A Smart Classroom of Wireless Sensor Networks for Students Time Attendance System

Fawaz Alassery, member IEEE
Computer Engineering Department
Taif University, Saudi Arabia
Email: falasser@tu.edu.sa

***Abstract*—Today, Wireless Sensor Networks (WSNs) have been included in many researches to form smart environments. IoT is becoming increasingly integrated in our daily life at homes, streets, schools and everywhere. Using IoT based on WSNs in the educational filed is an important resource for better preparing students for the future digital world. Digital students attendance system in schools or universities is an example for case that technology can facilitate the traditional ways for checking students attendance instead of using the manual paper sheets which consume time and resources with higher probability of failure. In literature, there are many time attendance systems that proposed to enhance the manual traditional methods for taking and calculating students attendance in smart ways. In this paper, we proposed a user friendly students time attendance system that can be applicable in different schools or universities in order to form a smart classroom based on WSNs and IoT technologies. We proposed intelligent chairs that can be identified as the sources of information, which integrated with four 50 kg load sensors and HX711 amplifier that measure the students weights and send the digital signals to a receiver in order to recognize the student presence during class schedule. This smart classroom is also installed with one ZKTeco ZK4500 fingerprint reader in order to increase the identification for students. The transmitted signals from the intelligent chairs will be connected by Android application which will be installed on the lecturers' smart phones. So, teachers will get details and summary report of students attendance through the Android app. We implemented our proposed idea using java language, database and android system.**

***Keywords*—Android applications, Wireless Sensor Networks applications, android system, students time attendance system, smart classrooms.**

I. INTRODUCTION

It is difficult to manage students attendance in schools or universities especially in classrooms which include many students where the checking of their attendance using the manual methods consumes time and efforts to recognize or remember their faces by lecturers. Also, it is challengeable to digitalized the time attendance system due to the fact that it is important to accelerate the decision making mechanism and minimize the probability of failure. Facilitating the time attendance system by using WSNs technology will help lecturers for better managing students in their classes.

Schools and universities where the internet access must cover all of their areas need to shift to automated time attendance system. People management is one of most difficult issues in the organizations, and keeping the traditional paper sheets or records for attendance is another issue increase the complexity of traditional/manual time attendance system. Many schools and universities hire a non-academic employee for the purpose of taking the students attendance everyday which consume time rather than resources which need to be updated from time to time such as the number of paper sheets and spaces for saving theses records [1].

The current problem is the management of students' attendance still done in a manual process. This poses difficulty for lecturers to take the student attendance, which they have to use valuable time to verify each student who has attended the class. Besides the lecturer verifying the attendance himself or herself, the other way is by passing around a sheet of student attendance to the students. This allows uncomfortable learning experience to students. The student also faces the problem of signing their attendance on the attendance sheet, which sometimes need to wait until the end of the lecture just to be able to sign. Moreover, cheating in signature frequently happens in which absent students ask their friends to help them to sign the attendance sheet.

This paper focus on managing the student attendance as an alternative solution from the manual way of sign in attendance to computerized method. Students only need to sign their attendance by using fingerprint on prepared equipment in addition to the intelligent chair components which are integrated in each chair the smart classroom. In the real situation, students usually help their friends to sign the attendance without attending the lecture. However, by applying the uniqueness of fingerprint technology in attendance management, it gives an advantage to validate and record the attended students. In addition, the smart four 50 kg load sensors and HX711 amplifier can be useful to determine how many minutes/hours students attend the classes from the whole class timeline. At the end of a semester, it can be easy to calculate how many hours that our students attend a specific class in comparison with idle timeline that should be attended by students in such a class.

This work has been supported by Taif University, Taif City, Saudi Arabia.

These feature has given better alternative for students and lecturers if compared to the manually way of sign in attendance paper sheets which is time consuming and involves uncomfortable learning process

The aim of this paper is to design and develop user-friendly attendance system that can be implemented in schools and universities based on IoT and WSNs. The advantages of our system can be summarized in the following: In this paper, our works will help in the following:

- We will be helping the environment by reducing the number of papers that are used in our schools and universities. In another words, reducing the usage of paper, which will provide an Eco-Friendly environment.
- By using our proposed automated time attendance system, there will be no way that a student will be able to mimic his classmate fingerprint, also the database will be in the lecturer phone, not in the internet, and this will protect the data from being hacked.
- Using our system, the lecturer can go back and check the data anytime he wants. He can use the data to keep track of students' attendance percentage and inserted in the university system.
- Save the students attendance history in the lecturer phone, which will make it easier to retrieve it.
- Learn more by saving the time of the lecturers and the students.

The rest of the paper is organized as follows. Section II discusses some related works which focused on different time attendance systems. Section III details the methodology or our proposed time attendance system. We will explain in details the waterfall model phases (i.e. requirements, analysis, design, coding, implementation and acceptance). Finally, the conclusion is summarized in section IV.

II. Related Works

In literature, there many computerized time attendance systems. They all focus on how to change the traditional and manual paper sheets mechanisms used in different schools and universities.

Authors in [2] proposed a real-time attendance system that uses smartphones to detect online the current locations of employees based on GPS technology as well as the fingerprint readers. Idea is based on accessing the attendance system database based on the fingerprints of employees that can be entered via their smart phone, and the GPS technology can be used to determine the current location of users preventing any try to cheat the absence of employees. If the current location is in the workplace then the system will accept the attendance of users, otherwise it will be rejected. Checking the situation of the attendance can be done via sending MMS messages between users and the system administrators. One of the most problems of using GPS to detect employees' locations is the accuracy to identify the real-time locations. Some rooms in a building may suffer from weak internet connections which make the accuracy for time management system based on such technology is more complex. In addition, using GPS in [2] needs further checking for the arrival time of users at the workplace such as using fingerprint devices for better authentication.

Authors in [3] proposed time attendance system based on RFID technology. Users at working places or schools use the RFID tags which represent their ID numbers, and they need to make the RFID reader identify their cards one they arrive to the work place. The system immediately will detect the arrival times and record them in the database. However, the main disadvantage of using the RFID tags is the possibility of some employees will carry some other tags for their friends. In another words, the possibility for cheating in such technology can be increased. Using a cloud system based on Near Field Communication (NFC) technology for time attendance is proposed in [4]. NFC technology is the newer version of the RFID technology that can be integrated with users' phones rather than using user ID cards. Authors proposed their NFC time attendance system based on web application that can be accessed at any time showing the arrival time, leave and many other report fields.

Face recognition technology for time attendance system in classrooms is proposed in [5]. Authors proposed a portable face recognition device that can be transferred from one room to another where students must stand in front of the device to recognize their faces and compares the results with what is registered in the system database. The device uses deep convolution networks for better face assessment and recognition. The main disadvantage in using face recognition systems for time attendance is the limitation of the images captured by the devices. The limitations such as the ability of devices to recognize the face when the image size is changed (i.e. the case when users stand in different distance from the device). Another disadvantage is the face angle which need to be compatible with the algorithm used to recognize the face making students suffer from queueing delay. Also, image quality needs face recognition devices to be installed with high resolution cameras which may become expensive.

In order to solve the queueing delay that may cause by using only one terminal device inside the classroom (e.g. face recognition device or fingerprint device), authors in [6] proposed time attendance system that can use students smart phones for their arrival time entry. Authors proposed Bluetooth low energy device that can be installed in the classroom in order to send a magic number to all student devices located inside the room. So the students will use this number to access to the android application in their devices and register their attendance. Again, the main limitation of this idea is the possibility for some students to carry their friends' smart phones in order to register their attendance.

Many ideas and method have been discussed intensively in literature such as using smart phone applications [7], video surveillance cameras [8] and QR codes [9]. However, in time attendance system for students, it is mandatory to combine between cheap and efficient/secure ideas which is the main concern of our proposed system that is based on a single fingerprint device and cheap wireless sensor nodes.

III. The Proposed System Methadology

In our methodology, we follow the well-known waterfall

model as shown in figure 1.

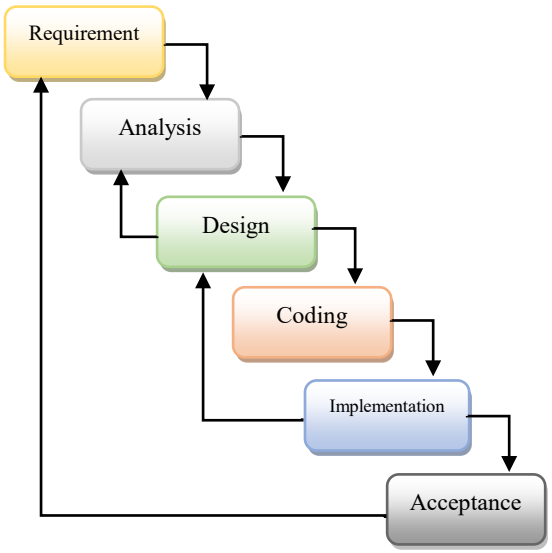

Fig. 1. The general methodology based on waterfall model.

We start with the system requirements, which can be divided into functional requirements, non-functional requirements, user requirements and system requirements. Then we analyze the proposed system. The designing phase become next. After that, we will generate the code of the proposed algorithm that can be used for the time attendance checking. Testing our proposed Android application based on the system requirements is final phase before measuring the level of the acceptance of the overall proposed time attendance system. In the waterfall model, it is necessary to notice that any change in the system design must become after changing the system analysis. Also, if we want to make a change in the testing phase, it is mandatory to change in the system design phase. Finally, after measuring the users experience in the acceptance phase some changes may be considered in the system which enforce us to change the first phase (i.e. requirements) and all the following phases.

A. Requirements Phase

The system requirements include functional requirements, non-functional requirements, user requirements and system requirements.

For the functional requirements, they represent the operations that should be processed on the data of the system. They must include the following:

- New students will be able to register to the system by clicking on the "sign-up" button. This is done only once at the first time.
- After registration of students, they should be able to login to the system by entering the unique username and password. If the login is successful, they will be able to access to the main features of the application. Otherwise, an error message will be prompt.
- Admin can be able to add new courses by clicking on "add new course" button. Also, he/she can be able to delete existing courses by clicking on "delete course" button.
- Admin can be able to add new groups to a course by clicking on "add new group" button. Also, He/she can be able to delete existing groups by clicking on "delete group" button.
- Admin can be able to add new students to a group by clicking on "add new student" button. Also, he/she can be able to delete existing students by clicking on "delete student" button.
- System shall be able to read the fingerprint of a student and compare with information stored in the database to save attendance information.
- System can be able to retrieve information when required by admin or students.

For non-functional requirements, they represents the system capabilities in terms of security, performance, reliability, flexibility and etc. They can include the following:

- System can be able to read the fingerprint of a student and compare with information stored in the database to save attendance information.
- Efficiency of the system should be high. For example fast response when users made requests to display information, or presenting accurate data that match users requests.
- Simplicity of the interfaces so that the user can easily use the features without facing complications.
- Flexibility to add and change some features in system.
- Security. So, users information can be saved in a secure database where unauthorized people cannot access to students information.

For user requirements, they represents the requirements that usres expect to meet their satisfactions such as:

- Simple explanation on what to enter in specific textboxes.
- Simple procedures to reset passwords once the users forgot their login information. For example, sending emails to reset passwords or usernames.
- The application shall have capabilities to fast response to users requests.
- Enough information shall be accessible when users request reports for their attendances during specific semesters.

For data requirements, they represents the data that should be access and presented in the application such as lecturer identification number, user login info, email address, course information (i.e. course ID number, course name, course date), students information (i.e. students names, ID numbers, fingerprints and attendance report).

B. Analysis Phase

In the analysis phase, we define all required system functionalities such as students login, students registrations, students fingerprint photos, students names, students ID numbers, attendance time, lectures IDs, lectures dates, lecturers names, lecturers ID numbers, lecturers emails, lecturers login info, courses IDs, and courses names.

An overview of the general relationship between the proposed system members is illustrated in figure 2 (i.e. the

case diagram). This figure shows the interaction between a student and a lecturer. It is necessary to mention to that a lecturer is considered as the system administrator in order to facilitate using the app and give him/her the opportunity to manage students and their information based on his/her own classes he/she taught. As we can see in figure 2, the lecturer is the administrator for the system. He/she can register in the system, login, update profile, view report, manage student attendance and their accounts, and accept adding fingerprint photos, while a student is the second level user for the system where he/she can register in the system, login, view reports, update profile and scan the fingerprint.

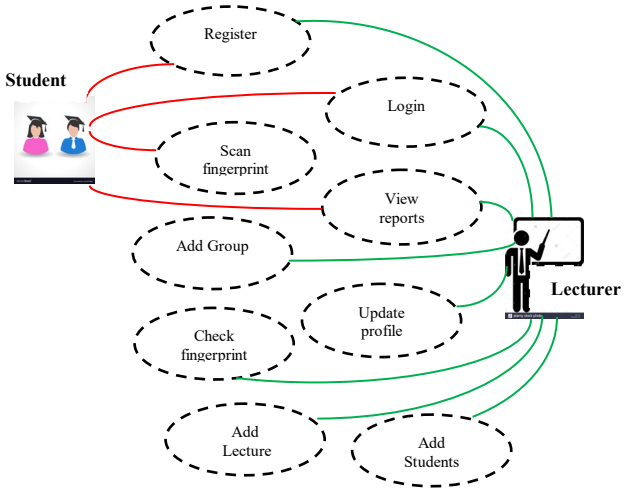

Fig. 2. The case diagram of the proposed system.

The entity relationship diagram is illustrated in figure 3.

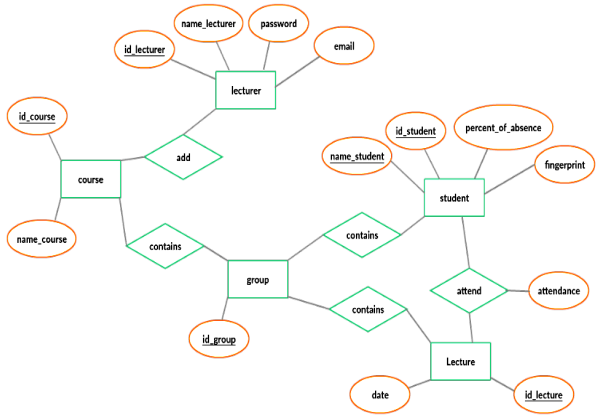

Fig. 3. The entity relationship diagram of the proposed system.

In addition, we analyze all requirements in order to build a smart classroom based on our proposed four 50 kg load sensors and HX711 amplifier, and a single ZKTeco ZK4500 fingerprint reader. The proposed smart classroom includes five intelligent chairs which are integrated with twenty 50 kg load sensors (i.e. four 50 kg load sensors integrated in each chair). The purpose of these sensors is to communicate with one master sensor node (a receiver) which is installed in the smart classroom. The master sensor collect packets from all sensor nodes that are integrated in the intelligent chairs. These packets represents the weight of students who are sitting on the chairs. As long as the sensors can detect and measure the weight of students, it means that the students are sitting on chairs during the lecture timeline. So, in our proposed analysis we pre-defined the intelligent chairs, so every student has his/her own chair which are pre-assigned to him/her. The master sensor detect the weights of the attended students by measuring his/her weight. In the report profile, the system administrator can manage the class and discover how many hours students attend the class during the semester. Suppose that a student leave his/her intelligent chair for couple of minutes during the class timeline, the sensors can detect that and subtract the leaving time duration from the overall timeline of the class. An overview of the proposed time attendance system architecture for a smart classroom is demonstrated in figure 4.

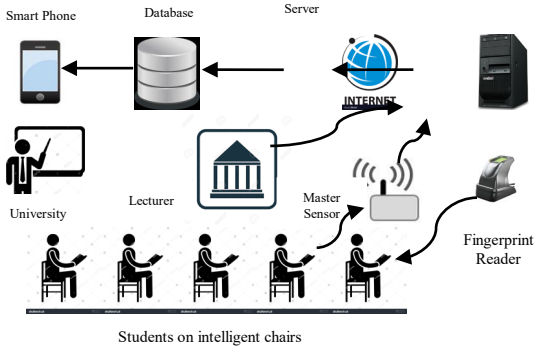

Fig. 4. An overview of the proposed time attendance system architecture.

C. Design Phase

In the deign phase, we describe the user interface for the proposed Android application and its architecture. In addition, we explain the proposed design for the intelligent chains which are integrated with the load sensors.

For the Android application, the home page for the application is shown in figure 5. It includes the login screen where users based on their authority will have the ability to register in the application. For those who already registered in the application, they can be able to enter their username and passwords in order to access to the main features of the application.

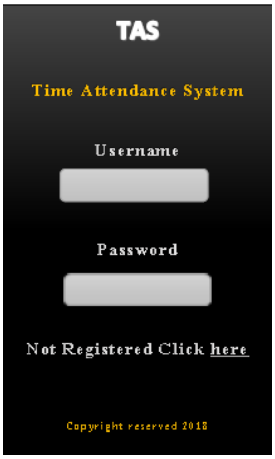

Fig. 5. The main interface for the Android application.

Figure 6 shows the registration interface. In this interface the users need to enter their names, emails, passwords and confirm their passwords. The emails should be institutional and valid emails addresses. The passwords have to be more than 6 digits include numbers and letters. These entries are connected to the active directory for the school or the university.

Fig. 6. The main registration interface.

The main features that can be checked by either the student or the lecturer is shown in figure 7. The lecturer have the ability to add the student, the course and the group while the student have the ability to view the report and scan his/her fingerprint.

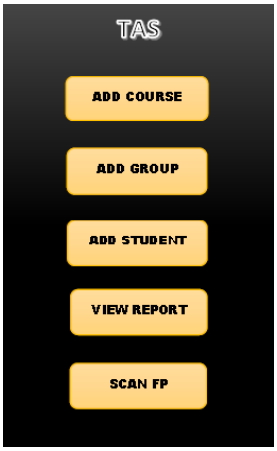

Fig. 7. The main features interface.

In the main feature interface when the lecturer add a course, a group or a student the resulting interface will be similar to figure 8. This figure shows the required fields that should be entered by a lecturer to add courses. Similar mechanism is for adding students or groups.

When students registered in the application, they have to confirm their fingerprint photos. This fingerprint photo will be saved in the database and compared with the daily fingerprint reading process which is taken by the ZKTeco ZK4500 fingerprint reader that is installed in the smart classroom. Figure 9 shows the case where a student press on the scan fingerprint bottom, it will show him/her the fingerprint photo that is registered in the database at the first time. He/she needs to confirm it only once after the registration, otherwise the system will not be able to process his/her attendance in the database. When a lecturer press on the scan fingerprint bottom, he/she will be able to see all his/her students fingerprints and make sure that all students confirm their fingerprints photos as shown in figure 10.

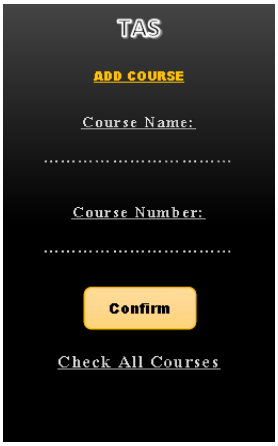

Fig. 8. Add courses interface.

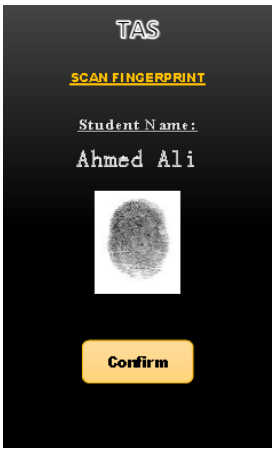

Fig. 9. Scan fingerprint interface (student).

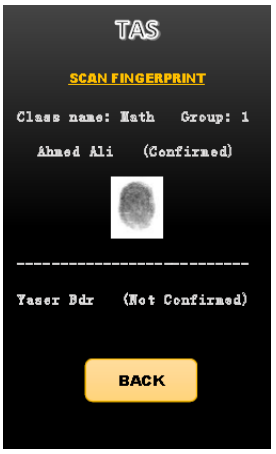

Fig. 10. Scan fingerprint interface (lecturer).

View the report for a student is shown in figure 11 where he/she can understand his/her time attendance percentage and munities (i.e. the intelligent chairs play the main role in order to detect how many minutes that students are sitting on

their own chairs for all classes during the semester). A lecturer also can see all students' attendance states by pressing the same bottom (i.e. view report) as shown in figure 12. We assume the total number of minutes in one class during a semester is 2520 min, where it is common that each class has 3 hours (180 min) and there are 14 weeks for each semester.

Fig. 11. View report interface (student).

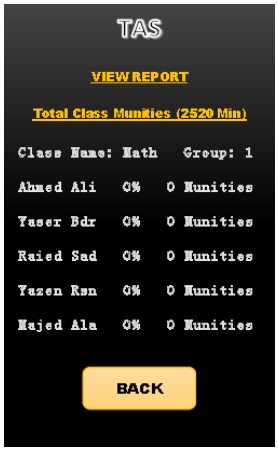

Fig. 12. View report interface (lecturer).

For the intelligent chairs, we have integrate the chair with HX711 amplifier (i.e. the purpose of this amplifier is to amplify the signals from the four load sensors of ever chair to the master node sensor which is responsible to collect all packets (weights). Here, we have to mention that in our smart classroom, we have 5 intelligent chairs (20 load sensors for all chairs), and every chair has 4 load sensors. The master sensor can recognizes all received packets and determines from which load sensor that packet is sent. For example, the packet has a unique Identification Number (ID) with two digits. If that ID is 1.1, it means the packet comes from chair 1 and load sensor 1. If that ID is 2.3, it means the packet comes from chair 2 and load sensor 3. In other words, the first digit represents the chair number and the second digit represent the load sensor number. Also, the intelligent chair is integrated with Arduino chip with power supply (batteries), and four 50kg load sensors to measure the weights that sit on the chairs and send the signals to the HX711 amplifier that is responsible for transferring packets to the master sensor nodes. The master sensor node collect packets and transfer them the time attendance system server in order to calculate how many minutes that weight sit on the chair during the semester. That information will be stored in the system database and updated during the class timeline. The intelligent chair components is shown in figure 13 [10].

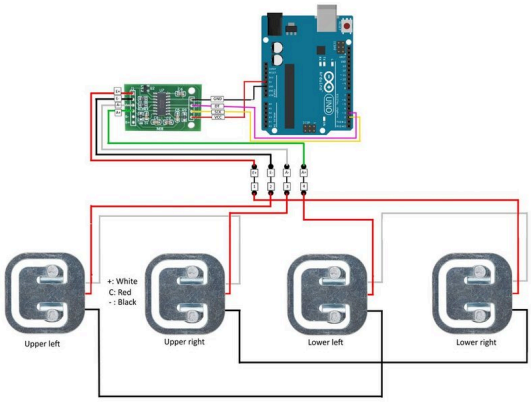

Fig. 13. The intelligent chair components with four load sensors, HX711 amplifier, and Arduino chip.

D. *Coding Phase*

In the coding phase, we run the code that is used to configure our proposed system based on all previous phases. We tried to solve all related errors that we faces after running the code. We used Android Studio which is Integrated Development Environment (IDE) for Android app development. based on powerful code editor and developer tool. We also use Java language to define strings, lay out window, create GUI controls, and assign event handlers. In addition, Extensible Markup Language (XML) is used to describe data. The XML standard is a flexible way to create information formats and electronically share structured data via the public Internet, as well as via corporate networks. Furthermore, SQLite is an embedded SQL database engine. Unlike most other SQL databases, SQLite does not have a separate server process. SQLite reads and writes directly to ordinary disk files. A complete SQL database with multiple tables, indices, triggers, and views, is contained in a single disk file. We use this database because it is local, light and easy to implement in the android app.

The time attendance system algorithm based on WSNs and the fingerprint reader is illustrated below:

Time attendance algorithm based on intelligent chair and fingerprint reader

1. Students download the TAS application and register as new users and confirm their fingerprint photos (only once).
2. Students arrive to the smart classroom and enter their arrival time by pressing on the fingerprint reader.
3. Students sit on their pre-assigned intelligent chairs.
4. **For** all students
5. **If** a student sit on the chair during the class timeline
6. Load sensors send his/her weight to the master sensor
7. The master sensor sends the packets to the sever
8. The server start calculating the duration for that sitting.
9. The server sends the arrival time to the database.
10. The server sends the sitting duration to the database after the class timeline (pre-determined).
11. The database is updated.
12. **End if**

13. **If** a student leave his/her chair during the class timeline or not sitting on his/her chair (absent)
14. Load sensors send zero weight to the master sensor
15. The master sensor sends the packets to the sever
16. The server send the leaving time immediately to the database, it will be 0 if the student is absent.
17. The database is updated.
18. **End If**
19. **End or**

E. Implementation Phase

In the implementation phase, deploy our proposed time attendance system. We also installed the ZKTeco ZK4500 fingerprint reader in the smart classroom and five intelligent chairs which are integrated with twenty 50 kg load sensors and HX711 amplifiers (i.e. four load sensors and one amplifier in each chair). We direct five students to download the TAS application and enter their registrations as well as confirm their fingerprint photos in the application. After that, we let four students sit on their pre-assigned intelligent chairs. One chair is left which is considered for the case where a student is absent in order to test the efficiency of our proposed system. We let one student leave his chair after 10 munities from the class beginning, we also let one student leave his chair after 20 munities from the class beginning and return to his chair 20 minutes before the end of the class timeline. (so, the total attendance time he attend or sit on his chair is 30 minutes). Furthermore, the remaining students (two students) are still sitting on their chairs for the all the class duration (i.e. assumed to be 100 minutes). After the class timeline, we analyze the system efficiency by checking the report which is stored in the database. The results was incredible and the system can recognize perfectly the situations for all five students. In addition, the load sensors can communicate accurately with the master node which send packets to the system server that calculate the attendance durations for all students. Figure 14 illustrates the review report which is accessed by the lecturer. Here, we have to mention that we make the class duration is 100 minutes in order to show the percentage of attendance and the number of minutes attended by each student clearly.

Fig. 14. View report interface (lecturer), Implementation phase.

F. Acceptance Phase

In the acceptance phase, we have made a survey which includes couple of question that measure the users experiences in terms of the TAS applications and the Intelligent chairs. In addition, we have tried to let people who involve in the survey use the TAS application and sit on the intelligent chair in order to consider them as real users for the system. The number of people who involve in this survey is 50. Table I shows the survey questions and the level of acceptance in percentages for the target people. Here, we define the level of acceptance in percentages as follows:

- 20% to 40% represents a very poor level.
- 40% to 60% represents a good level.
- 60% to 80% represents a very good level.
- 80% to 90% represents an excellent level.
- 90% to 100% represents a perfect level.

TABLE I
A SURVEY FOR THE LEVEL OF ACCEPTANCE FOR THE PROPOSED TAS SYSTEM

QUESTION	ACCEPTANCE LEVEL	MEAN PERCENTAGE
THE GENERAL DESIGN		
The Attractiveness of the TAS App	PERFECT	95.4%
The text size and the interfaces design	PERFECT	98.3%
The color of the interfaces	EXCELLENT	85.9%
The general structure is understandable	EXCELLENT	83.1%
THE UTILIZATION		
The App is easy to use	EXCELLENT	86.4%
Moving forward and backward is easy	EXCELLENT	89.5%
No delay when moving between interfaces	PERFECT	97.3%
THE CONTENT		
The content has enough information	PERFECT	92.1%
The content is accurate	EXCELLENT	85.7%
The presentation of the content	VERY GOOD	78.3%
The reports are understandable	PERFECT	98.2%
THE INTELLIGENT CHAIR		
Comfortability when sitting	VERY GOOD	79.8%
The general appearance of the chairs	EXCELLENT	88.1%

IV. CONCLUSION

In this paper, we have proposed time attendance system based on WSNs where sensor nodes are installed in intelligent chairs. We build a smart classroom where it is included with twenty 50kg load sensors and five HX711 amplifiers. In addition, the smart classroom installed with ZKTeco ZK4500 fingerprint reader in order to read the daily fingerprints of five students who sit on pre-assigned five intelligent chairs. The load sensors measure the weights of a student while he/she is sitting on the chair. Those weights are sent in form of packets to a master sensor node which collects these packets and forwards them to the system server which is utilized to calculate the durations of students attendances. When a student is absent, zero weight will be sent in the packet, which means that there is nobody is sitting on the chair. When a student leave his chair the sensor nodes send packets again to the master sensor node

which forward the packets with zero weight to the server, this indicates that the student is leaving the chair and hence calculation the attendance duration which is stored in the database. We implement our proposed time attendance system in a real smart classroom which has all components that explained early. We found that the proposed Android TAS application works perfectly.

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