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RESEARCH ARTICLE

In-Classroom Faculty Attendance Monitoring System based on Ultra High Frequency (UHF) Radio Frequency Identification (RFID) with Captured Image Cross-verification Mechanism

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Abstract

Objectives: Faculty attendance in schools are monitored based on Daily Time Record (DTR) which captures a daily time-in and time-out of teachers in and out of the school campus using various technologies and methods, however there is a scarcity of studies in monitoring faculty attendance in the actual bounds of the classroom. Hence, this study aimed to develop an In-Classroom Faculty Attendance Monitoring System based on Ultra High Frequency (UHF) Radio Frequency Identification (RFID) with captured image cross-verification mechanism. **Methods:** The system comprises two modules, namely the Teacher Attendance Module and Attendance Monitoring Web Application module. The Teacher Attendance Module, it is composed of a UHF-RFID reader and a camera module that is interfaced to the Raspberry Pi board. Passive tags are embedded on the teachers' ID cards for them to be uniquely identified by the UHF-RFID reader when they are within the 2-meter read distance. Meanwhile, the Attendance Monitoring Web Application module is developed using a PHP framework connected to a MySQL database. It aggregates the attendance data collected from the Teacher Attendance Module for monitoring purposes which is accessible to both the monitoring staff and teachers via a web browser. **Findings:** Based on the evaluation results, the proposed system received positive feedback from the end users in terms of its functionality and usability and was found to be more favorable over existing attendance monitoring systems. **Novelty:** The system provides a non-obtrusive way of checking teachers' attendance by utilizing the UHF-RFID technology which has a longer read range than other RFID categories used in previous studies. Moreover, unlike existing solutions, the system checks for attendance multiple times, not only during entrance and exit which then calculates the

total stay-in time of the teacher during a class session. Most importantly, the system can prevent fraudulent activities through a camera module.

Keywords: UHFRFID; Attendance; Faculty; Raspberry Pi; Camera

1 Introduction

While most educational institutions aim to provide quality education for students by ensuring they hire qualified and effective teachers and by providing state-of-the-art classrooms conducive for learning, another important aspect of quality education that has received little attention is teacher attendance. Regardless how engaging or talented teachers are, they can only have an impact on student learning if they are present in the classroom. Hence, in order to ensure that teachers are conducting classes, schools are assigning staff to make rounds and check for teachers' attendance. But as the student population grows, more teachers are hired and checking attendance of an overwhelming number of teachers becomes a challenge.

As a result, several attendance monitoring systems have been developed to alleviate this problem as it allows the calculation of the hours worked, particularly in cases of hourly employees, such as in the case of teachers.[(1)] Presently, most systems use Daily Time Record (DTR) logs to monitor daily time-in and time-out of teachers in the school campus using biometric sensors or mechanical Bundy clocks. However, there is not much research conducted in the monitoring of teacher attendance inside the actual bounds of the classroom.

Several studies have presented solutions relevant to the attendance monitoring problem, and they have used an array of devices and/or methods in pursuit of an efficient, dependable and cost-effective attendance monitoring system. One of the relevant studies is a biometric attendance system with online monitoring for a university system.[(2)] It utilizes a fingerprint scanner that will be installed in classrooms to verify student or faculty attendance using a unique fingerprint of every person. However, it is not cost-effective since it will need a fingerprint scanner and a laptop with certain specifications for every classroom setup and also needs direct contact to the device for identification.

In order to eliminate the need for direct contact with devices, many studies have taken advantage of the capabilities of RFID technology which does not require actual contact with any device for identification during the attendance monitoring process. It will just need an RFID reader to read RFID tags embedded in the teachers' identification cards within a specified read range. The read range depends on the frequency (Hz) in which they operate, the higher the frequency the wider the read range, the lower it is, the shorter the range. It does not also need to maintain line of sight alignment with each other because at any angle or even if there is obstruction in between, tags can still be read. But even though the vast majority of attendance monitoring solutions embodied in various studies utilized RFID technology, they commonly used the RC522 reader which has only 3cm read range with operating frequency of 13.56 Megahertz.[(3–7)] Given that specifications, it will require at least a tap to the reader for the tag to be identified. Moreover, one issue with using the RFID technology is the lack of security features to prevent fraud, which is emphasized in similar studies conducted on Internet of Things based smart attendance monitoring system using RFID.[(3–5)] and the prototype of college student attendance using RFID at Musamus University conducted by Putra et al.[(6)] The solutions they have presented were excellent in identifying RFID tags, however, when using RFID technology, you can only verify if the tag matches a record in the database but it cannot verify whether or not the cardholder is really the person associated with the tag in the database.

Aside from RFID technology other attendance monitoring systems used Bluetooth low energy (BLE) beacons for proximity sensing to transmit a universally unique identifier picked up by a compatible app installed on the teachers' smartphone. The teacher's attendance is recorded when his/her smartphone is within the range of the beacon inside the classroom.[8] However, it still does not have a mechanism to verify the holder of the smartphone and proxy attendance is very probable. To prevent fraudulent activities in attendance monitoring, the use of cameras for verification purposes was introduced. Some studies even took it to the next level by applying machine learning algorithms for facial recognition along with other integrative technologies such as QR code scanners[7,9,10]. But so far, the solutions presented do not clearly provide a concrete technical and methodical embodiment for implementation in the real world. One obvious reason is the limited capabilities of current IoT or mobile devices to run complex machine learning algorithms, particularly for facial recognition.

In summary, there have been several studies conducted, and have presented various technologies and methods to facilitate the checking of teachers' attendance in classes for the best interest of the students. By far, the application of Artificial Intelligence is the most promising method, but for now, the required expertise and resources outweighs its potential benefits and as far as the reviewed literature are concerned, there was no concrete technical and methodical embodiment for its actual implementation in the school setting. Other methods have achieved significant level of success in terms of checking attendance. However, none of them have provided an efficient, dependable, and cost-effective solution that could be implemented in the schools for monitoring teacher attendance in the actual bounds of the classroom in a non-obtrusive manner. Moreover, the previous studies only record a single time-in and time-out timestamp as the basis of teachers' attendance and have no way of verifying if the teacher is indeed in the classroom.

In this study, we present an In-Classroom Faculty Attendance Monitoring System using Ultra High Frequency (UHF) - Radio Frequency Identification (RFID) with captured image cross-verification mechanism to address the issues in the previous studies, such as the need for direct contact to a device to check attendance, the inability to monitor the total stay-in time of teachers in their classes beyond the entry and exit in the classroom and also the lack of verification mechanism to prevent proxy attendance. The system can provide an efficient and non-obtrusive way of monitoring faculty attendance by producing detailed and accurate attendance information, such as the calculated actual stay-in time of faculty within the bounds of the classroom and most importantly, the system employs a cross-verification mechanism to prevent fraudulent activities such as proxy attendance through a camera module. Finally, it is cost-effective for schools to implement this attendance monitoring system as it requires less hardware to operate and can be easily integrated to the existing school network.

2 Materials and Methods

2.1 System Design

2.1.1 System Architecture

The system comprises two modules, namely the Teacher Attendance Module and Attendance Monitoring Web Application module. The system runs over the existing intranet of the school, which means the system does not require internet connection to be operational. In Figure 1, it shows in detail the sub components of each module and their interconnection in the system architecture. For the Teacher Attendance Module, it is composed of a UHF-RFID reader and a camera module that is interfaced to the Raspberry Pi board. The school ID cards of teachers are embedded with passive UHF-RFID tags for them to be uniquely identified.

The UHF-RFID reader will constantly read for RFID tags embedded in the teacher's school ID within two (2) meters read distance in all directions, which is more than enough to cover the entire classroom. If the teacher is within the classroom premise during the scheduled class period, it will automatically log a time-in timestamp in the database. Otherwise, no timestamp will be logged. Multiple time-ins and time-outs are allowed within a class period in case the teacher comes in and out of the classroom. The duration between each time-in and time out will then be calculated and will be added up to get the total time spent by the teacher in a class schedule. In addition, the camera is programmed to capture images of the teacher at the start, in the middle, and at the end of the class. The captured images will be permanently stored in the central server and also save a local copy in the Raspberry Pi board but it will be automatically deleted before the next day to free up the memory.

For the Teacher Attendance Module to access the database it should be connected to the server preferably via a wireless network. Meanwhile, for the Attendance Monitoring Web Application module, it utilizes the teachers' time logs data stored in the database that was collected from the Teacher Attendance Module. The web application is also hosted within the same server running the MySQL Database and is accessible to both the attendance monitoring staff (Admin) and teachers via a web browser. It will not necessarily require the internet to access the web application if users are accessing it through the school's intranet but will require otherwise, if teachers attempt to access outside.

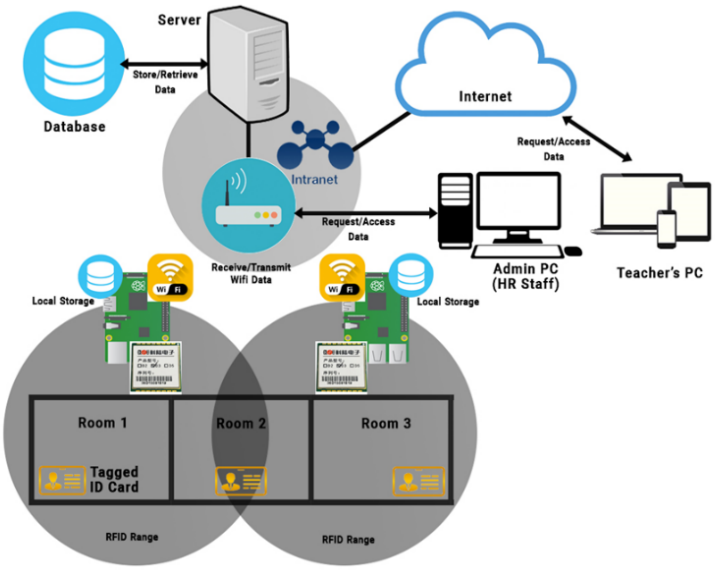

Fig 1. System Architecture

2.1.2 Circuit Diagram

The hardware components necessary in this study is the Raspberry Pi 3 Model B, Raspberry Pi Camera module and the UHF-RFID Reader. In order to make them work together the circuit diagram shown in Figure 2 was implemented. Firstly, the Pi camera module is connected in the camera port of the Raspberry Pi Board. Secondly, the UHF-RFID reader will then be interfaced to the GPIO 8 and GPIO 10, which are the UART_RXD and UART_TXD pins of the Raspberry Pi Board respectively. The Raspberry Pi board will need a 5V DC power source to operate which is taken from a continuous supply from the AC outlet or an alternative battery pack in case of power interruptions.

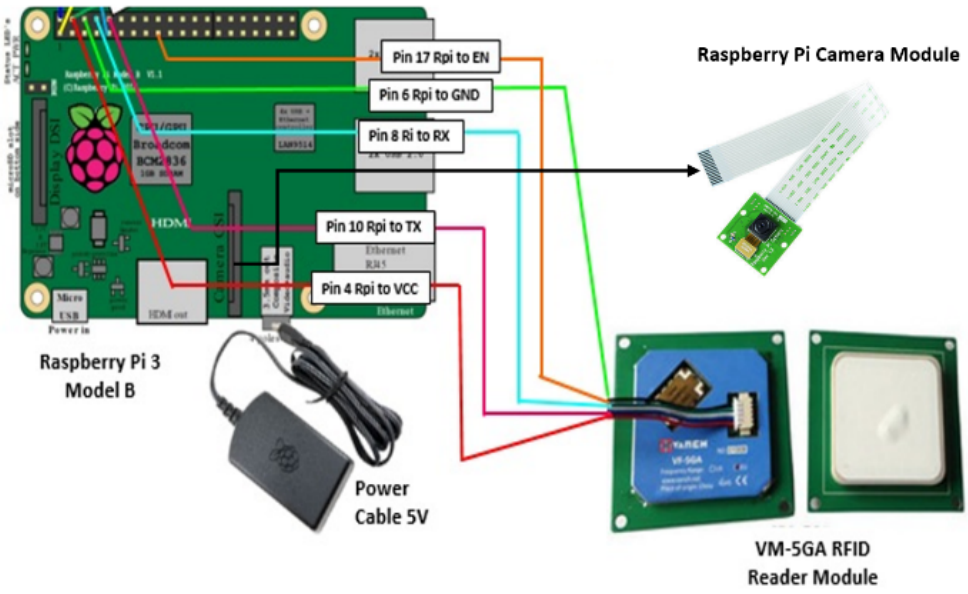

Fig 2. Circuit Diagram

2.1.3 System Flowchart

Figure 3 shows the flowchart of the system. The UHF-RFID reader is constantly checking whether there is a UHF-RFID tag that is within its range. Once there is a UHF-RFID tag detected, it will verify if it is the specific instructor's schedule. If yes, it will record the time-in timestamp of the instructor in the database. Otherwise, it will go back on detecting tags within the range of the UHF-RFID reader.

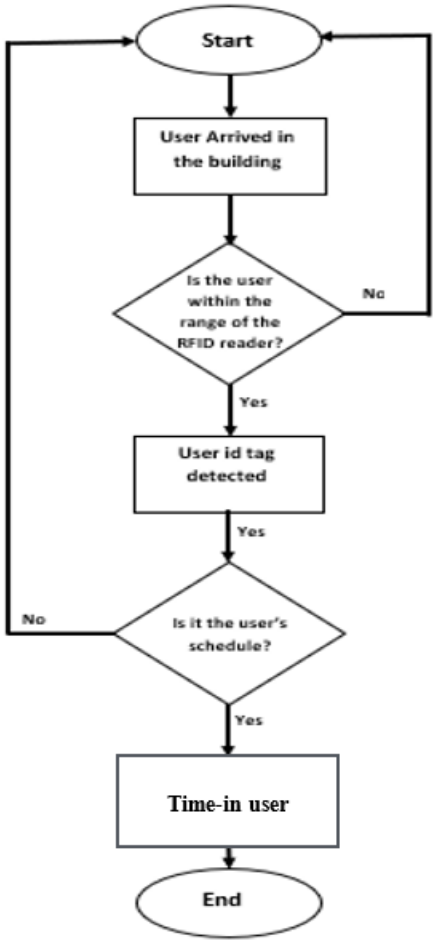

Fig 3. SystemFlowchart

2.1.4 Database Design

Figure 4 shows the Database Design of the system which is implemented using Relational Database Schema. The system database consists of eleven (11) tables where collected attendance data are stored. The stored data can be retrieved using Standard Query Language (SQL)for it to be accessible in the different parts of the web application. Only authenticated users are allowed to access the database to ensure data security. The database is intended to be replicated, which means it will be primarily on the central server but will also run on individual Raspberry Pi boards as local copies.

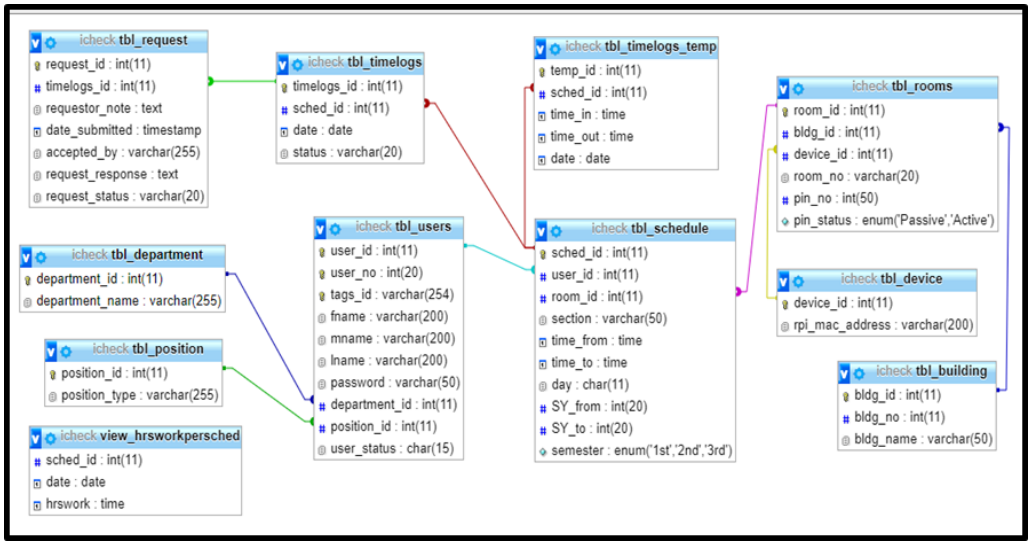

Fig 4. Database Design

2.2 Web Application Development

In order for the users to access attendance information recorded by the UHF-RFID Reader and Raspberry Pi Module, a web application was developed. A PHP framework is used in the development of the web application together with additional web technologies for developing responsive and interactive web applications. The system is accessible to only two (2) user groups, namely the Admin user group and Teacher user group. Essentially, for both user groups, access to the system is limited through the implementation of an authentication mechanism applied in the login page. Only authorized users will be granted access and it shall be redirected to the dashboard as shown in Figure 5 (a). Once a user is granted access and verified as admin, the admin user can manage users and resources in the system such as buildings, rooms, and devices as presented in Figure 5(b) and manage teacher requests and generate the report for a specific date range as presented in Figure 5(c). The admin user can also verify the teacher's presence in the class by viewing the captured image inside the classroom as shown in Figure 5(d). Meanwhile, the teacher user, when granted access, will be able to generate reports of individual time logs and monitor daily hours worked as shown in Figure 5(e) and Figure 5(f) respectively.

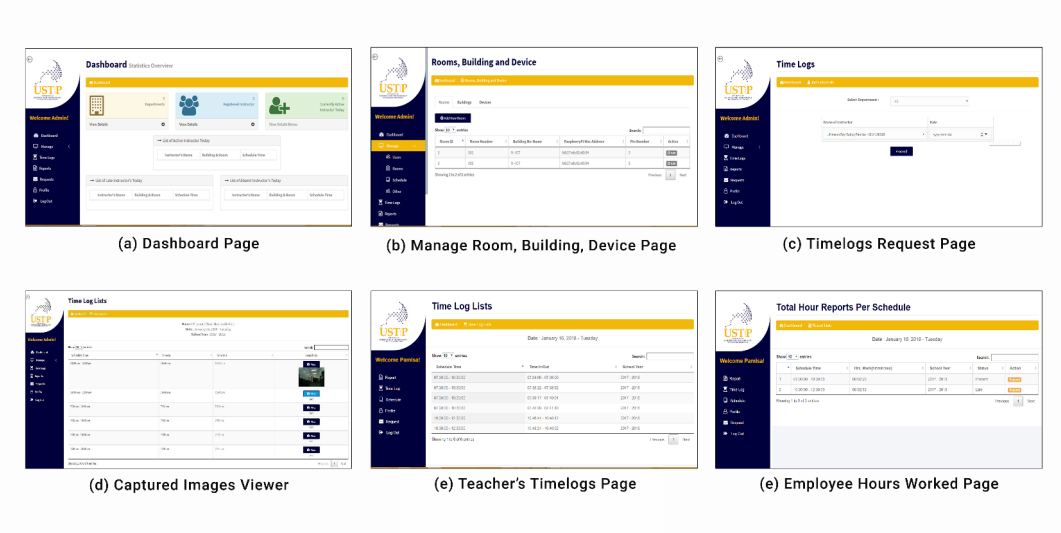

Fig 5. Web Application

3 Results and Discussion

3.1 Functionality Test

The correct reading of the RFID tags around the reader is of utmost importance for the system. Hence, it was tested to ensure that it is functional. Figure 6 shows the specific configuration of the RFID reader that directly communicates with the Raspberry Pi Board using a Python script. It is also important to take note that the baud rate is set at 9600. Otherwise, nearby RFID tags will not be read correctly. By setting the right configuration, the system was able to identify the RFID tags correctly as shown in Figure 7 as long as it was within 2 meters or 6 feet distance from the base position of the reader.

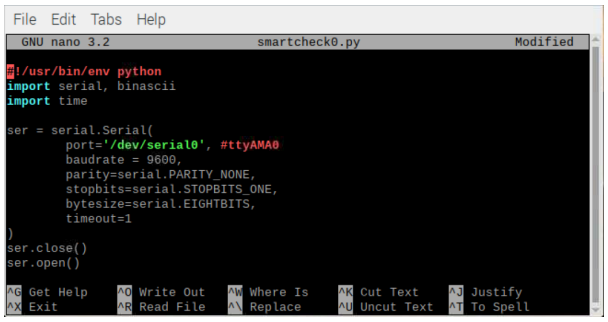

Fig 6. RFID reader detecting RFID tag correctly

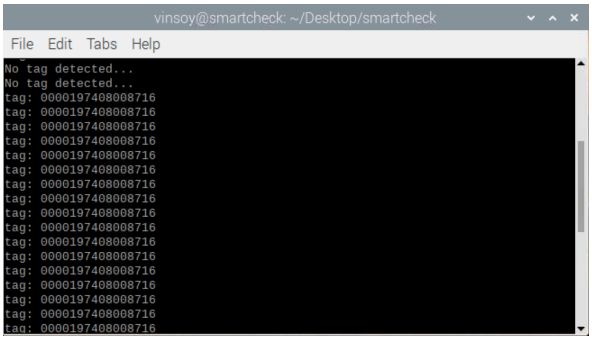

Fig 7. RFID reader configuration

Meanwhile, for the usability test, a survey was conducted with 5 respondents from the Attendance Monitoring staff and teachers, 4 of them strongly agreed that the developed system is easy and convenient to use, helping make their work easier without the need for intensive training or supervision. Consequently, Figure 8 shows a graphical representation of the System Usability Scale survey results. It shows that 80% of the respondents strongly agree that the system is easy to use, very helpful, makes their work easier and faster, very convenient to use, and the various functions in the system were all integrated. Thus, only 20% agree that they will need the support of the technical person to be able to use the system.

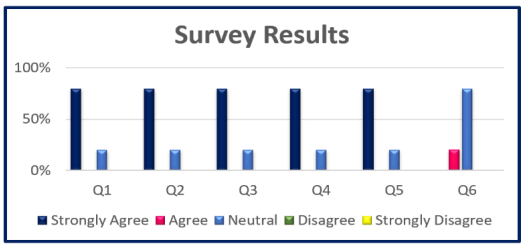

Fig 8. Usability Test Results

Table 1 below presents a comparison of attendance monitoring systems based on technologies and methods used.

Table 1. Comparison Table

Comparison of Attendance Monitoring Systems			
High Frequency (HF)/NFC based attendance Systems	Artificial Intelligence (AI)/QR Code – based Attendance Systems	BLE Beacon based Attendance Systems	Proposed System
• Checks attendance by reading tags using HF Radio Frequency Identification • Teacher is associated with Tag ID in the database • Database is running on the central server • Requires tags to be very proximate to the reader (distance must be < 3cm) – at least a tap is needed • Obtrusive attendance checking • Proxy attendance is probable • Only records single time-in and time-out • Requires ID cards with RFID tags and Microcontroller • No Power Outage Support	• Checks attendance based on camera capture images using Artificial Intelligence (facial recognition) • Teacher is associated with facial features in the database • Database is running on central server • Requires log-in to a web application • Obtrusive attendance checking • Proxy attendance is unlikely • Only records single time-in and time-out • Training and re-training of facial recognition model is tedious and labor intensive • Requires mobile devices/smartphones • No Power Outage Support	• Checks attendance using Bluetooth proximity sensor and smartphone application. • Teacher is associated with smartphone's physical address/MAC address in the database • Database is running on central server • Requires log-in to a mobile application • Obtrusive attendance checking • Proxy attendance is probable • Only records single time-in and time-out • Requires mobile devices/smartphones and BLE beacons • Beacons can be easily stolen or misplaced • No Power Outage Support	• Checks attendance by reading tags using Ultra High Frequency Radio Frequency Identification and camera captured images for verification • Teacher is associated with Tag ID in the database • Database is running on Local machine and Central Server • Tags can be read up to 2 meters • Non-obtrusive attendance checking • Proxy attendance is unlikely • Performs multiple checks during class • Requires ID cards with RFID tags and Raspberry Pi. • Continues to operate under power outage

The goal of all presented systems is obviously the same but the means to achieve it is quite different. Among the four (4) attendance monitoring systems, the use of Artificial Intelligence is the most promising one, however as of the moment, its practicality in real-world implementation is still far from ideal. Especially, if we consider the technical expertise and resources needed in building and maintaining the model for facial recognition. As far as the presented attendance systems are concerned, the proposed system stands out in addressing the pressing issues in monitoring teacher's attendance in schools. One clear advantage of this proposed system is the ability to check attendance in a non-obtrusive manner, since the Ultra High Frequency (UHF) – RFID reader does not require actual contact nor any external operation to be performed in order to facilitate the checking of teachers' attendance. Moreover, the proposed system can calculate the total time teachers have stayed in their classes which is not only based on a single time-in and time-out data, rather a summation of duration based on multiple checks of the UHF-RFID reader. An additional advantage of the proposed system is the replicated databases that simultaneously run on the central server and on each Raspberry Pi board. The replicated databases are very important to create a fault tolerant system that can withstand server failure, network failure and even power outage.

4 Conclusion

In this paper, we present an innovative approach for an efficient, dependable and cost-effective faculty attendance monitoring. We developed an In-Classroom Faculty Attendance Monitoring System, which provides an non-obtrusive way to check the teacher's attendance. The system was successfully implemented using Ultra High Frequency (UHF) - Radio Frequency Identification (RFID) technology, since it has an extended read range of up to 2 meters, which is far more superior that the 3-centimeter read distance of its Near Field Communication (NFC) counterparts used in previous studies. Moreover, unlike existing solutions, the system checks for the attendance multiple times inside the classroom not only during entrance and exit. The system can then calculate the total stay-in time of the teacher during a class schedule in order to avoid misuse of intended class hours.

Furthermore, proxy attendance and other fraudulent activities were addressed in the proposed system by integrating a camera module to capture images to verify the presence of the teacher inside the classroom. An added value to the proposed system is the ability to withstand server failure, network failure and even power outages. It is possible because individual Raspberry Pi boards can serve as a local database server which allows it to continue collect attendance data even if it is disconnected from the network or run over a battery pack as an alternative power source during a power outage. Overall, the proposed system succeeded in coming up with an efficient, dependable, and cost-effective faculty attendance monitoring

system that can be implemented in schools to help ensure that students will receive the quality education they deserve.

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