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International Journal of Engineering, Science and Technology
Vol. 10, No. 1, 2018, pp. 23-39

INTERNATIONAL JOURNAL OF ENGINEERING, SCIENCE AND TECHNOLOGY

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SwyftTapp: An NFC based attendance system using fingerprint authentication

B. Kommey[1]*, O. Anyane-Lah[1], W.E. Amuzu[1]

[1]Department of Computer Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, GHANA*
[*]Corresponding Author: e-mail:bkommey.coe@knust.edu.gh, Tel +233-50-7703286

Abstract

Attendance has evolved to become a key requirement in educational institutions worldwide. With empirical evidence showing correlation between students'academic performance and attendance, parents, guardians, lecturers and school administrations make effort to monitor attendance of students to classes and academic events. The conventional method for recording attendance in the Kwame Nkrumah University of Science and Technology (KNUST), is the manual system, where sheets are passed round for students to write their names, student ID numbers and then append their signatures. The current manual system was observed to be both inefficient and time-consuming. In this paper we discuss the use of NFC technology coupled with fingerprint verification technology, designed to work with an API and a web-based application to implement a more effective approach for recording and managing attendance in the university. The Department of Computer Engineering, KNUST was used as the scope of the project.

*Keywords:*Attendance, RFID, NFC, Fingerprint Technology, API, Web-based Management System

DOI: http://dx.doi.org/10.4314/ijest.v10i1.3

1. Introduction

The concept of attendance and attendance monitoring has been in existence since man learned to count and keep records. Attendance monitoring has since evolved to become an integral part of every functional society. The activity of monitoring attendance is practiced by institutions such as schools, societal groups and business organizations to keep track of attendance ergo the development of systems used to monitor and manage attendance in these institutions. Research has shown that there is a significant relationship between students' academic performance and levels of attendance (Newman-Ford et al., 2008). In educational institutions, attendance has become both a requirement for institutions and a responsibility for students. Educational institutions keep track of students' attendance and set corrective measures to ensure students conform to the set rules relating to attendance.

In the Ghanaian educational system, attendance, regularity and punctuality are qualities that are programmed into the student from an early age. At the primary and junior high school levels, a teacher takes attendance in most schools by calling out a student's name and checking the corresponding date of attendance in a book known as an attendance register. In most senior high schools, prefects are given the mandate to record attendance of their colleagues. This trend of monitoring attendance has moved on into Ghanaian universities, with institutions practicing either the primary and junior high school or the senior high school technique of taking attendance, or fusing both methods. In KNUST, a majority of lecturers take attendance between once and thrice per semester, while the school examination board takes attendance during examinations to monitor student turn-up. During lectures and quizzes, lecturers pass sheets of papers during classes for students to enter their names, student identification numbers and verify using their signature. In examination situations, the examination authorities come round to inspect student ID cards manually before handing the students a list for them to find their names and append their signatures against them. To make data obtained from monitoring attendance useful, there is a need to ensure quality of information in order to reflect the true attendance of the student, a need to ensure the activity of taking attendance does not disrupt the purpose for which the presence of the individual, in this sense the student, is required. There is also a need to maintain records of attendance history. The current method of attendance taking in Ghanaian universities comes with drawbacks such as time wasting, problems of authentication, verification and the problems that come with the organization and storage of hard copies of attendance data and its analysis.

The aim of this paper is to outline the development and prototyping of a scalable attendance monitoring system using NFC for identification and fingerprint technology for verification while providing a platform for the effective management of data obtained from attendance recorded. Considering the significance of attendance monitoring and management, studies have gone into the advancement of ways to automate, improve the speed of taking attendance and authentication of the information gathered during the activity of attendance taking using modes of technologies such as RFID and NFC, fingerprint readers and facial scanners. In Ghana, biometric information is being used for identification during registration for elections and passport processing. KNUST also uses biometric technology during the registration of students. However, an issue for KNUST is the application of these modern technologies to the process of attendance taking and the manipulation of such information.

2. Literature Review

The importance of an effective Attendance Management System has fueled substantial research into the field. Researchers and industry professionals have proposed and designed alternate methods to take attendance and manage data from attendances taken. To develop our system, we reviewed existing efforts and identified their characteristics and ease of implementation.

NFC Supported Attendance System in a University Environment

This system, known as TouchIn, proposed by AnugerahAyu Media employed NFC technology, Android and a web-based application for management of attendance information (Anugerah, 2014). In this system, the user i.e. the student taps his or her NFC-enabled mobile device to a poster or a lecturer's NFC mobile device, both connected through Wi-Fi to a database. Attendance data can then be accessed via a web-based application by the appropriate authorities. Mobile devices used in the system were running a special application that facilitated communication between the device and the server. This system though fast and works to solve the problem of time wastage comes with certain drawbacks. The dependence of the system on the ownership of NFC-enabled phones by all students and lecturers who want to use the AMS brings about a limiting factor in the effective implementation of the proposed system since it might not be possible for all lecturers and students to have NFC-enabled mobile phones. The implementation of this system without ensuring all users have NFC-enabled mobile phones will lead to difficulty in effectively monitoring student attendance, and the fragmentation of attendance data.

Benyo's proposed system, student attendance monitoring at the university using NFC (Benyo, 2012) also employed the use of NFC technology. Their system involved the use of NFC capable student ID cards to mark attendance. Users therefore do not require an NFC enabled phone, thus solving the problem in AnugurahAyu'sTouchIn solution. A backend application was created to generate the identification policies, collect and store data accessible via a web interface. This system just requires a tap to identify a user making it very fast secure to use. This system however as with other NFC based attendance systems does not provide a way to verify the identity of individual students. Students can therefore take attendances for absent friends.

Biometric Attendance Monitor

This system employs biometric technology and an application hosted on a client PC to monitor user attendance and manage attendance data (Yusof, 2006). In this system, user biometric information and data is collected and stored in a database. During the process of attendance taking, a fingerprint reader connected via USB to a PC running the attendance module scans the student's fingerprint. The student's fingerprint is verified and his or her attendance record is updated. The system also generates periodic reports. Reports are available to authorised users, lecturers and examination officers when they sign in into the AMS web application. Asante, Ohenebah-Amissah and Osei implemented a similar system where a fingerprint scanner was connected to a terminal running a PHP web application hosted on a server (Asante et al., 2014).

Gonnade et. al. and Rao and Satoa in 2013 proposed an automated system for attendance management using fingerprint verification done by the extraction of minutiae technique (Gonnade et al., 2013) (Rao &Satoa, 2013). These systems run by checking the fingerprint captured by the fingerprint reader against templates stored in the application database. And updated the user's attendance records if biometric data matched with what was in the system. In 2014, Chandrasekar and Natarajan proposed an AMS that worked on a handheld fingerprint device (Chandrasekar& Natarajan, 2014). The system captured the fingerprints of the students, compared them to templates stored in local storage (Walia, 2016), and automatically created an attendance sheet into an excel sheet for each attendance session. The device could however be connected to a computer system to retrieve attendance sheets for management and analysis of attendance data.

Walia and Jain's (2016) review of fingerprint attendance systems showcased the reliability of biometric technology used in attendance systems. They captured the advantages and disadvantages of fingerprint attendance systems implemented with different tools and techniques including LabView, Internet of Things, GSM and ZigBee, RFID and android, ZigBee, DSP and Matlab, RFID, GSM and .Net and cryptography. These technologies could be combined to produce more efficient systems. A major issue in the biometric technology however still existed. Although biometric AMSs provide an almost fool proof method of verifying user identity, the systems identified all pose an underlying problem of relatively high time consumption since they all require a one-to-many matching system i.e. one fingerprint to be matched to all fingerprint templates stored in the database. For an institution like a university, the scalability of these systems is not realistic.

Automated Biometric AMS with Bluetooth and NFC Technology

This system uses NFC and Bluetooth technology to establish connection to a computer terminal to identify a user, then relies on a fingerprint biometric scan to authenticate the user's identity, transferring details of the user, if identity is correctly authenticated, to be stored in a database over a TCP/IP connection (Opoku, 2013). This system required that a user would have his/her phones Bluetooth address, biometric information and two NFC tags: an entry tag and exit tag, with the user's details in a database connected to a dedicated terminal. The user has to establish a connection with the terminal via Bluetooth to verify the phones MAC address (Vishal et al., 2013). If the address is found, the user verifies his identity-using fingerprint. If both processes are successful, the user uses his entry tag, if arriving into the building, or exit tag, if exiting the building, to finally register his tag ID; Bluetooth address and time the tag was read to the server to mark attendance. In an effort to bridge the gap between user identification and verification, these systems added Bluetooth technology to serve as a second authentication layer. The primary drawback of these systems is also the problem of actual integration into the system since not all students are likely to use a Bluetooth capable NFC-enabled phone. Another issue associated with these systems is that students at all times have to carry at least two tags, which can be cumbersome and confusing as to when to use each.

NFC Based AMS with Facial Authorization

This AMS system makes use of an NFC reader module on a Raspberry Pi to validate the system user i.e. the student, the system then performs a real-time facial scan to authorize the user (Wani et al., 2014). In this system, the student's details and facial template is pre-loaded into the AMS database on through a registration process, during attendance taking, the student is identified when he taps the NFC reader with his NFC tag. The identification of the particular student is then authenticated through a real-time facial scan. If both validation and authorisation are successful, the student's attendance record is then updated in the application database. This system was designed to give admin access to the database in order to generate reports based on data collected from the attendance monitoring process. Unnati and Swaminarayan (2014) proposed a variation of this system, replacing the NFC module with an RFID-based module due to its ability to read several tags simultaneously. This system also modified the real-time facial scan procedure into an image capture and analysis system. The user's image was to be captured by the camera module, then analysed by an underlying facial recognition algorithm. Unnati and Swaminarayan's system's working principle was adapted and made mobile by Bhise et. al. (2015), proposing the use of an NFC enabled mobile device with an embedded camera. In this system, the student taps the lecturer's NFC-enabled phone with his or her NFC tag for identification. The lecturer then takes a picture of the students face to authenticate through facial recognition.

These systems amalgamate the use of NFC technology and facial authentication while avoiding other redundancies such as Bluetooth. Although these systems are theoretically efficient, facial recognition and authentication has certain limitations that hinder effective performance. The 2D facial scanners, which are currently the most popular facial recognition systems have a problem with accuracy of scans under certain conditions such as low light and image capturing angles; caused by user movement during scanning (Grant, 2014).

3. Methodology

3.1 System Design Overview

The design of the system proposed in this paper as shown in Figure 1 is broken into two parts; the hardware design - the SwyftTapp Reader and the software design - the SwyftTapp LecturerPortal, API and Database. The hardware design of this project which is the SwyftTapp Reader is a handheld device that is envisaged to enable lecturers take attendance of students using NFC enabled ID cards with biometric authentication. The SwyftTapp Reader has Wireless LAN (WLAN) capability, which enables it to communicate information over a Wi-Fi network to be able to authenticate a student's identity using a prepopulated database containing unique codes for the student's NFC ID card and fingerprint biometric information.

The SwyftTapp Reader was modelled with a basic BCM2836 as an underlying microcontroller as shown in Figure 2. The microcontroller system communicates serially over UART with an on-board NFC Module (PN531 NFC Module) designed by Philips. These modules, integrated, are then connected via GPIO pins to a fingerprint scanner; to register fingerprints from users (students) and an LCD Touch Screen for information display and user interaction. The on-board microcontroller draws its power from an inbuilt power management system that generates 5V supply from an external voltage source with voltage regulation.

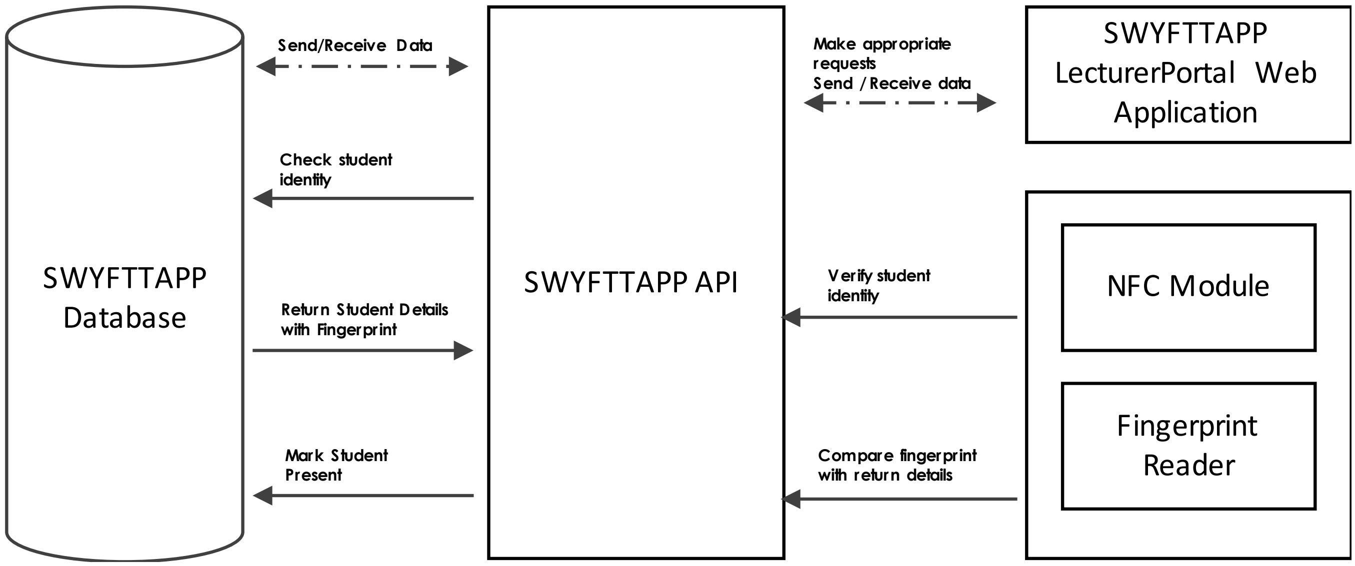


Figure 1: System Design Overview

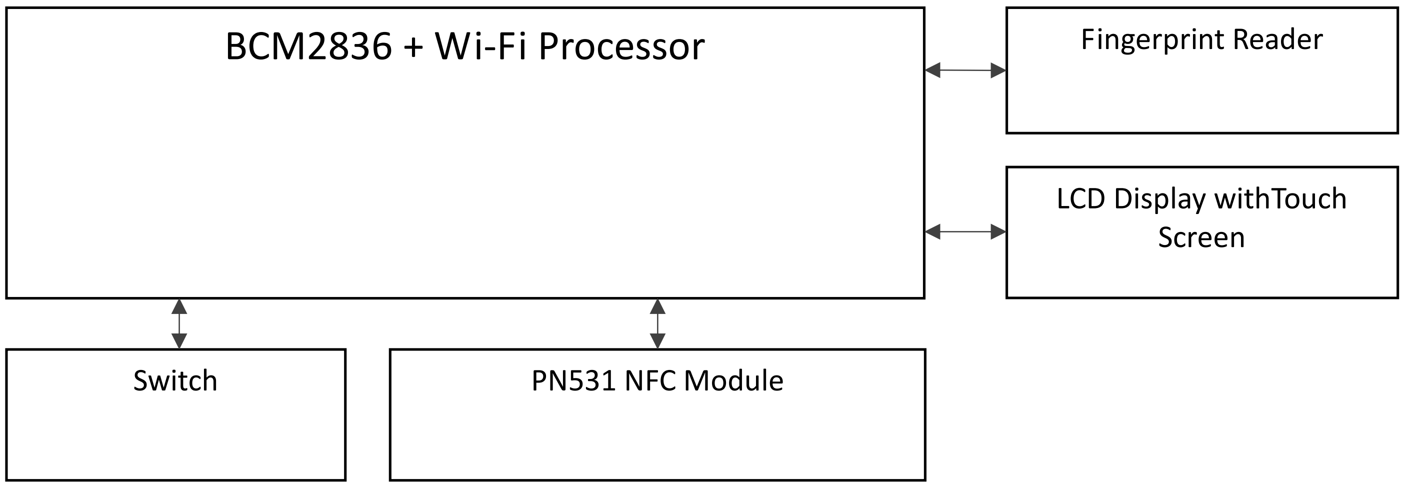


Figure 2: Hardware Design Overview

The software design of the project, as shown in Figure 3, involved three main components, a database, an API and a web application. A MySQL relational database system optimized for efficiency and security of data was used as in the development of the propose solution. The API, or SwyftTapp API, is a RESTful API built using Java on the SpringBoot framework to facilitate communication with the SwyftTapp Reader and SwyftTapp LecturerPortal web application relaying information to and from the database. The SwyftTapp API is built to facilitate interaction through HTTP requests making it possible for connection from other applications such as mobile applications. The SwyftTapp LecturerPortal serves as a portal for lecturers to view attendance data in a simple and intelligent environment. The SwyftTapp LecturerPortal was designed and built using the latest web technologies; HTML 5, CSS and JavaScript using the AngularJS framework to communicate with the SwyftTapp Database via the SwyftTapp API through HTTP requests using JSON data.

The hardware and the software system come together to form an integrated interactive system which provides an efficient, user-friendly means of recording and viewing attendance data for the benefit of both the lecturer and the students in the class. When using the SwyftTapp system, the lecturer or exam officer starts a new attendance event on the SwyftTapp reader. On starting the event, the reader sends a request to the API which replies with a list of students in the particular class. Students then take turns tapping the NFC Reader with their cards to identify themselves, and then use their fingerprints to authenticate their identity. After all students present have gone through this process, the lecturer closes the attendance event. Optionally, the lecturer can decide to take another attendance for the same event by selecting the option to take a closing attendance. After the event - class, mid-semester or end-of-semester examinations and all attendances have been closed, the lecturer can then log into the SwyftTapp LecturerPortal to view data and statistics about the attendances taken

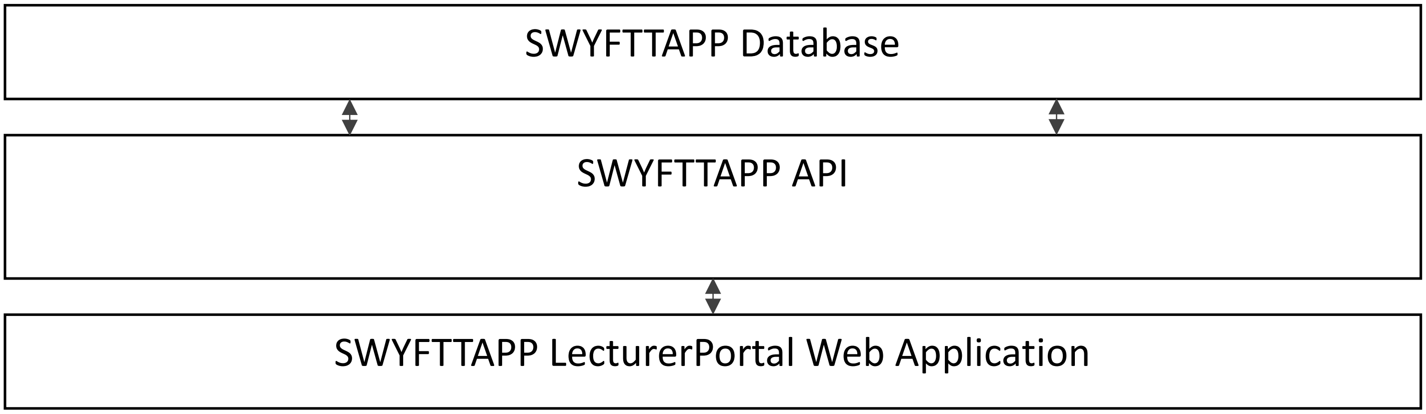


Figure 3: Software Design Overview

3.2 Software Design

The software for the application was designed as a distributed system comprising a front end web application (SwyftTapp LecturerPortal) which serves as the access point of the lecturer where he/she can login to view and manage attendance records and a back end API that handles all the business logic of the application. To perform its tasks, the SwyftTapp LecturerPortal makes HTTP requests to the backend application (API) using RESTful protocols. The API then returns data as JSON objects which is then used by the frontend application to populate its views and perform other tasks. The user friendly GUI makes it easy to navigate the application and present data to the user in a clean easy-to-read format.

The SwyftTapp API serves as the brain of the application as it handles all the logic and database interactions. This reduces the load on the front end application, making it more efficient and provides a central access point for both the LecturerPortal and the reader applications. Its RESTful nature also means that it can be easily integrated with existing applications. To ensure that only authenticated users are allowed to access information, every request to the API requires a unique token without which access is denied.

3.2.1 Requirements Capturing and Analysis

In order to meet the expectations of the end users of the software, frequent communication was kept with users, in this case the students and lecturers, to capture their views and opinions of the prototype developed at each stage of the lifecycle of the project. The software was then developed using these specifications gathered as guidelines.

The main mode of gathering these requirements was by interviewing the target users i.e. the lecturers and students, and recording observations made. After developing a working prototype of the SwyftTapp LecturerPortal, it was shown to a selected number of lecturers and students in the computer engineering department of KNUST which represents the scope for the project. The students, who are going to be users of the SwyftTapp reader were also interviewed to discuss the present methods of attendance taking in KNUST and their thoughts on the proposed solution.

The lecturers provided useful information on how they would like the app to work including the information they wanted to capture about the student in the attendance list, how they wanted to rate the attendance of students to their lecturers, and the details they wanted on the dashboard page of the application. After recording these specifications and their desired changes to the application, the lecturers were again interviewed and shown the improved prototype of the application to make sure their specifications were met.

The lecturers provided useful information on the use cases they wanted the app to address including the information they wanted to capture about the student in the attendance list, how they wanted to rate the attendance of students to their lecturers, and the details they wanted on the dashboard of theLecturerPortal. After recording these specifications and their desired changes to the application, the lecturers were again interviewed and shown the improved prototype of the application to make sure their specifications were met.

Students in the scope of the project were also invited to answer a questionnaire hosted on Google Forms. This questionnaire was to assess students' views on the state of attendance in the department. The questionnaire looked specifically at the student year, students' thought on how attendance is taken and the effectiveness of the rate at which it is taken. Students also answered questions on whether they believed attendance was important, whether there was a need for a better system of taking attendance, and if they felt the scores being allocated for attendance reflected their actual attendance to class. The questionnaire received 109 responses in total. These responses were then analyzed and represented in graphical form. The various charts below show a graphical representation of the results (Figures 4 – 7).

From Figure 4, it can be observed that the majority of respondents to the questionnaire were first (1st) year students, with the least respondents being in the third year (year 3). Figure 6 shows that the majority of students who responded to the questionnaire were of the opinion that the current methods of attendance taking and the frequency at which attendance was being taken in the school was fair.

Figure 4: Distribution of Students Who Responded to the Questionnaire

Do you believe taking attendance is important?

Do you believe scores given for attendance reflect student attendance to class?

Do you think there is a need for a better method of taking attendance in KNUST?

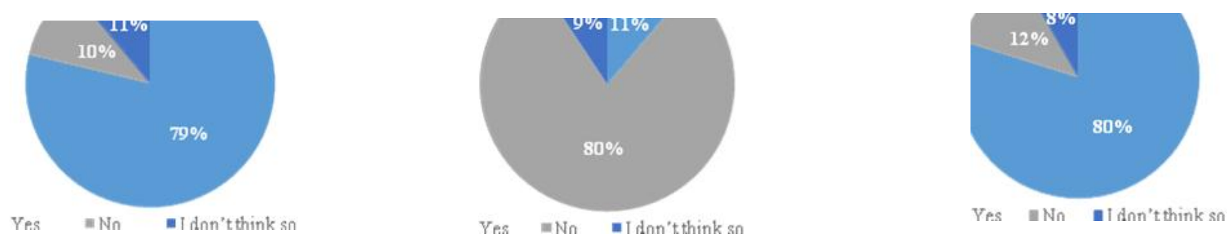


Figure 5: Students' Views on the Current State of Attendance I

From observations in Figure 5, it can be observed that the majority of respondents believed attendance taking was important, that the scores given for attendance did not actually reflect a student's attendance to the said course. It also shows that the majority of respondents also thought there was a need for a better method of taking attendance in KNUST

What is your opinion on how attendance is currently taken in KNUST?

What do you think about the number of times attendance is taken during the semester?

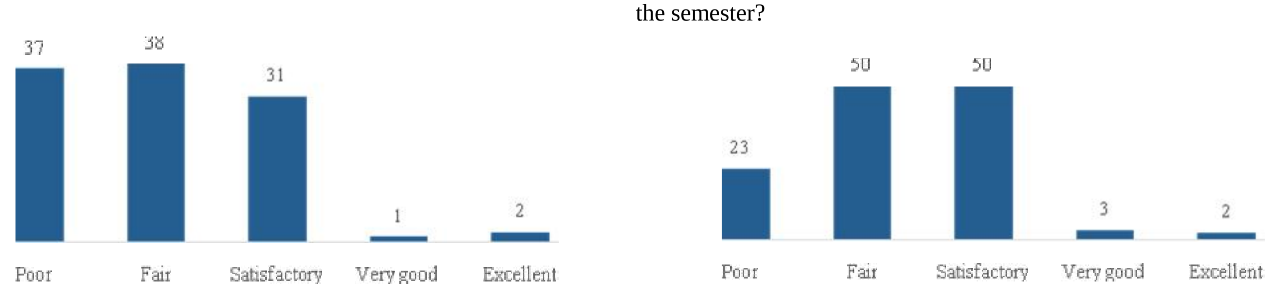


Figure 6: Students' Views on the Current State of Attendance II

Figure 7: Methods of Taking Attendance by the Lecturers of the respondents

Figure 7 proves that majority of the attendance taken in the department was either by passing sheets around for students to sign or by a combination of the afore mentioned and the lecturer mentioning the names of the students.

Functional Requirements

The following functional requirements were gathered at the end of the requirements gathering process.

- On the LecturerPortal, the lecturer should be able to view attendance list, perform analysis on attendance data, class and course lists
- On the reader, the lecturer or exam officer should be able to start, end or take a closing attendance
- On the reader the student should be able to verify his identity using his NFC card and authenticate his attendance by using his fingerprint

Non-Functional Requirements

The non-functional requirements of this system, representing the system specifications, security requirements, and software and hardware quality constraints were gathered to produce an easy to use, secure, safe and fast system to provide the best user experience to the end users of the application.

Use Case Diagrams

The use case diagrams shown in the Figures 8, 9 and 10 below provide a pictorial representation of the actors and the actions they can perform in the two identified use cases of the system. Lecturers and exam officers represent the recognized actors for application.

Students also use the application through the reader. They can tap their school ID cards with NFC stickers on the reader and verify their identity using their finger print. If these steps are successful, the student is marked present in the database.

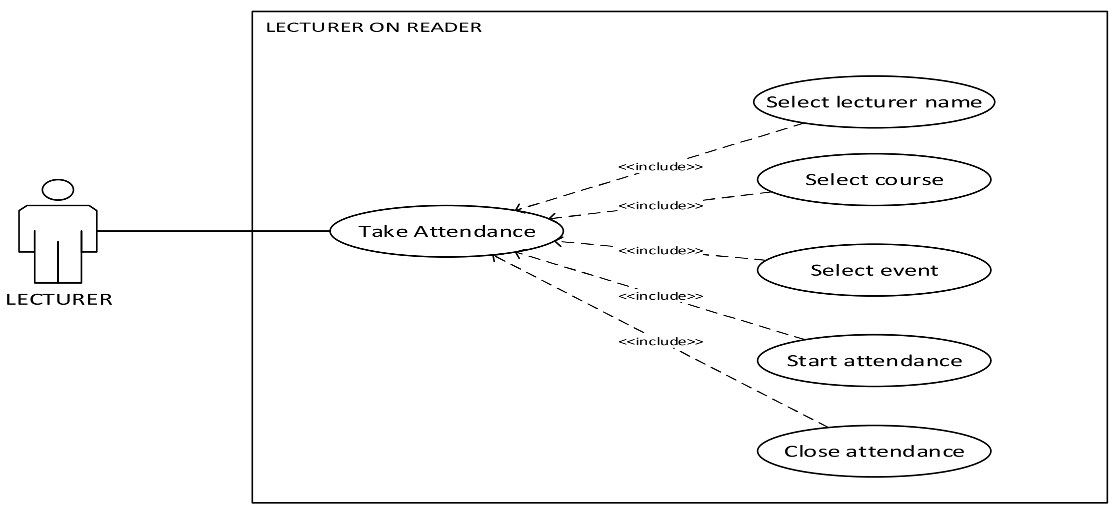


Figure 8: Lecturer on Reader

As shown on Figure 8, on the reader, the lecturer or exam officer should be able to:

- select a lecturer's name
- select a course
- select an event type (lecture, mid semester exam or final exam)
- start an attendance
- end the attendance

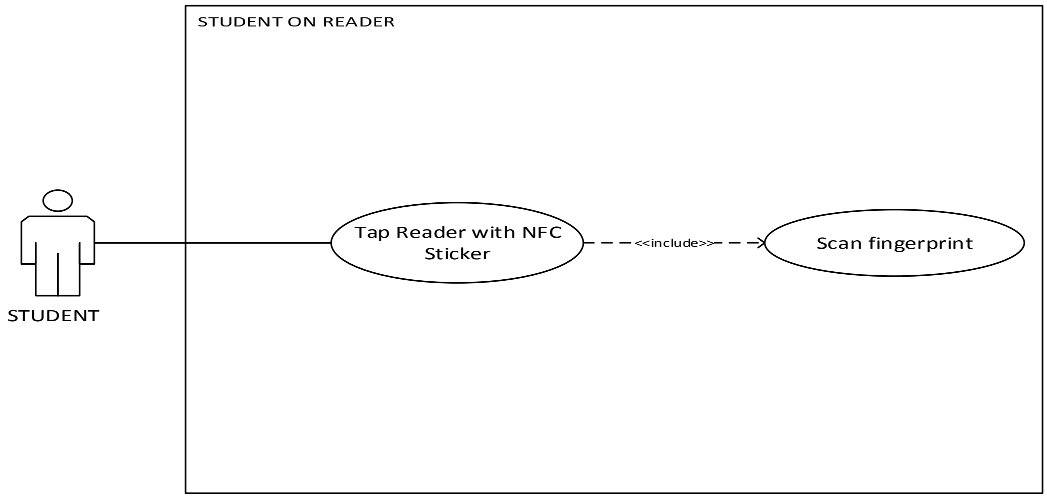


Figure 9: Student on Reader

As shown on Figure 9, on the reader, the student should be able to:

- identify him/herself by tapping with his NFC-enabled card
- authenticate his identity by scanning his fingerprint

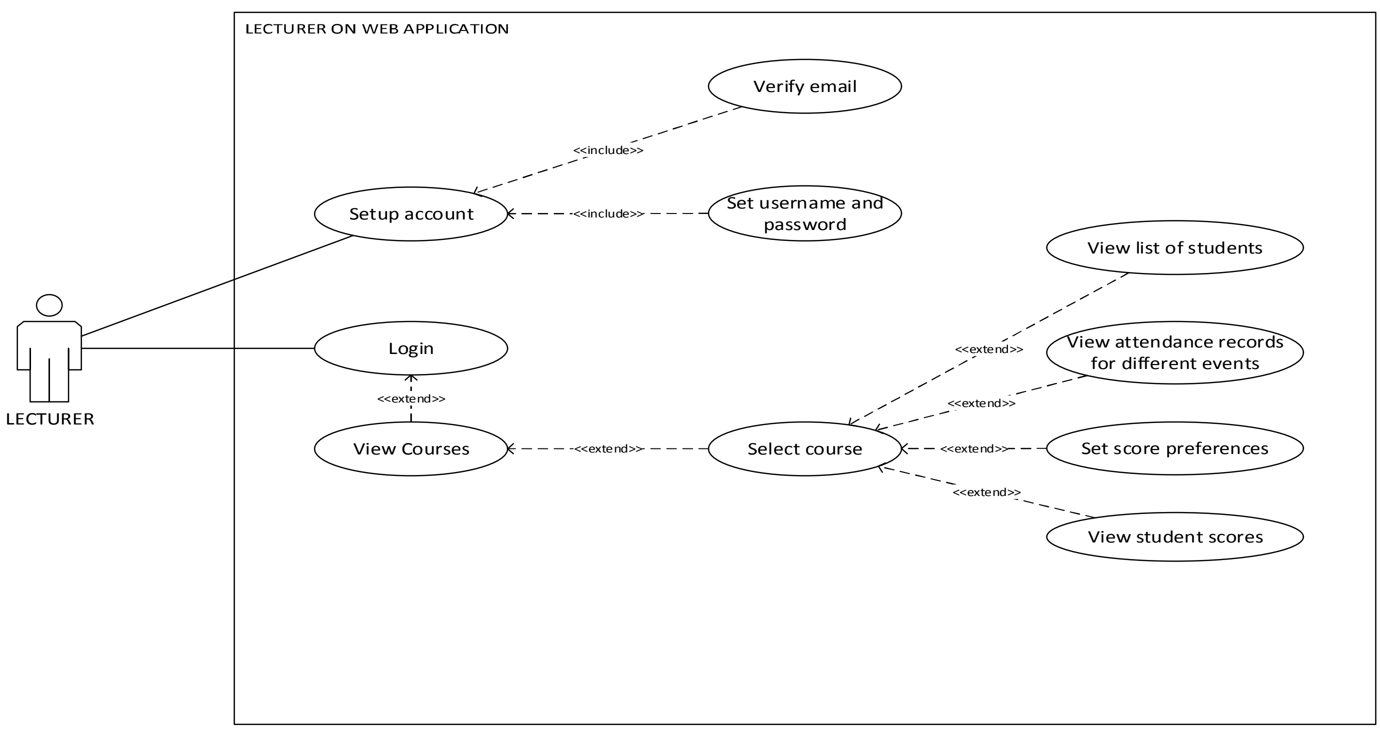


Figure 10: Lecturer on web application

On the LecturerPortal as shown in Figure 10, the lecturer should be able to:

- verify his or her email
- set a username and password

- login to his account
- view his courses
- view attendance records for a course
- view attendance records for different events

3.2.2 SwyftTapp Database

To store and manage all the attendance records data and their related information, a relational database was designed and created in SQL. The database was designed to implement the functionalities of the application, taking efficient use of storage space and easy management into consideration. To add to the security of the application a token table was created to store all the valid tokens that client applications can use to access the API. These tokens are created once a user logs in with a valid user name and password and are expired and deleted once a user logs out of the LecturerPortal. The SwyftTapp Reader's system software also requires a token to access the API.

To easily manage attendance events a table called events was created to store the course for which the attendance was taken, the lecturer who takes that course, the type of attendance event (mid semester exam, end of semester exam or lecture) and a timestamp of when the attendance was started and ended. Attendances can be taken at the beginning of an event or at the end or both. To implement this a Boolean field is used to specify whether a particular attendance is a closing attendance or an opening attendance.

3.2.3 Database Schema

MySQL's efficient storage, searching, sorting and retrieval of data made it an easy choice for the project. Using an MySQL Database Management System, a total of 12 tables were created to cover information about students, lecturers their courses, programs, attendance events and tokens and the relationships between them. The appropriate data types and limits were used in order to use the storage space available more efficiently.

The database ER Diagram in Figure 11 represents the database on top of which the SwyftTapp API was built. In order to make the signup process secure, the details of lecturers are entered into the database leaving their user name and passwords null. To use the application, the lecturer first checks if he is eligible by verifying his college email address. If he is eligible, he then sets his user name and password using a link sent to his college mail. Once the username and password are set the lecturer has access to the application.

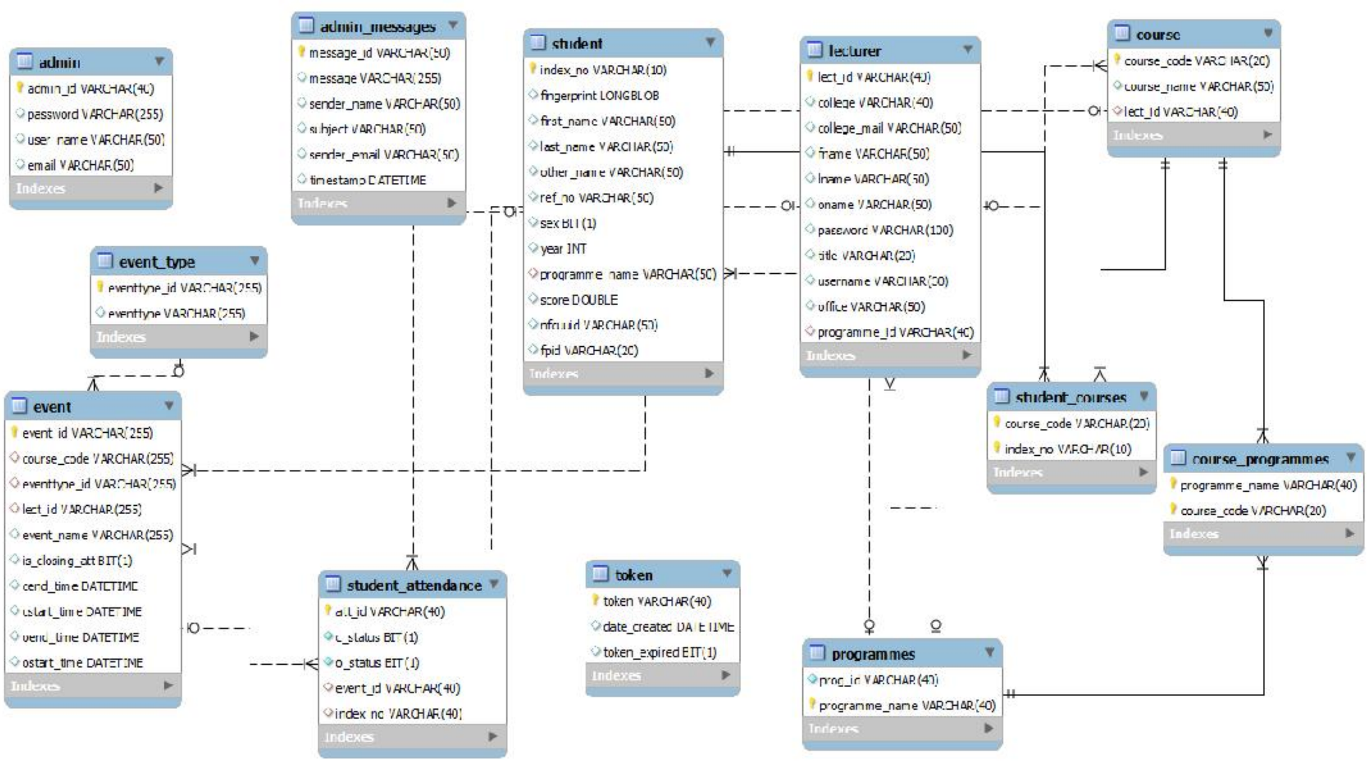


Figure 11: Database Schema

3.2.4 SwyftTapp API

Inputting and retrieving data from the database processed through a Java backend was achieved by creating an API. Classes were created to perform basic CRUD functions as well as other functionalities not related to the database. The SwyftTapp API provides services to both the reader and the LecturerPortal applications using the data retrieved from the database and processed by the backend.

The API is made accessible to the client applications over a network using a RESTful protocol. Each API call has a specific URL through which the backend of the application developed in Java can be accessed.

3.2.5 SwyftTapp LecturerPortal

With the correct credentials a lecturer can login to the LecturerPortal to view his attendance records, generate students' attendance marks as well as view statistics relating to courses the lecturer teaches. The user interface of the application is made simple and easy to use and presents information to the lecturer in a clean and easy to read format.

The signup process is made easier and very secure by pre-populating the database with the details of the lecturers in a department. The lecturer then has to verify that his or her college email exists and is authorized to use the application. Once the lecturer is eligible, an email is sent to the lecturer containing a link to a page where he can set his username and password. From there he has access to all the services provided by the portal through the API.

The LecturerPortal has a dashboard page which shows different chart and graph representations of statistics pertaining to the lecturer's attendance records. The lecturer can get information about the number of students he teaches in total, the number of students present and absent in his courses over the past five weeks, a ranking of his courses from best course to worst course based on student turn up and other very useful information. The API computes these statistics and feeds the LecturerPortal.
This application was built using basic web technologies i.e. HTML, JavaScript and CSS together with Angular JS framework.

3.2.5.1 Software Development

The code sample below shows a CORS filter which specified the HTTP methods and tokens that clients are allowed to make to the API.

```
//Simple CORS Filter
public void doFilter(ServletRequestservletRequest, ServletResponseservletResponse,
FilterChainfilterChain) throws IOException, ServletException {
HttpServletResponseresponse = (HttpServletResponse)servletResponse;
response.setHeader("Access-Control-Allow-Origin", "*");
response.setHeader("Access-Control-Allow-Methods", "POST, GET, PUT, OPTIONS, DELETE");
response.setHeader("Access-Control-Max-Age", "3600");
response.setHeader("Access-Control-Allow-Headers", "Origin, X-Requested-With, Content-Type, Accept,
token, api_key");
filterChain.doFilter(servletRequest, servletResponse);
}
```

Once allowable HTTP requests were allowed, an API controllers were written to control data received from the client applications and data sent from the server. The code snippet below shows the API controller for the request that returns the attendance list for a particular attendance event.

```
//Get Attendance List API Controller
@RequestMapping(value = "/getAttendanceList", method = RequestMethod.POST)
@ResponseBody
public JSONResponsegetAttendanceList(
@RequestBodyObject event
@RequestHeader("token") String token
) {
return studentAttendanceLogic.getAttendanceList(event);}
```

In the code snippet above, the API controller receives the requested event's details in a JSON object together with the access token of the lecturer logged on, then returns the attendance list for that particular event.

The development of the SwyftTapp LecturerPortal was achieved by following best practice rules to ensure security, speed and ease of use. Node through npm and bower were used as package managers for the system.

Using the MVC approach the structure of the working folder was categorized into views and controllers with the model being built as a collaboration of both the views and information received through API calls from the API.

HTML was used as the main language for building the views of the application. Using AngularJS DOM manipulation attributes, displaying information obtained from the API was simpler and faster requiring less lines of code and design.

For example, in the code snippets below, the AngularJS ng-repeat directive is used to display a list of students present for a particular attendance event after an HTTP request had been made to the server to return the list of students present for the class.

AngularJS also makes it simple to bind the model to the views using scope – accessed through the $scope keyword.

```
//Get Attendance list from API
$http.post(SERVER.url + '/getAttendanceList', {eventId: $scope.eventId}, {
headers: {token: $scope.lectInfo.accessToken} , cache: true})
  .success(function (data) {
$scope.attendanceListData= [{
startTime: data.result.startTime,
closeTime: data.result.closeTime,
attendanceLists: [
{students: data.result.students,
programmes: data.result.programmes}]
    }];
})

<!-- Display list of students present-->
<tr
ng-repeat="student in filteredPresentStudents = (attendanceList.students.studentsPresent |
filter:programme.programmeName | filter:search) | orderBy:orderProperty">
<td class="last-row first-column">{{student.indexNo}}</td>
<td class="last-row"><a ng-href="#/sprofile/{{student.indexNo}}">{{student.lname}}
    {{student.oname}}
    {{student.fname}}</a></td>
</tr>
```

3.3 Hardware Design

To implement the proposed system, it was necessary to use embedded programming that facilitated the ability to get maximum features using minimum space and minimum time. It was also important to find a way to get the microcontroller to communicate over a network with the SwyftTapp API.

3.3.1 SwyftTapp Reader System Design

Following the steps in the development of embedded systems to develop SwyftTapp, it was necessary to build a block diagram in order to determine the functional components that will be required to implement the reader system and identify the role of each component in the SwyftTapp reader. A design concept for the SwyftTapp (handheld) Reader was also developed.

The SwyftTapp Reader block diagram, as shown in Figure 12, illustrates the various selected functional components and the way they relate and communicate with each other to produce an efficient hardware system, with the necessary processing power, memory management and a small code footprint.

The block diagram also goes further to illustrate the embedded components pointed out in the hardware design overview (Figure. 12). It clearly shows each component and sub-components, the links and direction of information flow between them and selected specifications.

3.3.2 Functional Components

In the SwyftTapp system, the AMBA APB was used to connect the power management system to the UART, Clock and over a bridge to a Multilevel Advanced High-Performance Bus Matrix which interconnected the CPU, GPU, SDRAM and ROM. The AMBA AHB was chosen for this project due to its efficient usage in high-performance, high clock frequency system modules. The AHB acts as the high-performance system backbone bus. AHB supports the efficient connection of processors, on-chip memories and off-chip external memory interfaces with low-power peripheral macro cell functions. AHB is also specified to ensure ease of use in an efficient design flow using synthesis and automated test techniques. The ML-AHB Bus Matrix implements a multilevel AHB which abstracts a multipath master-slave bus system.

On the Broadcom BCM2836 there are 54 general-purpose I/O (GPIO) lines split into two banks which possess at least two alternative functions within the processor. The alternate functions; usually peripheral I/O and a single peripheral which appear in each bank to allow flexibility based on the chosen voltage. The GPIO peripheral has three dedicated interrupt lines with 32-bit accesses. The GPIO also has function select registers that are used to define the operation of the general-purpose I/O pins. In the development of SwyftTapp, The GPIO interface was used to connect the main board to the fingerprint reader and the LCD touch screen controller. The GPIO is also used to power LEDs to indicate power and operation.

In the SwyftTapp Reader the UART is used to bridge the AMBA APB and the GPIO interface. The UART is also used in the system to communicate with the PN531 NFC Module which requires serial data communication.

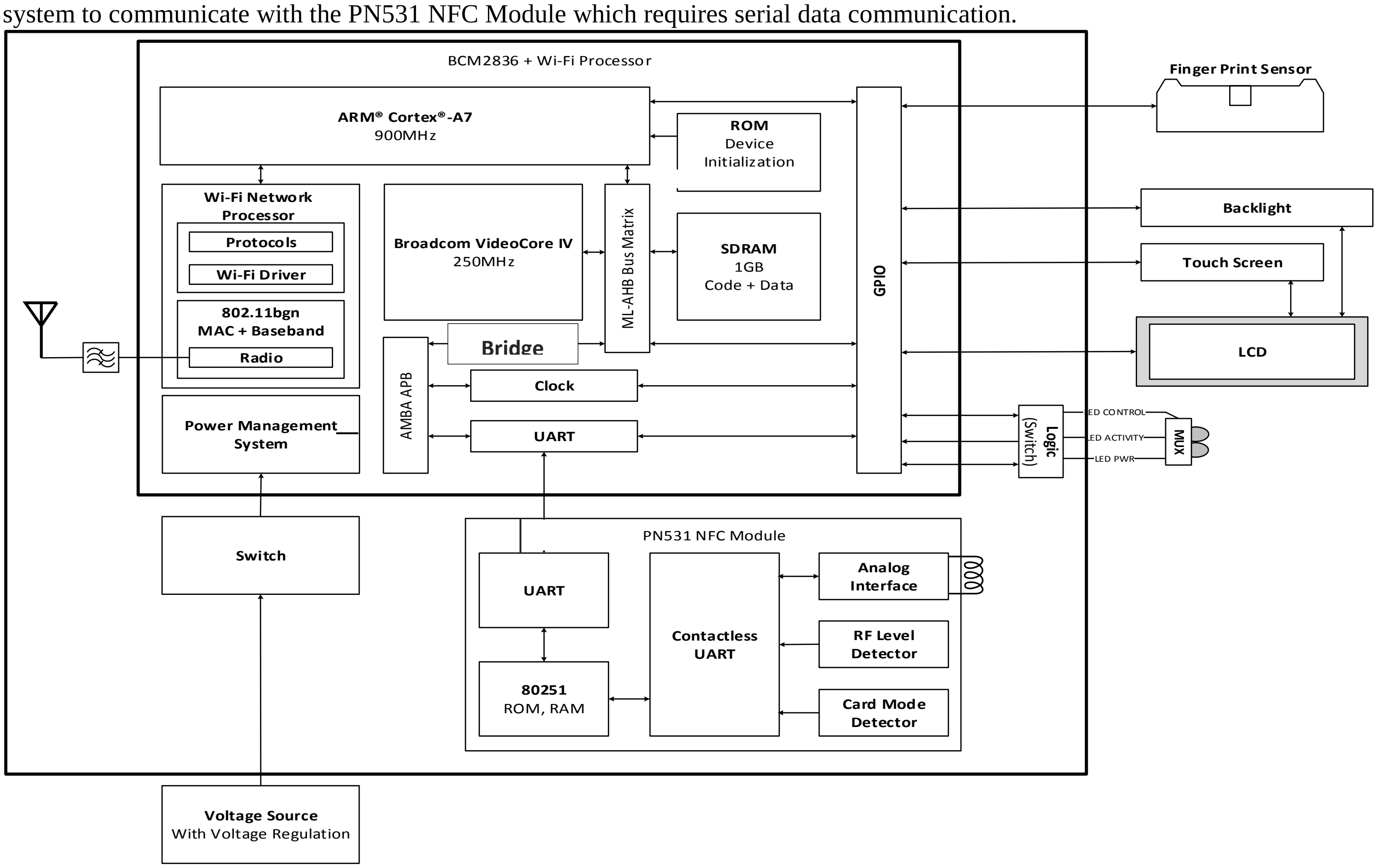


Figure 12: System Design Block Diagram

The PN531 NFC Module was selected to build the SwyftTapp Reader. The PN531 IC uses an 80C51 processor with 32 Kbytes ROM and 1 Kbytes RAM. It supports various industry standard read/write modes. The PN531 can act also as a smart card in combination with a security controller IC. Furthermore, the embedded firmware and internal hardware support the handling and the host protocols for USB 2.0, I2C, SPI and serial UART. The PN531 NFC Module communicates with the BCM2836 SoC integrated with the Wi-Fi Processor.

The transmission module combines an outstanding modulation and demodulation concept completely integrated for different kinds of contactless communication methods and protocols at 13.56 MHz with an easy to use firmware for the different supported modes and the required host interfaces.

As shown in Figure 13, the PN531 NFC modules contains certain functional components that facilitates its operation. These include an analog circuitry interface, a radio frequency level and card mode detector, an 80251 microcontroller all connected to a contactless UART. The NFC module then communicates through microcontroller to the designed SoC via UART

- The analog circuitry interface handles the modulation and demodulation of the analog signals according to the card mode, reader /writer mode and NFC mode communication scheme.

- The RF level detector detects the presence of an external RF field at the NFC operating frequency - 13.56 MHz
- The card mode detector detects a MIFARE®, FeliCaTM or NFC coding of an incoming signal in order to prepare the internal receiver to demodulate signals that are sent to the PN531.
- The integrated contactless UART and the firmware handle the protocol requirements for the communication schemes including the RF based protocols as well as the protocols for host communication.
- The 80251 microcontroller with its embedded firmware allows autonomous management of communication both on the RF interface and with the host.
- The UART interface communicates information serially to the BCM2836 SoC through its UART interface.

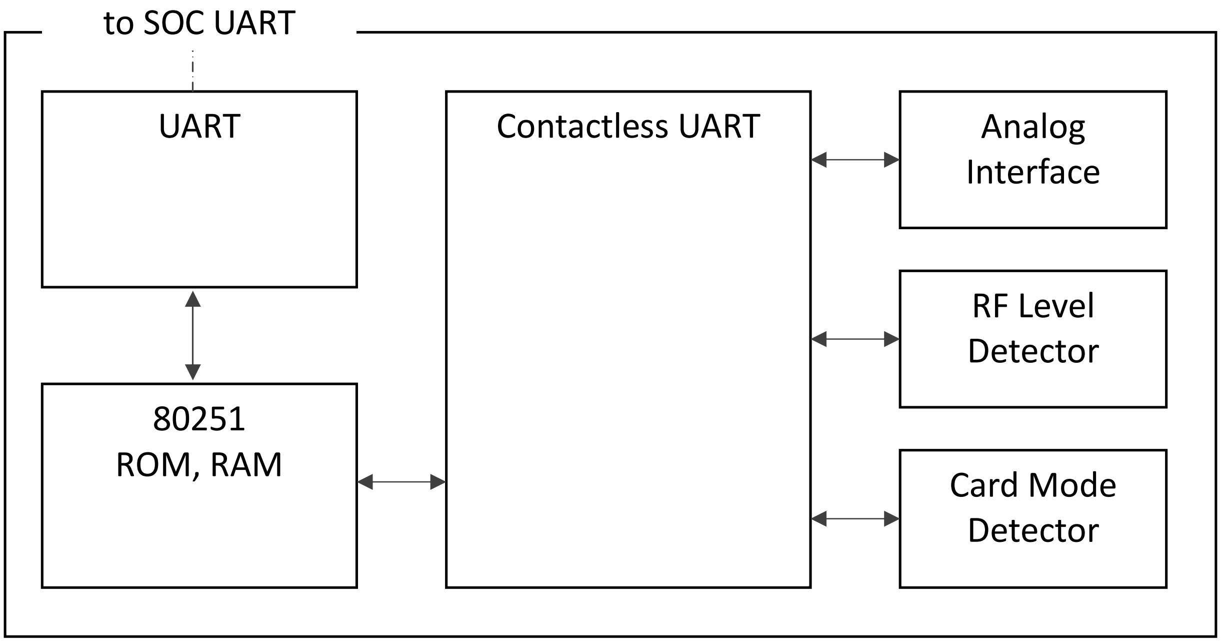


Figure 13: PN531 NFC Module Components

3.3.3 Fingerprint Scanner

To authenticate a student's identity, biometric information is taken after NFC identification is verified. To build the SwyftTapp Reader to be compatible with the existing KNUST fingerprint database, the fingerprint reader selected to be used on the reader uses the same fingerprint recognition technology as the one used for student biometric registrations - the Futronic FS80 fingerprint scanner.

This scanner is a semiconductor type fingerprint reader which uses advanced CMOS sensor technology and precise optical system to deliver high quality fingerprint images in about 100ms relying on 4 infra-red LEDs behind a 14mm thick crown glass for illumination during scanning.

The SwyftTapp Reader, modelled after the FS80 has an optimum fingerprint scanning window of 16 x 24mm and stores images as 8-bit 256 grayscale images with a raw image file size of 150K bytes.

3.3.4 SwyftTapp Reader – Concept Design

In the development of a working concept for the SwyftTapp Reader, a concept design of the final look of the device was created. This design sought to meet modern design demands of simplicity and ease of use while fulfilling requirements for functionality.

The concept design developed for the SwyftTapp Reader looks at all views of the reader whiles placing the necessary ports or output devices that will be used to interact with the device.

From Figure 14:

- The reader could have a charging slot at its base.
- The back of the reader could optionally have a removable back cover.
- The right side will have a switch to turn the device on or off.
- The front side of the reader will then have the screen, space to use the NFC Module and ample space to access the on-system fingerprint reader.

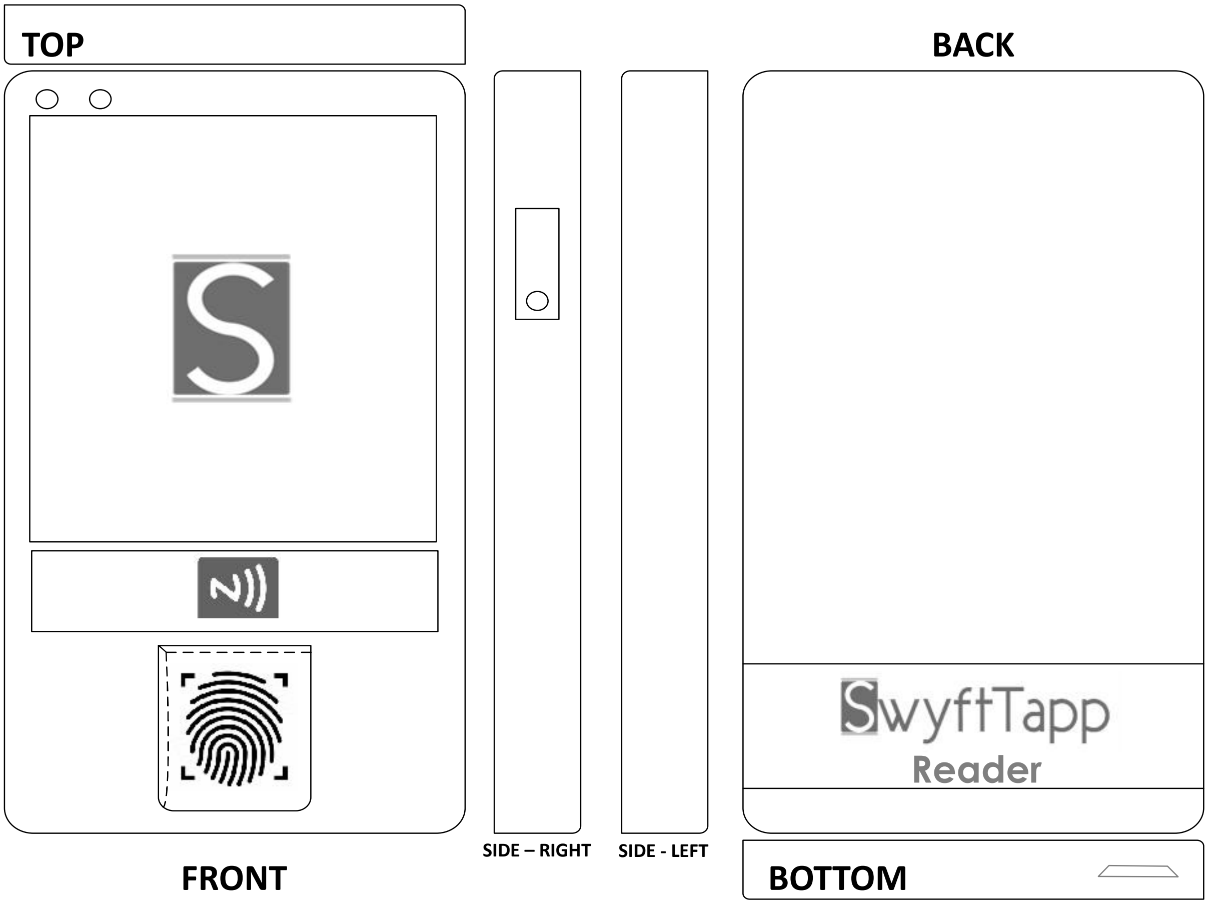


Figure 14: SwyftTapp Reader Package Design

4. Conclusion

This project was conceived in an effort to provide a solution to the need for a faster and more effective way of taking and monitoring the attendance of students and the provision of a platform to handle and analyze data collected from such attendances in KNUST.Using the Computer Engineering department of KNUST as the scope for the project, a system named SwyftTapp was developed. SwyftTapp is comprised of 3 sub-components;

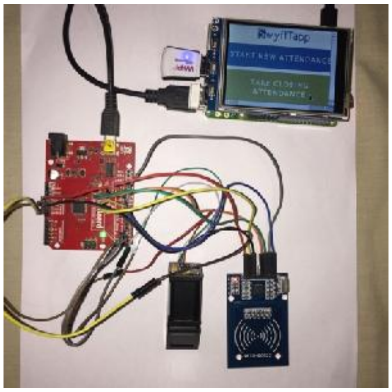
SwyftTapp API

SwyftTapp API was developed to be the processing center for all computationally intensive processes that were to be done in the background of the system. The SwyftTapp API formed the link between the database and both the Reader and LecturerPortal applications.The SwyftTapp API was built to handle expansion and on the principle of the modularity, making it possible for the creation of other applications, such as mobile applications to tap into the SwyftTapp ecosystem.

SwyftTapp Reader

The SwyftTapp Reader was developed as a concept design with functional components and block diagrams clearly explained. Also the rationale behind the selection of those components were broken down. The SwyftTapp Reader was then prototyped using a raspberry pi, and MFRC522 RFID module and a fingerprint module to simulate the operation of the reader.

The images below show the prototyped reader in action.



The image above shows the complete setup for the SwyftTapp prototype reader

The image above shows s lecturer starting a new attendance event

The image above shows s lecturer starting a new attendance event

After a student taps the RFID reader, his details are displayed on the touchscreen with a notification to take a scan of his fingerprint. The fingerprint reader lights up –to wait for a fingerprint style.

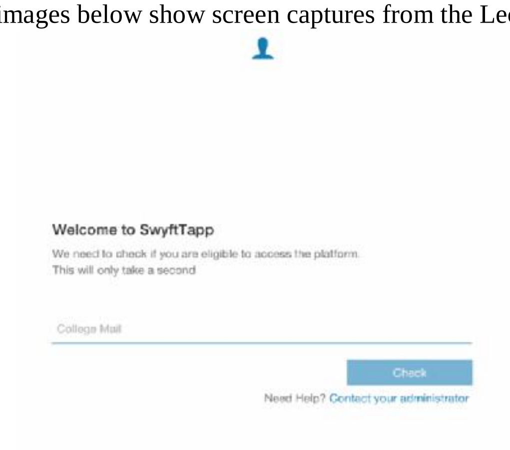
The image above shows a student scanning his finger on the fingerprint reader.

If a student's fingerprint matches his detail, a notification pops up on the screen to show the attendance was recorded

SwyftTapp LecturerPortal

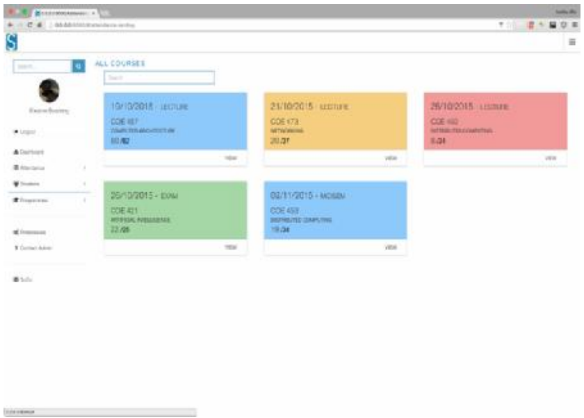
The LecturerPortal is a web application built for lecturers to be able to access first hand data obtained from attendances that are taken using the SwyftTapp Reader. The portal was built using modern web development technologies that promote modularity and ease of use without compromising on security.

The images below show screen captures from the LecturerPortal:

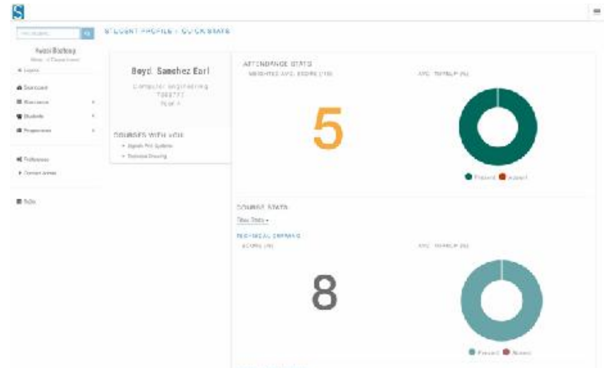


Account activation page: The lecturer checks the SwyftTapp Database to verify his details. If successful the lecturer can proceed to sign up onto the system

Upon login the lecturer is greeted with a dashboard showing all relevant highlights relating to student attendance to his lectures and examinations



The picture above shows a screen that lists all attendance event a lecturer has recorded with realtime searching and sorting. The card-based interface is color coded depending on the quality of attendance to each event



The SwyftTapp LecturerPortal automatically calculated attendance scores for student according to total scores allocated for each course by the lecturer

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Biographical Notes

B. Kommey received Dipl.-Ing. from the Technical University of Berlin, Germany and thereafter worked in Germany for many year as Field Application Engineer as well as Embedded Systems Products and Applications developer for companies like ABB, Heinrich-Hertz Institute HHI, Aglaia, ProContour, Nanatron Technologies and Promess Berlin GmbH. He has extensive working experience in software and hardware design. Currently, he is a lecturer in the Department of Computer and Biomedical Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

O. Anyane-Lah and W.E.Amuzu both received BSc. in Computer Engineering with Honors from the Department of Computer and Biomedical Engineering, Faculty of Electrical and Computer Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Both are currently, working as partners in their own startup company focused on Blockchain technology

Received May 2017
Accepted July 2017
Final acceptance in revised form July 2017