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RESEARCH ARTICLE

Design and implementation of faculty class attendance monitoring system using BLE beacons

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Abstract

Objectives: To create a hardware and software tool that can be used for monitoring the faculty attendance and to generate customized reports. **Methods/Statistical Analysis:** The Bluetooth Low Level Energy (BLE) beacons would be set as stationary device that has proximity unique identifier. Once the smartphone of the faculty is within the range of the beacon, it can then record the faculty's attendance. Calibrated beacon range makes the proposed design unique in terms of addressing common attendance tracking issues. Also, an automated attendance monitoring tailored based on the periodic report the Human Resource (HR) of the university. The researchers conducted a testing in the laboratory classrooms to check the functionality and reliability of the automated attendance monitoring. **Findings:** Based on the testing conducted, the system is capable to detect the faculty once he/she is inside the classroom, records his/her attendance and generates reports. The mean percentage error is 8.02% which means that the BLE beacon is acceptable in detecting the faculty's smartphone prior entering to his/her class.

Keywords: Faculty class attendance monitoring system; Bluetooth low level energy beacons

1 Introduction

The attendance of a teacher is an important part in teaching-learning process. Study revealed that teacher attendance had a significant impact on students' learning. Teachers with lower absenteeism had students scoring better on achievements tests, when compared to their counterpart [(1)].

Some universities in the Philippines today still uses the traditional pencil and paper to check the faculty's attendance which are compiled manually for record keeping. Universities such as Loyola Schools of Ateneo de Manila University, Holy Trinity College of General Santos City, University of Science and Technology of Southern Philippines (USTP) use manual system in monitoring the attendance of the faculty in the college department. A checker which is a

staff or a working student roams around the campus and with the use paper, pencil and attendance sheet checks if the faculty really attended to his classes. Policies such as 15 minutes late prior to the class schedules is closely monitored.

The problem with manual system is that it is prone to human errors. Sometimes, the attendance sheet accidentally lost which results to inaccurate dissemination of data. This is also a tedious task as there will a number of faculty and class schedules to be monitored. Report generation will be time-consuming and costly. Universities have to employ additional workers who require salaries and benefits to consolidate the papers and work on the reports. With these, there is a need for automated attendance monitoring.

Nowadays, several automated attendance monitoring exist including biometric attendance monitoring system. Biometric is another way of identifying an individual based on physiological or behavioral characteristics (Klein, 2003). Biometric identification includes fingerprint scans and retinal scans. It needs the user to be enrolled in the system wherein use data are stored in the database such as the fingerprint scan. By history, the fingerprint recognition is the oldest and most successful biometric-based identification used by the government and some private individuals[(2)].

Radio-frequency identification (RFID technology uses radio frequencies or radio waves to get the data from the identification card (ID) of the employee which has electronic tag, or the RFID tag attached to everyone's ID. The individual information of employees is stored electronically in a RFID tag which has an antenna that transmits the data to the transceiver for data storage[(3)].

Another existing attendance monitoring is the location based attendance tracking system using Global Positioning System (GPS). The location of an organization has a specific location, which can be determine by the GPS. Each employee's location can be determined by the GPS using smartphone[(4)].

However, the aforementioned attendance systems have disadvantages as the usage of biometric will not be practical for classroom level. It will be expensive to install one biometric in each classroom considering that there are many classrooms in the institution. The same goes with RFID transreceivers which are also very expensive.

Also, GPS location based attendance system does not work well in indoors. The GPS can provide good location estimates. However, the GPS solution cannot be used in indoor environments. In this kind of environment (which is typically called GPS denied environment) the GPS signal is very poor because of the lack of line of sight between satellites and the receiver[(5)].

Bluetooth Low Energy is becoming increasingly popular in mobile applications due to the possibility of using it for proximity data. Proximity can be estimated by measuring the strength of the Bluetooth signal, and actions can be performed based on a user's proximity to a certain location or object[(6)].

The introduction of low-cost, low-power BLE beacons for proximity detection provides a new signal of opportunity with which to perform more fine-grained positioning[(7)]. The proposed system will introduce the use of Bluetooth Low Level Energy(BLE) Beacons. It is one of the latest technologies that has emerged and become an industry standard available on most devices today. It is more accurate to use in indoor localization than GPS. It has the advantages of low cost, accurate positioning, large coverage, and long battery life[(8)]. Installing beacons can save cost on salaries expense as there's no need to hire for a manual checker. Although there will be additional costs to install the beacons but there is beacon equipment being sold by bundle at a low price.

As the USTP (University of Science and Technology of Southern Philippines) pursuits to provide innovation and technology solutions, the proposed system would like to replace the paper and pencil attendance monitoring of the faculty. This system will only monitor the faculty and will not include the attendance of the students.

The suggested system automatically uses the Bluetooth 4.0 communication of the instructors' smart phones when the instructor enters the room to check its classroom location and automatically acknowledges attendance if it is valid location. The pilot testing of the system will be in University of the Science and Technology in Southern Philippines (USTP) in the ICT Bldg. 9. This said teachers' attendance monitoring is different from the biometrics attendance of the employees.

2 Objectives of the Study

The general objective of this project is to create an automated faculty attendance monitoring system.

2.1 Specifically, this study aims:

1. To design a device using a programmable Bluetooth Low Level Energy (BLE) beacons as a device to detect the smartphone of the faculty if within the specified range.
2. To design and develop a mobile application that would display the class schedules of the faculty and notifies him 15 minutes before his time.
3. To design and develop a web application that would enable the administrator (HR personnel) to manage colleges, departments, courses, rooms, users, beacons, and schedules of the faculty. Moreover, generate customized reports tailored to the reports currently generated by the administrator (HR personnel).
4. To evaluate the usability of both the device, mobile application and web application.

3 Methodology

3.1 System architecture

Figure 1 shows the system architecture of the automated faculty attendance monitoring. This composes of the attendance application, BLE beacons, cloud, web application and database.

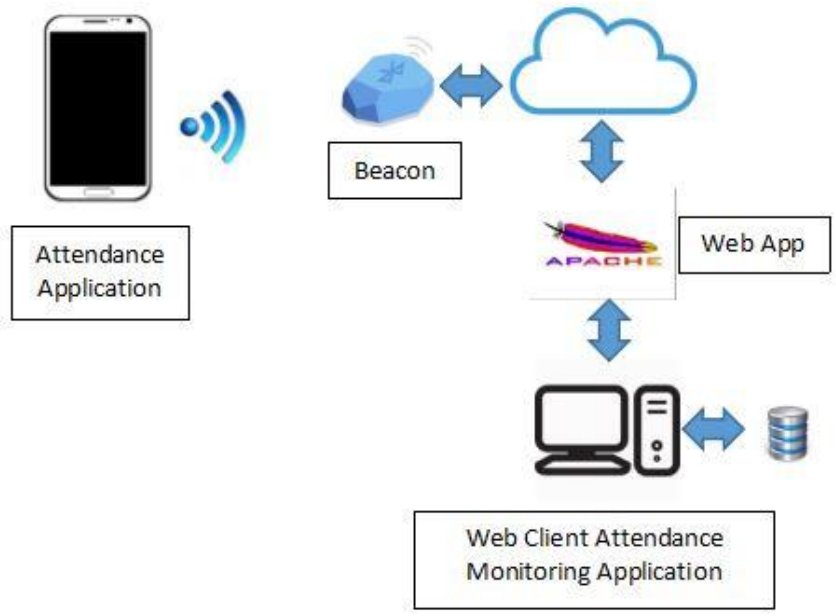

Fig 1. System architecture

The admin (HR personnel) registers the users (faculty) on the web application and the Media Access Control (MAC) address of their smartphones. The faculty can be able to log in with the mobile application being installed in his smart phone. The mobile application also display his upcoming lectures and notifies him 15 minutes before his class. Once he is inside the classroom, the BLE beacon then detect his smartphone. It will be synched on the web application.

3.2 Use case diagram

Figure 2 shows the use case diagram of the system. There are two major users in the system namely: admin and users. The admins are the HR personnel who monitors the attendance of the faculty and the users are the faculty. The admin has all the privileged in the system such he/she can be able to manage users, devices, accounts, schedules, attendance and reports. The users on the other hand can be able to view schedule and attendance as well as print attendance.

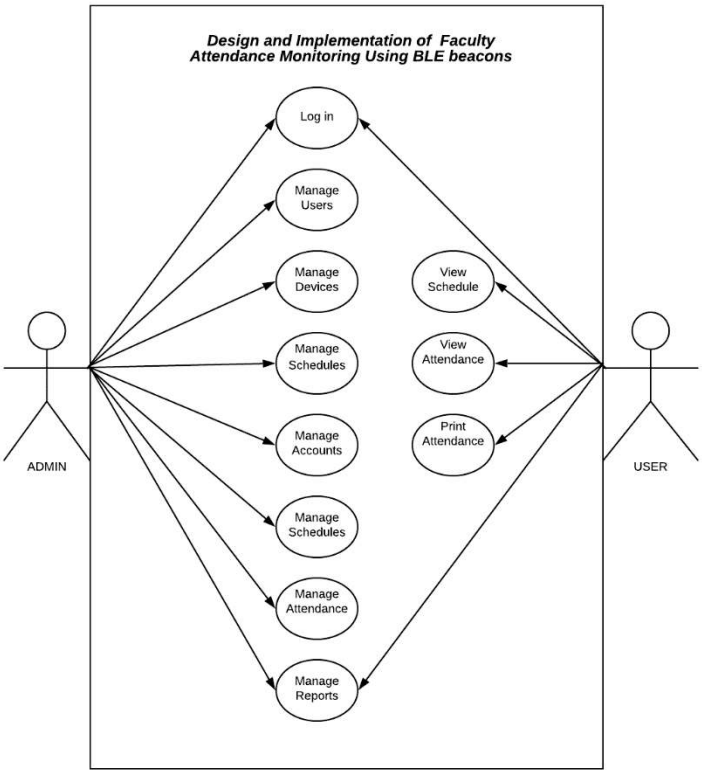

Fig 2. Use case diagram

3.3 Context diagram

Figure 3 shows the use case diagram of the system. There are two major users in the system namely: admin and users. The admins are the HR personnel who monitors the attendance of the faculty and the users are the faculty. The admin has all the privileged in the system such he/she can be able to manage users, devices, accounts, schedules, attendance and reports. The users on the other hand can be able to view schedule and attendance as well as print attendance.

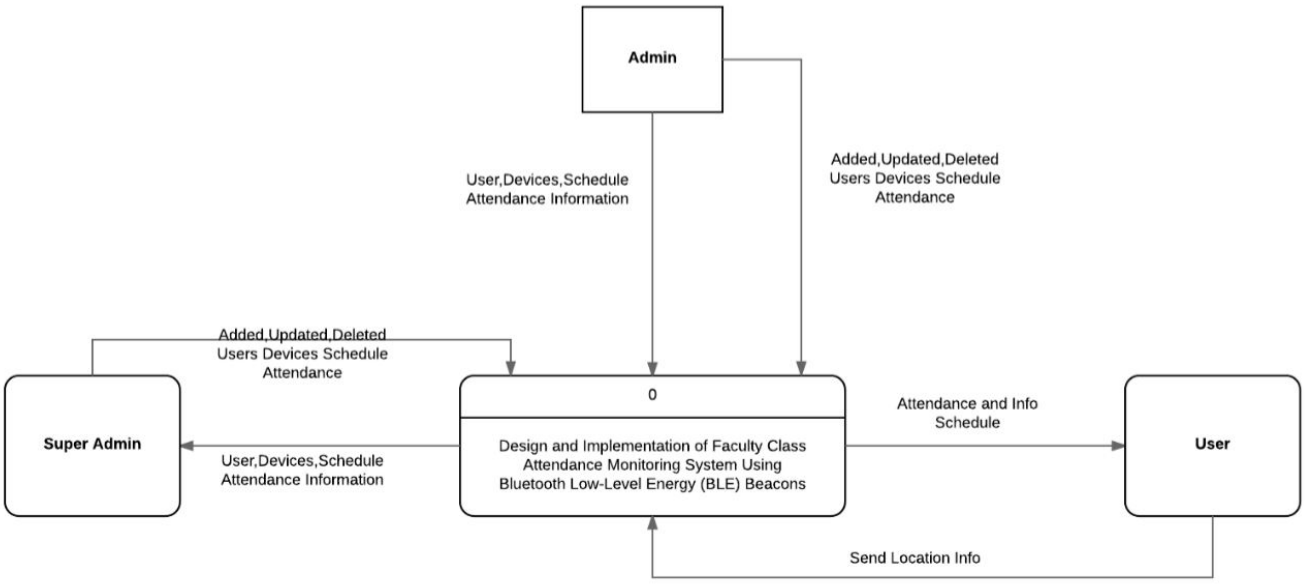

Fig 3. Context diagram

3.4 Database design

A database will be designed to store data time logs from the users, sent from their android device during time-in and time-out. The database is used to store the input from the HR Staff of the users' class schedule, subject, time and room. All generated reports from HR comes from this database.

3.4.1 Entity Relationship Diagram (ERD)

Figure 4 shows the database design of the system using entity relationship diagram. There are 13 database tables. Primary keys are unique attributes for each table which are represented by "PK". Foreign keys are fields that uniquely identifies a row of another table which are represented by "FK". Notations such as and indicates one to many relationships.

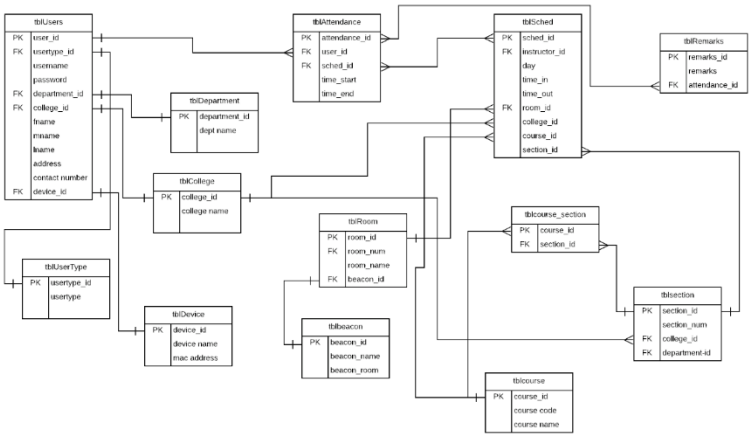

Fig 4. Entity relationship diagram

3.5 System Evaluation

3.5.1 Functionality Testing

During the pilot testing, the accuracy of the system will be evaluated. The system will be tested if the added faculty will be able to log in to his mobile application once added on the web app. The faculty schedules also must displayed in the mobile application. Moreover, the range of the beacons can be calibrated. If the instructor is outside from this classroom, the attendance of the instructor will NOT be recorded. However, if the instructor is inside the classroom, his attendance will be recorded with the particular subject.

The testing will be conducted in the 3rd floor of the ICT building of University of Science and Technology of Southern Philippines (USTP).

3.5.2 Proximity Testing

Received Signal Strength (RSS) based distance estimation is a popular method in wireless sensor networks[9]. There will be comparison the actual distance of the instructor to the beacon versus the received signal strength of the beacon. The Mean Absolute Percentage Error will be then be calculated. It a statistical measure of how accurate a forecast system. It measures this accuracy as a percentage, and can be calculated as the average absolute percent error for each time period minus actual values divided by actual values as shown below.

$$\mathrm{M} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right| \tag{1}$$

where A_t is the actual value and F_t is the forecast value.

4 Results and Discussion

4.1 Functionality testing

4.1.1 Log in testing

Figure 5 shows the testing on the Web Application and Mobile Application Log in Interface. The admin was able to log in successfully on the web application and the faculty was able to log in successfully in the mobile application.

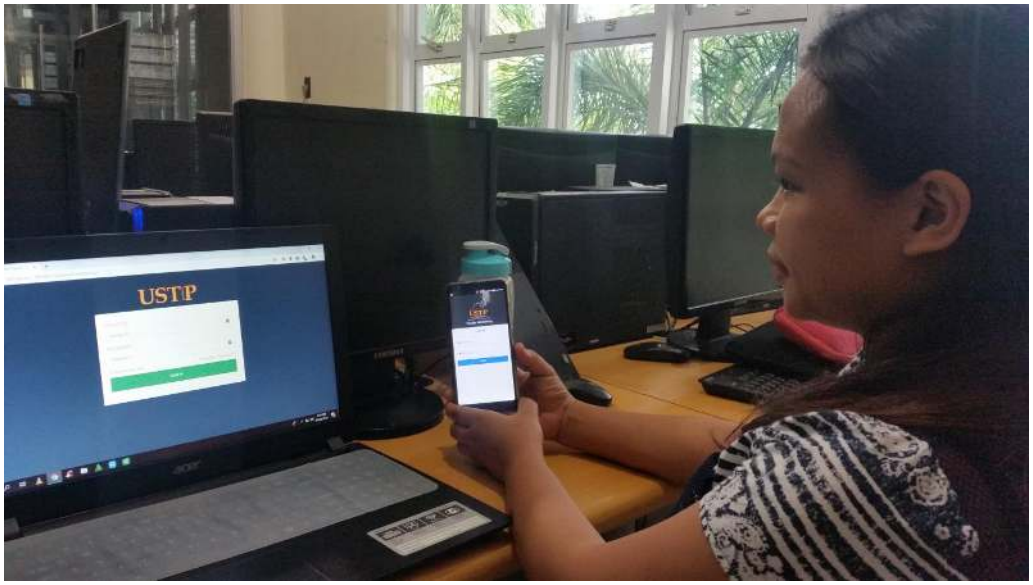

Fig 5. Log in testing

4.1.2 Faculty schedule testing

Figure 6 shows the testing on the faculty schedule found on the web application which is synced and/or reflected in the mobile application after successfully logged in. together with this screenshot t, are the BLE beacons devices.

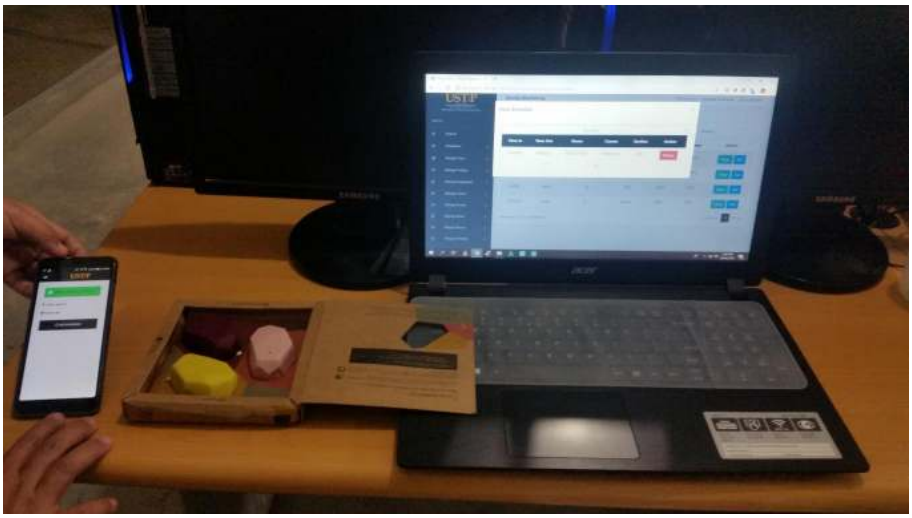

Fig 6. Faculty schedule testing

4.1.3 BLE beacon testing

Figure 7 shows the BLE Beacon added on the web application but not yet enabled or ready to detect the proximity of the faculty.

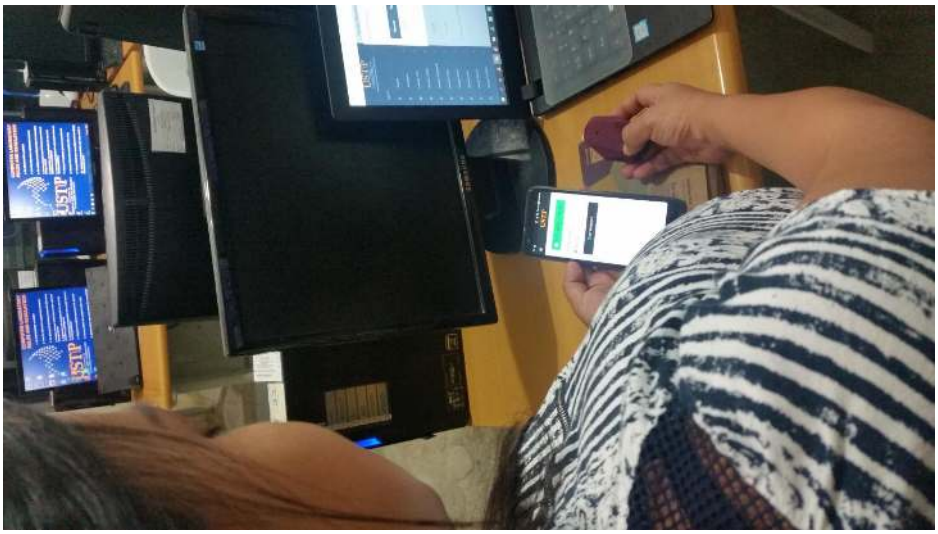

Fig 7. BLE beacon testing

4.1.4 Outside classroom testing

Figure 8 shows the testing outside the classroom. The mobile application shows the current class schedule of the logged in faculty member. In this figure, the beacon has not yet detected the mobile application since the faculty is still outside the classroom.

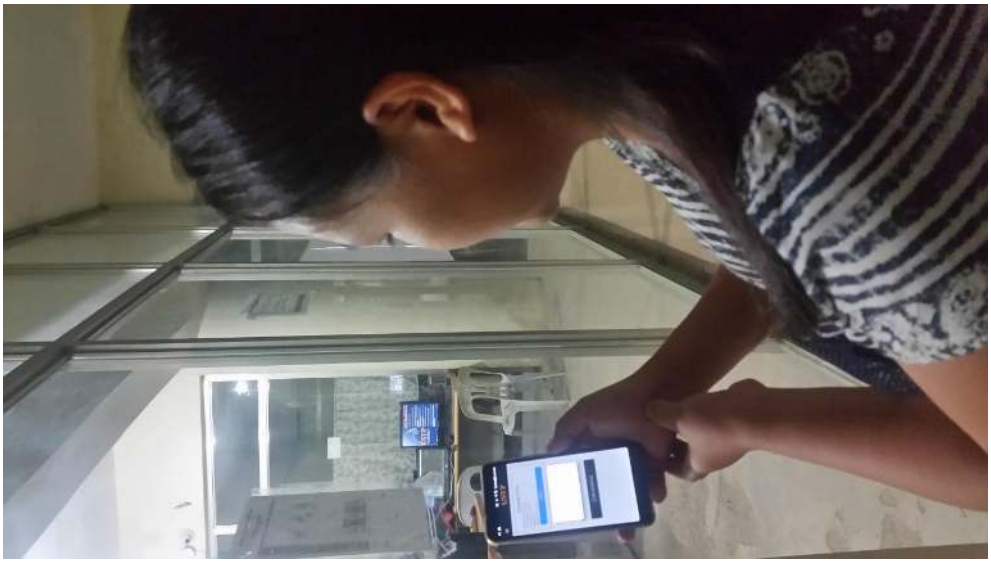

Fig 8. Outside the classroom testing

4.1.5 Inside classroom testing

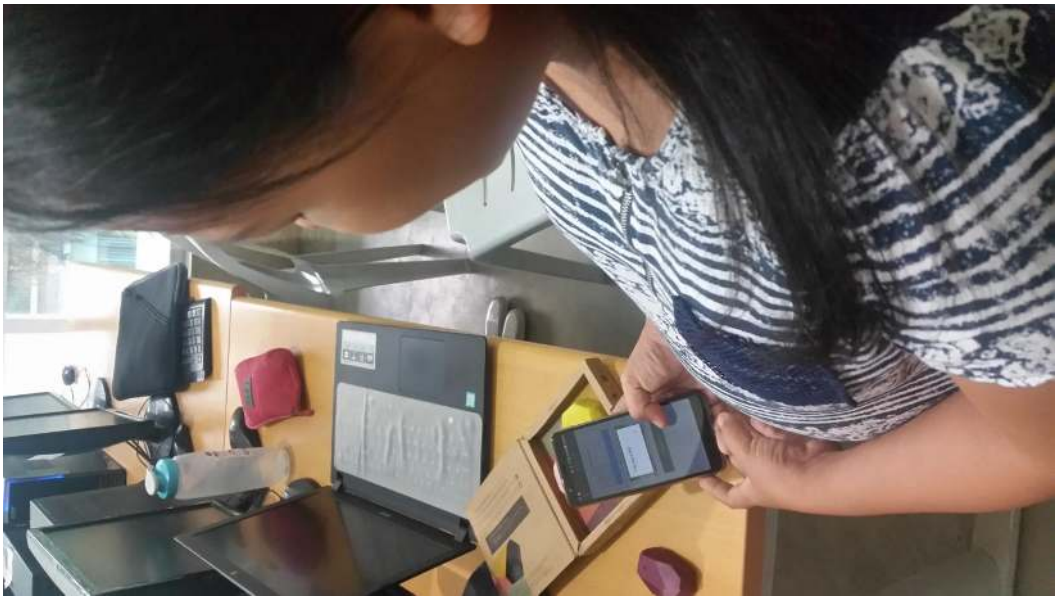

Fig 9. Inside the classroom testing

4.1.6 Report generation testing

Figure 10 shows 'Generate Report' interface of web-based monitoring system for faculty class attendance monitoring. This is where the HR selects a specific college he/she wants to monitor to and select a date range to preview attendance report. It has the following buttons namely Generate and Reset. Clicking Reset button will empty the College, From and To fields and clicking Generate will generate a PDF report.

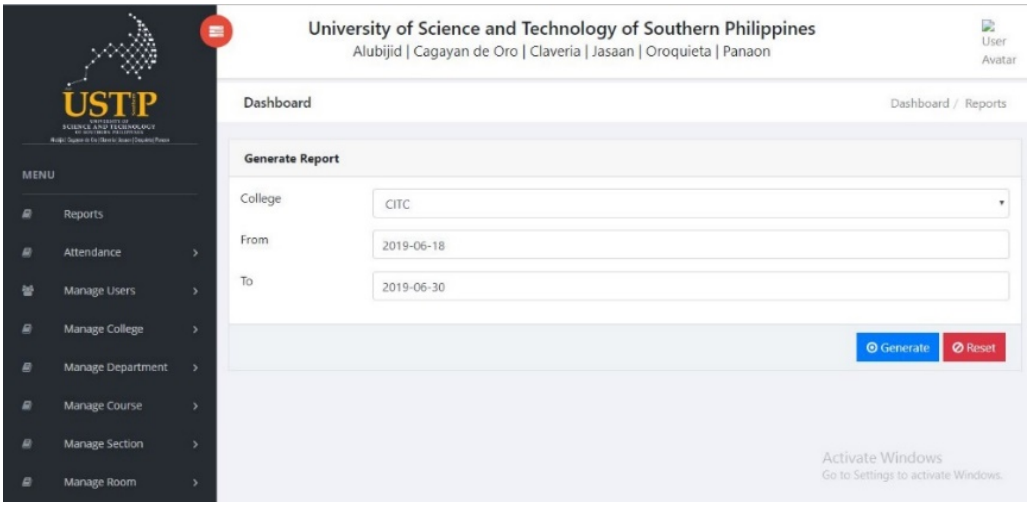

Fig 10. Generate report

4.1.7 Sample PDF report

Figure 11 shows a sample PDF report of web-based monitoring system for faculty class attendance monitoring. Based on the current attendance report being generated and monitored by the HR, this is PDF report of the attendance monitoring. It has the following fields schedule date, name of faculty, BLDG-Room, schedule time and department.

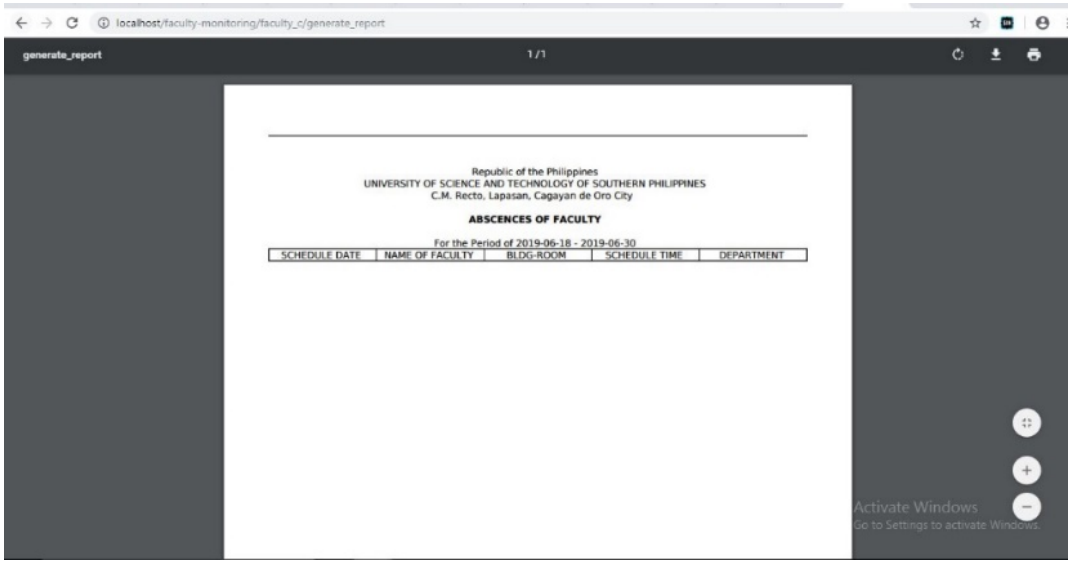

Fig 11. Sample PDF report

4.2 Proximity testing

Table 1 shows that the mean absolute percentage error is 8.02%. As per inspection, beacon's distance is inversely proportional to the accuracy rate. This is already an acceptable result since the closer the percentage value to ZERO (0%), the more accurate.

Table 1. Distance errors of the instructor to the classroom with enabled beacon.

Test	Actual Distance (m)	Received Signal Strength (RSS)	Absolute Percent Error %
1	25	30	20.00%
2	23	27	17.39%
3	21	24	14.29%
4	19	21	10.53%
5	16.25	18	10.77%
6	14	15	7.14%
7	11.25	10.25	6.67%
8	9.5	9	5.26%
9	5.25	5	4.76%
10	2.9	3	3.45%
		Mean	**8.02%**

5 Conclusion

The use Bluetooth Low-Level Energy (BLE) Beacons for faculty attendance monitoring, of web and mobile-based application provides an easier and more organized way of monitoring the attendance of the faculty to his/her classes. The result of the study in terms of functionality and proximity testing is acceptable.

It is also recommended that there should be another study to add students' attendance, including additional faculty verification such as facial recognition and indoor mapping method. This study is limited to the bringing of faculty's smartphone prior entering to his/her classes.

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