (Docker), Raspberry Pi Pico W IoT node. The data received can be visualised for the students and the administrators to track their attendance with ease. The Node-RED tool is used to integrate all the nodes and connect MQTT to the database to data, also to debug the output values. The Grafana tool is used to visualise the output in user-interactive dashboards. The user can also view the data graph of each individual motion sensor measurement. The graphical interface of the tool can be accessed by navigating to the Docker server's IP along with the tool's protocol and port number.

Figure 2. System hardware

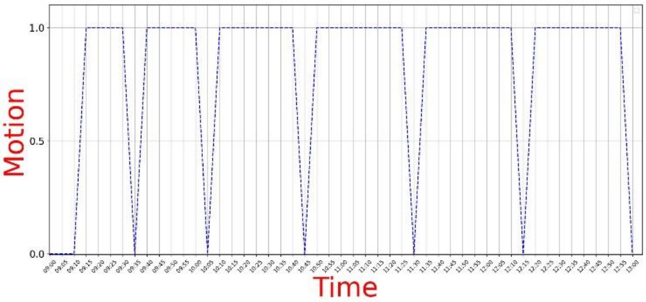
To make the controller with connected sensor functional, we utilized the MicroPython language through the Thonny IDE, and installed MQTT libraries in Thonny. The created code for Pico W is shown in Figure 3.

Figure 3. Python script

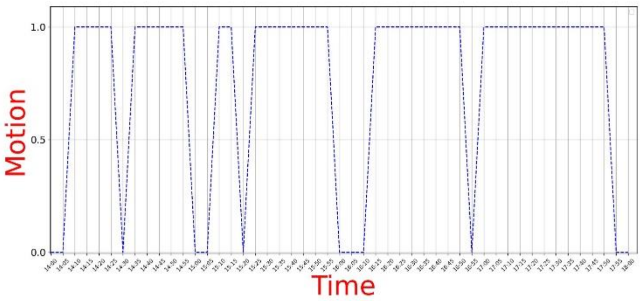
III. Results

The micro PIR (Passive Infrared) motion sensors collect data such as student's motion in the classroom – more specifically on their desk. The test was conducted in a simulated environment, we collected data student allocated data for one UG class and compared it with our simulated IoT results. We used classroom-type simulations to conduct the study. The number of students posed a challenge, as we required multiple sensors and input nodes to record attendance at a time. To eliminate the need for using multiple sensors for study, we calculated the motion sensor data over a period of time (2 x 4 hours), calculated the average data collected, and then compared it with the manually calculated attendance result. The data is collected over tone UG course periods that are approximately 4 x 60 minutes each.

The motion sensor is used to record attendance. Each graph represents real-time measurements from motion sensors without sacrificing time, student count, data readings. The motion vs. time slots (9:00 – 13:00 and 14:00 - 18:00) graphs for student 1 are shown in Figure 4a and 4b, respectively. Figure 5a and 5b show the motion vs. time slots (9:00 – 13:00 and 14:00 - 18:00) graphs for student 2. The Grafana application tool to provide data visualisation is used. The tool is used to plot real-time data and allows users to switch between different sensor readings. The tool allows the user to track participation pattern in a course and usage rate over various time periods by selecting the course dashboard tab. We saved the data we received from Grafana as a csv file and turned it into understandable graphs using the graph creation program, created in Python.

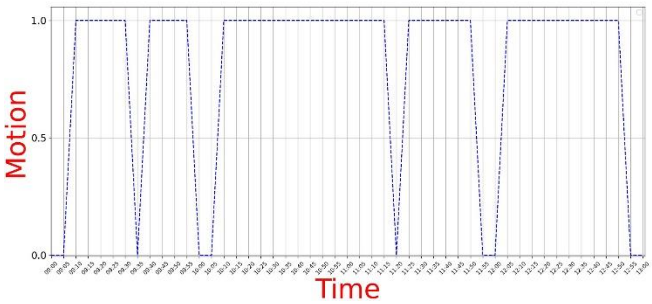


a)



b)

Figure 4. Student 1 Motion vs. Time slot a) 9:00 – 13:00 and b) 14:00 to 18:00



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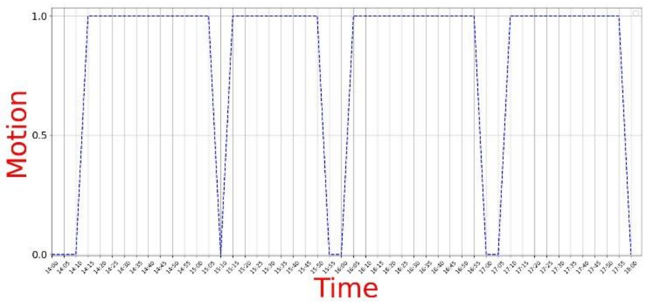

b)

Figure 5. Student 2 Motion vs. Time slot a) 9:00 – 13:00 and b) 14:00 to 18:00

IV. Conclusion

The monitoring of student attendance in a Smart Campus using the IoT Motion Detection Sensors, and the implementation of IoT technology in educational institutions has been presented in this paper. The IoT setup is composed of IoT motion detection sensors, Raspberry Pi devices (Rasp. Pi 5) and Rasp Pi Pico W. The IoT devices are embedded into the existing campus environment for data to be collected, transmitted through Wi-Fi using MQTT protocol and store data in local server. The collected data is then accessible to the management with real time insights and attendance pattern. A one UG course in real time over a period of two time slots (2 x 4) hours (9:00 – 13:00 and 14:00 -18:00) was tested.

Acknowledgment

This work was supported by a WIUT-UOW Research collaboration funded project under grant RCF2022-003.

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