Ministry of Education and Science of the Republic of Kazakhstan
Suleyman Demirel University

Mamatnabiyev Zhumaniyaz

Application of IoT Technologies for Managing the Educational Process in University

THESIS

Presented in Partial Fulfillment for the
Degree of Master of Science in Computing Systems and Software
(degree code: 6M070400)
Department of Computer Sciences
Faculty of Engineering and Natural Sciences

Supervisor: **Suliyev Rassim**

Kaskelen, 2019

Abstract

Recently, applications of Internet of Things (IoT) technologies have been established in many organizations offering low-costed, low-powered, automatic systems. In addition, IoT systems are secure, less time-consuming, and controlled remotely. Implementing IoT technologies in managing the educational process makes huge changes by creating digital classrooms and automation systems. However, taking students' absence report is still critical element or issue in the education sector that is more paper work, which is time-consuming, requires much workforce and efforts, and imposes inefficiency. Various automatic identification technologies have been developed using Radio Frequency Identification (RFID). Many research works and projects are produced to take maximum benefits of using this technology. RFID is an automatic technology and identifies tagged objects from an environment through radio waves. RFID reads data from RFID tag and sends it to server or cloud using IoT hardware platforms like microcontrollers and microprocessors. The current work proposes automatic attendance monitoring system (AMS) using IoT technologies including RFID and hardware platforms. The objectives of the proposed system are to check attendance of students automatically with human interface, inform students about gaps in attendance, and monitoring instructors whether they come to lessons on time. Based on the results, the proposed AMS time-effective, economically available, and has not any power consumption. The system is analyzed and criticized respect to other authors' works. Future works are also discussed and identified.

Аңдатпа

Қазіргі уақытта көптеген ұйымдарда арзан, төмен қуатты, автоматтандырылған жүйелерді ұсынатын Барша Заттың Интернеті (IoT) технологиялары үлкен қолданысқа ие. Сонымен қатар, IoT технологиялары операцияның орындалу уақытын азайтады, қашықтықтан басқарылады және қауіпсіз жүйе ұсынады. Оқу үрдісін басқару барысынды IoT технологияларын енгізу цифрлық сыныптар мен автоматтандыру жүйелерін құру арқылы үлкен өзгерістер алып келеді. Алайда, студенттердің сабаққа қатысуын қадағалау әлі де білім беру секторындағы проблема және маңызды элементі болып саналады. Сондай-ақ, бұл көп уақыт талап ететін, көп жұмыс күші мен күшжігерді қажет ететін және тиімсіздікке әкелетін қағаздармен жұмыс істеу болып табылады. Әртүрлі автоматты идентификациялық технологиялар Радио Жиілікті Сәйкестендіру (RFID) арқылы іске асырылады. Көптеген ғылыми-зерттеу жұмыстар мен жобалар осы технологияны қолданудың барынша пайдасын алу жолын көздейді. RFID автоматты технология болып табылады және радио толқындар арқылы қоршаған ортадағы тегтелген нысандарды анықтайды. RFID қабылдағыш тегтегі деректерді оқиды және микроконтроллер немесе микропроцессор сияқты IoT аппараттық платформаларын пайдалана отырып оны серверге немесе Бұлтқа (Cloud) жібереді. Осы жұмыс IoT технологияларын, соның ішінде RFID және аппараттық платформаларды пайдалана отырып, қатысушыларды автоматты түрде мониторинг жасау жүйесін (AMS) ұсынады. Ұсынылған жүйенің міндеті – студенттердің сабаққа қатысуын автоматты түрде тексеру, оқушыларға сабаққа қатыспағандығы туралы хабарлау және де мұғалімдердің сабаққа уақытында келуін қадағалау. Нәтижелерге сүйене отырып, ұсынылған AMS операциялық уақыты жағынан тиімді, экономикалық тұрғыдан қолжетімді және өте аз энергия қолданады. Ұсынылған жүйе басқа авторлардың жұмыстарымен салыстырылады және сынға алынады. Болашақ жұмыстар талқыланып, анықталады.

Аннотация

В последнее время во многих организациях, предлагающих недорогие, маломощные автоматические системы, созданы приложения технологий Интернета вещей (IoT). Кроме того, системы IoT безопасны, менее трудоемки и управляются удаленно. Внедрение IoT-технологий в управление учебным процессом вносит огромные изменения, создавая цифровые классы и системы автоматизации. Тем не менее, получение отчета об отсутствии студентов по-прежнему является важным элементом или проблемой в секторе образования, который представляет собой больше бумажной работы, которая требует много времени, требует много рабочей силы и усилий и налагает неэффективность. Разработаны различные технологии автоматической идентификации с использованием радиочастотной идентификации (RFID). Многие исследовательские работы и проекты производятся для получения максимальной выгоды от использования этой технологии. RFID является автоматической технологией и идентифицирует помеченные объекты из окружающей среды с помощью радиоволн. RFID считывает данные с RFID-метки и отправляет их на сервер или облако, используя аппаратные платформы IoT, такие как микроконтроллеры и микропроцессоры. В текущей работе предлагается система автоматического мониторинга посещаемости (AMS) с использованием технологий IoT, включая RFID и аппаратные платформы. Целью предлагаемой системы является автоматическая проверка посещаемости студентов с помощью человеческого интерфейса, информирование студентов о пробелах в посещаемости и мониторинг инструкторов, приходят ли они на уроки вовремя. Исходя из полученных результатов, предложенный AMS эффективен по времени, экономически доступен и не имеет энергопотребления. Анализируется и критикуется система в отношении работ других авторов. Также обсуждаются и определяются будущие работы.

Contents

Nomenclature

AMS Attendance Monitoring System

IoT Internet of Things

NFC Near Field Communication

PoE Power over Ethernet

RFID Radio Frequency Identification

1. Introduction

The Internet of Things (IoT) is being known as the main component of the new technological revolution called Industry 4.0 that focuses on automation, real-time data, interconnectivity and machine learning. Number of Internet enable devices that are increasing [14] and they can interact each other through the network to be informed and control the sequence of actions of users. Embedded sensors invisibly gather very big amount of data from the environment around us for storing, processing and analyzing, which are used while making decisions for both real-time and future actions. The IoT technologies use this data for controlling their systems according to the decisions made. There are several ways of collecting the data by their types and purpose of use such as sensor network technology and Radio Frequency Identification (RFID).

RFID technologies are one of the main components in IoT systems that works with tag, reader and system. Between reader and tag are not needed direct connection because of radio channels. Installed RFID systems simplify and accelerate the working procedure. It gives very good choice on monitoring people using tags on ID cards in real time location and attendance monitoring. There are two types of RFID tags: active and passive. Passive RFID tags are powered by the reader's power and no additional battery is needed in it. The applications that use passive RFID are found in access control applications and transportation. The active tags are powered by batteries and they can be identified in a long distance used in port containers for monitoring cargo [30].

Implementing IoT technologies in any organization makes huge changes that are secure, less time consuming, and controlled remotely [19]. Nowadays IoT applications are development in big projects like smart home, smart city, healthcare, automation systems, monitoring systems, etc. [Figure 1.1] [28].

Daniele at el. [8] resumes the three main system-level characteristics of IoT:

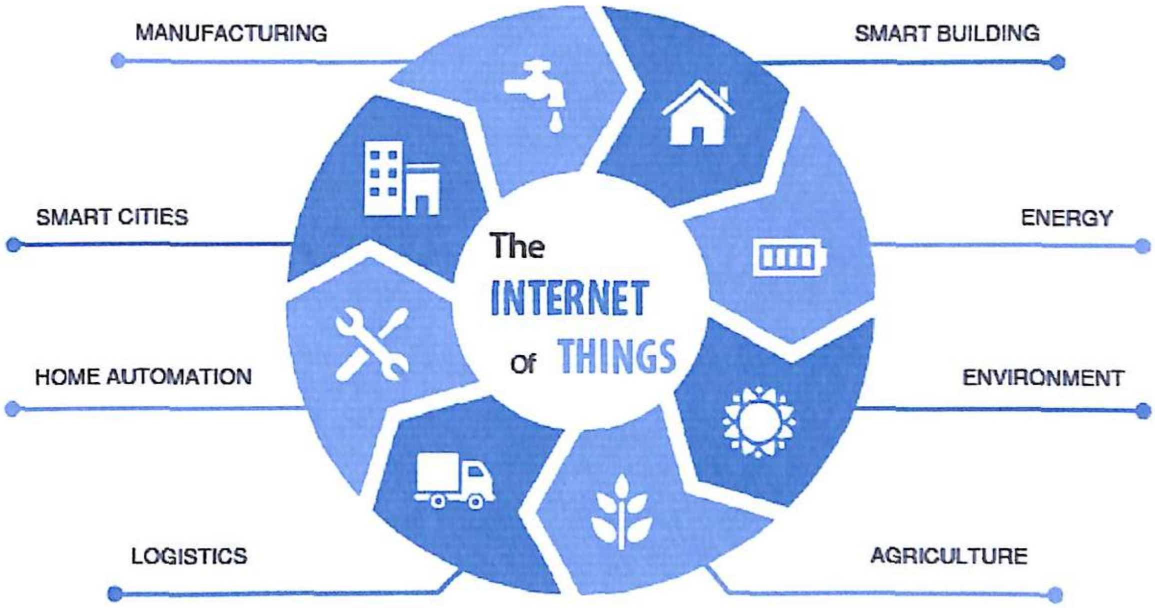

Figure 1.1: Applications of The Internet of Things is everywhere

anything communicates, anything is identifiable, and anything interacts. It means that objects should be identifiable and they must communicate and interact each other. For this reason, sensors and actuators have the main role in IoT actions, and they are the main components while creating IoT solution.

In the proposed system, an application is developed which uses RFID technology for identifying real-time objects using passive tag. A tag, which has a generated identification number, is placed in a card. The ID number is a unique number for every student and stuff of university. The card is used in all processes at university such as door entry and attendance monitoring system that we are proposing. This gives access to the managing stuff to control the real-time monitoring of people in an organization.

In current RFID systems, data about cardholders is registered and stored in the memory of the system's reader for the processing and computing. The data is available only when controlled manually. The importance of the system of our application is that the data is stored in the server and controlled remotely.

IoT platform does the main function in the IoT systems, known as microcontroller and microprocessor. Microcontroller is a small, low-cost computer on a single integrated circuit, whereas microprocessor is microcomputer that incorporates the functions of a CPU (central processing unit) on integrated circuit. Arduino and Raspberry Pi are the most popular IoT platforms used in educational process, DIY (Do It Yourself) projects, and prototype of the project and IoT system. These two IoT platforms will be compared and discussed for their purpose of use, and Raspberry Pi will be used when prototyping the system.

IoT systems require network for data transformation between sensors, actuators, and server. Networking in IoT offers wide range of connecting types such as Wide Area Network (WAN), Local Area Network (LAN), Bluetooth, gateways (Lora WAN), etc. Networking protocols like ZigBee, MQTT, and CoAP make connection and data transfer very easily, and they have different characteristics for various use of purpose. The IoT network is used for their distance and power. For this reason, they give many choices while making connection.

Data gathered by embedded sensors are stored for making computation. In some systems, the computation is made in the controller, whereas in others data is kept in the cloud for real-time monitoring. Fog is a storage where it is closer to the environment and decision is made before transportation of data to the cloud. It is fast way of computing data and low power and traffic for sending and receiving data to the storage. In the proposed system, the data is transferred to central university server through the Ethernet cable.

One of the benefits of implementing IoT is controlling remotely. The user is able to control actuators and take information from the sensors using an application that has a connection through the network. The desktop, web, or mobile applications allow users to make a contact with controller of the system. For our system, web application is developed for managing the process taking data that is stored in the server.

The system is composed of the hardware part, software part, the server, and network for data transportation. All these parts will be discussed, the architecture of the system will be explained, and the connections will be given in the next sections.

2. Related Works

Application of IoT technologies in the both closed and open areas make huge changes that increase the working process of the system and decrease human power on making actions. Benefits of using RFID with IoT technologies are mentioned in the introductory part. In the rest of other research projects, people also discussed how the system is good for definite reasons and how they can improve process of using it. The most of the systems are developed using IoT platform with RFID reader, which makes the hardware part of the system and send data to the server for controlling it in application part.

Kossonon at el. [9] developed IoT based Smart Restaurant System using RFID, where they used Raspberry Pi model 3B as an IoT platform, and ITEAD PN532 NFC module for reading tags. The things such as delivery assignment machine, order monitor, and middleware server are connected each other through the Ethernet cable. The monitor with an application is placed on the smart table that is connected via wireless network. The NFC module with Raspberry Pi is planted to the smart table and delivery assignment machine. Special plates have passive tags and used for controlling the correctness of the delivered dishes. The systems offer faster ordering scenery than manual ordering.

Ali and Canberk proposed Robotic Control System, where RFID reader services for capturing data and sending to the robotic arm via web app by using embedded computer. When Raspberry Pi gets data, it sends data to the Arduino Uno (with Ethernet shield) connected to the robotic arm through Ethernet cable. Computer is system is a part of a larger system and performs only peripheral function. The Raspberry Pi is used for communication between web application and robot controller [1].

Astriany at el. [6] offered Offline Intelligent Payment System that is composed of hardware, server, and application. The hardware part is consisted of

Raspberry Pi 3 model B, MFRC522 RFID reader, and LCD Waveshare 3.5. Tha data collected by RFID is kept in offline server which is installed in Raspberry Pi is uploaded the cloud when bus is arrived to the station and by administrator manually. The authors tested the system according the time, distance (between tag and reader), and special cases of algorithm. The results show that time is less for declined operation than successful operation. Administrator registers users manually by generating new ID for every user.

Evan at el. [10] built the RFID Ecosystem at University of Washington. The system includes 44 RFID readers, and each of them equipped with up to four antennas. The readers positioned at the entrances, on the stairwells, and throughout the corridors. The RFID readers run embedded Linux and report data to a central server via wired and wireless Gigabit Ethernet. Several RFID-based web applications are developed for registering tags, controlling and viewing data from the server, check the real-time monitoring in the building. The authors made analyze for four weeks and took very pleasing results.

Juraj and Michal implemented IoT for their Smart Home project. The main components of the project are Raspberry Pi 3, PN532 NFC/RFID controller, server side, software part, and user interface for data visualization. PN532 is able to work with Raspberry Pi's SPI and I2C bus. They used RFID technology for monitoring real-time attendance at home by web user interface app [16].

Sowmiya and Sabeenian presentated Security and Monitoring System that uses RFID tag, embedded sensors like gas sensor, weight sensor, Raspberry Pi module B+, and GSM module. Data read by sensors are stored in database located in raspbian SD card, and computing is done in Operating system of the microprocessor. When it is needed to send message, the GSM module is used for sending SMS with information to student [20].

Norsaidah at el. [22] discussed Wireless Sensor Node (WSN) with UHF RFID for monitoring system. Like previous discussed works, they also used Raspberry Pi 3. In this work, author compared two types of tags: UPM DogBone and AZ-9640. Concept of the data transfer is as follows: the tag is tagged to the reader from where the data is send to embedded computer that is connected to the router with a wire. Data is stored in the server, and monitored in monitoring center using application.

RFID based Paid Parking System is a good example of using Raspberry Pi as a central device where located server of the system. The server is based on MySQL. RFID reader is connected to the ESP8266 microcontroller, which has built-in Wi-Fi chip that is responsible to establish a connection with Raspberry Pi [2].

In Real Time Locating System, alongside with RFID and Raspberry Pi, biometrics has been used for not separating cards between students. The main purpose of this project is to monitor student participation in lectures, teaching and laboratory sections. Sending the participation information to parents also included [25].

Hasanein at el. [12] proposed Attendance and Information System that works with web-based application for academic sector. In the system, Milfare RC522 and Arduino platform are used for data capturing that is sent by Ethernet to the server. The Liquid Crystal Display (LCD) displays information about student and his/her timetable when the student tags ID card. The authors compared their system to the existing systems that works using QR code, Barcode and Magnetic stripe. In a result, they concluded that using RFID system is much faster than other systems. For future work, they offered to add face detection mechanism in the attendance monitoring system to control card replacement among different students.

Smart Classroom Roll Caller System is secure system using IoT architecture for monitoring students' attendance in classroom. There systems were compared: Traditional Teacher checker, RFID Roll Call, and Smart Classroom (SCRCS). The proposed systems is more secure than other two. The real-time data about ID card is stored in the Computer Center Server of University. The problem of the system is that teacher must control students while taking back ID cards from special places for the ID cards. Another problem is what if student forgets (or loses) his/her ID card. So, these problems must be solved [7].

Despite of many attendance monitoring systems and other similar systems were proposed and developed, there are still some problems to come up. All of projects discussed above used RFID and IoT platforms. Comparing the systems and their problems, other new systems should be developed and it require bit more research in this field.

3. IoT Hardware Platforms

The Internet of Things hardware platforms have a main role while creating the scenario of IoT based systems. Every single electronic device consists controller for making decisions, computing, and doing some actions. When it comes to drawing systems microcontrollers and microprocessors do some specific jobs, and associate with other devices. Embedded sensors and actuators are connected to the IoT platforms, and act by instructions. In the survey of IoT platforms done by Kiran and Divneet, different kinds of hardware and software platforms were compared and discussed for many features in terms of computing, connectivity, development environments and communications standards [18]. During development of the device, one of the main characteristic of the IoT platform is its price. Not every proposed system can be funded. That is why we choose two well-known and low-costed micros: Arduino and Raspberry Pi. Arduino is a cheap microcontroller and several kinds of modules can be added to make it more powerful, whereas Raspberry Pi is Linux based microcomputer, which has different versions to do certain tasks. We compare these two IoT hardware platforms for definite features used in the proposed system later.

3.1 Arduino

Arduino offers many kinds of easy-to-use boards that used for different purposes. The benefit of using Arduino is it has own boards and open-source software for programming the controller. Arduino board types are composed of wide range of official products in different categories such as entry level, enhanced features, Internet of Things, education, and wearable. Many kinds of modules, shields, proto shields are also included in the products list: Wi-Fi shield, Ethernet shield, etc. [3].

Arduino Uno board is the most used product in both Education and simple DIY projects. The board is based on the ATmega328P that has 32 KB flash memory, 2 KB RAM with 16 MHz clock memory. It has 6 analog pins for receiving inputs from many sensors, and 14 digital pins for controlling lights, motors, and other actuators as shown in the Figure 3.1 [17]. The size of the board is 68.6 mm to 53.4 mm, and weighs 25 grams, which is very comfortable to carry. The operating voltage is 5V. The advantages of Arduino Uno is it is low-costed (official US $22) and low-powered. However, it has no network connection. In order to use network, additional shields and modules are needed, which costs more expensive than board itself.

Arduino Mega is more complex than Arduino Uno board, and designed for big projects. It has 54 digital I/O pins, and 16 analog inputs. The controller is based on the ATmega2550 with 256 KB flash memory, and 8 KB RAM. The clock speed is as same as Arduino Uno is. The size is twice bigger, and weighs 37 grams. The board is recommended for 3D printers and robotics projects. Like Arduino Uno board, no network connection types are included.

Arduino Yun is retired version, but still available in internet markets. It is perfect board for network connection, and designing Internet of Things projects. Arduino Yun is combine of microcontroller and microprocessor [4]. The board supports a Linux distribution based on OpenWrt named Linino OS. Controller is based on the ATmega32u4 and Atheros AR9331. Unlike previous boards, it works with network, and has built-in Wi-Fi and Ethernet support, a USB-A port, and micro-SD card slot. Arduino Yun has also user interface application that lets its users to work with the board easily. Despite many benefits of use, the board costs expensive (about US $58), which is not available for everyone, and projects may not cost as a board's price.

Arduino IDE is a software platform that allows working with Arduino boards and writing program to them [21]. One benefit of using Arduino is that it has its own C like Arduino Programming Language, which is easy-to-code. The board can connect to the IDE serially, and data gathered by sensors can be viewed in serial monitor. The IDE supports connection and uploading programming code to the board.

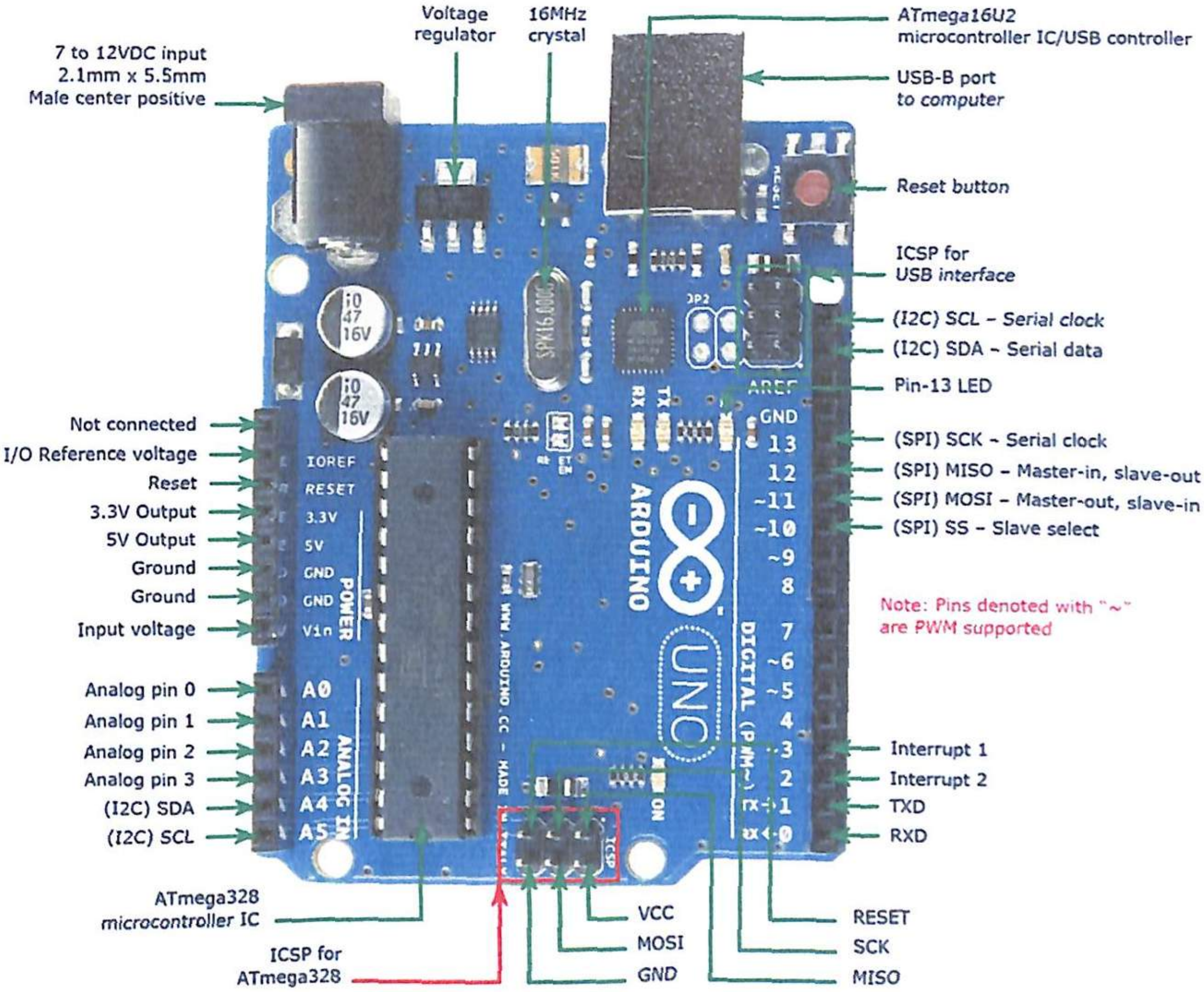

Figure 3.1: Main components of Arduino Uno Board

3.2 Raspberry Pi

Raspberry Pi is a small computer that allows learning programming and working with embedded sensors and actuators using GPIO pins. It operates like standard PC with operating system requiring keyboard and mouse. It interfaces with many devices and affordable for US $5-35 [23]. The latest version of Raspberry Pi supports Bluetooth, wireless connection, and Ethernet, and operating systems like Linux, Raspbian, Windows 10 IoT Core, etc. The operating system is installed in micro-SD card. The size of Raspberry Pi board is different according to its versions. The biggest one is credit card sized. The Raspberry Pi works with four distinct power modes that allows use in different projects saving power: run mode, standby mode, shutdown mode, and dormant mode. Raspberry Pi uses ARM BCM2835 processor, and RAM is 256-1024 MB. It powers from 5V by

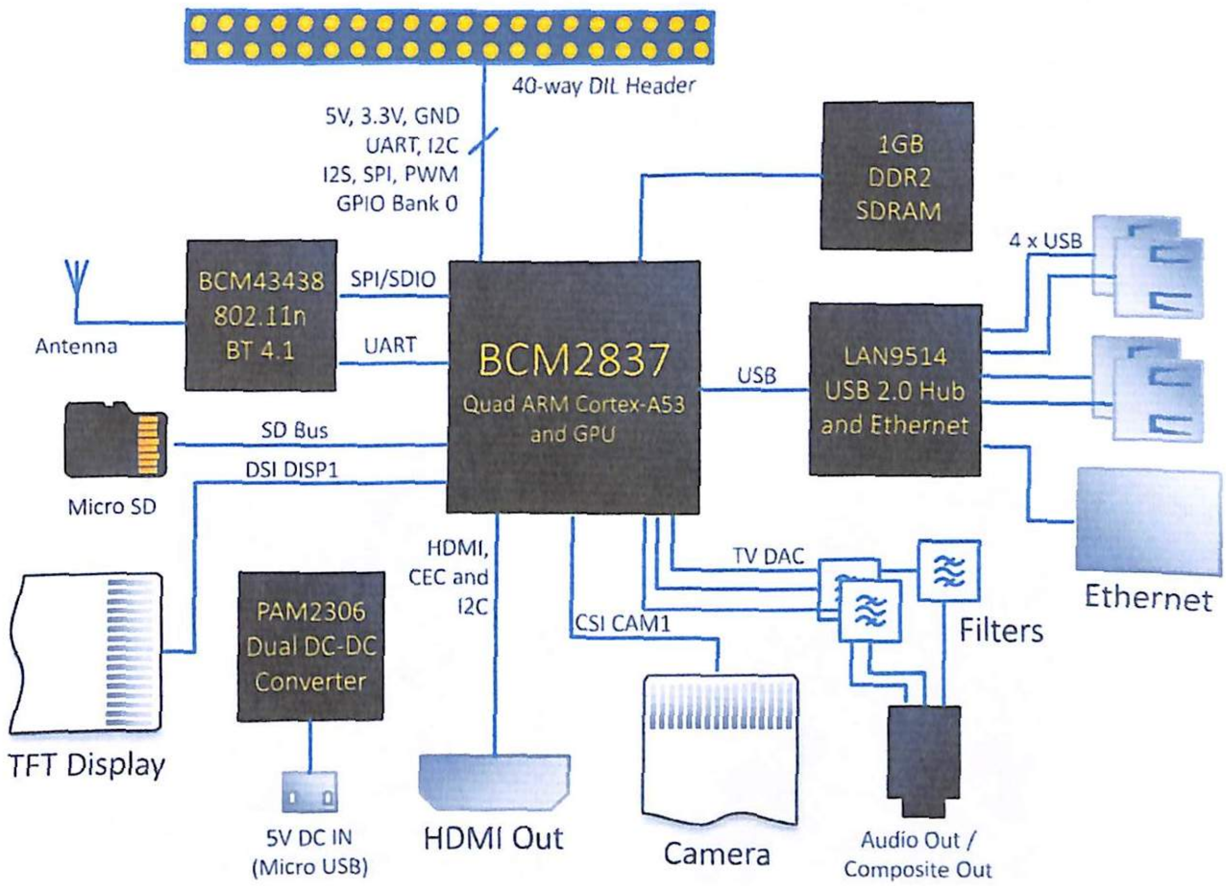

Figure 3.2: Main components of Raspberry Pi 3 model B

micro-USB. It has 26 GPIO pins that allows communication with other computing devices using different protocols including SPI (Serial Peripheral Interface) and I2C (Inter-Integrated Circuit) [27]. C, C++, Java, and Python are can be used to program sensors and actuator connected to the board. Raspberry Pi 3 model B+ takes power over Ethernet (PoE). The main components of Raspberry Pi 3 model B is shown in the Figure 3.2 [29].

3.3 Comparison of IoT Hardware Platforms

IoT devices must be low-powered, small-sized, low-costed, and fast communicated. Implementation of this kind of the IoT project makes huge change in the environment. In the Table 3.1, most often-used five IoT hardware platforms are compared in terms of connectivity and computing. Every electronic device must be available for everybody in terms of business. For this reason, engineers must mention it while creating new device. Raspberry Pi zero w is the lowest costed one. Nevertheless, it does not support Ethernet or Bluetooth connection. Arduino Yun is good in terms of connectivity. However, its price the highest in the list of boards. Raspberry Pi 3 model B+ has the same features, and its price is not as high as Arduino Mega and Yun. The difference between Arduino and Raspberry Pi is on their types. The first one is microcontroller whereas the next one is microprocessor. In some projects, using microcontroller is better than using microcomputer. Sometimes microprocessors are used as an internal server which is cheap and does not need internet connection.This is the main features everyone must mention while prototyping IoT systems and creating DIY projects.

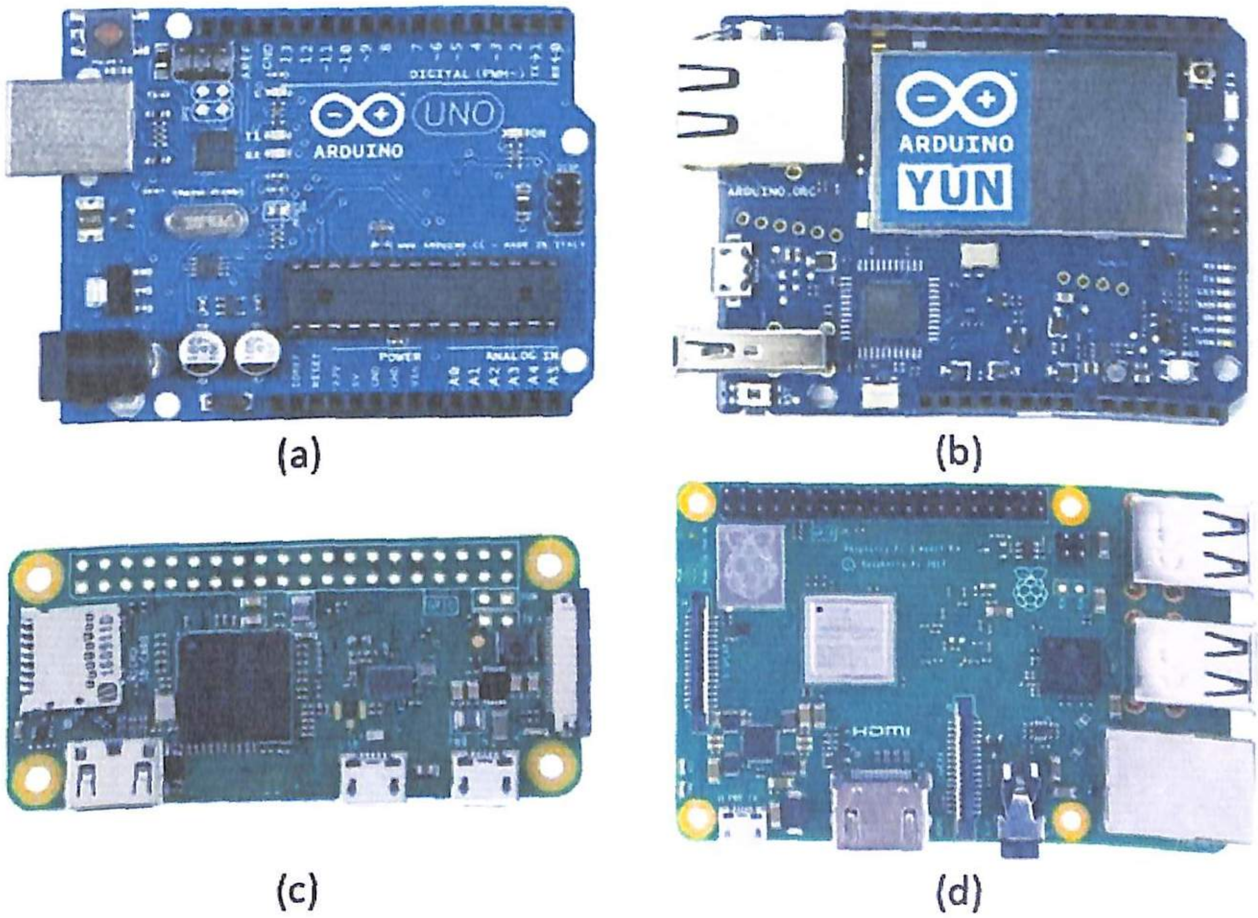

Figure 3.3: (a) Arduino Uno, (b) Arduino Yun, (c) Raspberry Pi zero w, (d) Raspberry Pi 3 model B+

Name	Memory	RAM	Clock Speed	I/O pins	Network connection	Size	Power	Prise (USD)
Arduino Uno [Figure 3.3(a)]	32 KB	2 KB	16 MHz	14/6	No	68 x 53 mm	USB cable, AC-to-DC adapter, batter, AREF	$22
Arduino Mega	256 KB	8 KB	16 MHz	54/16	No	101 x 53 mm		$38
Arduino Yun [Figure 3.3(b)]	32 KB and 16 MB + Micro-SD	64 MB DDR2	16 MHz and 400 MHz	20/12	Ethernet, Wi-Fi	73 x 53 mm		$58
Raspberry Pi zero w [Figure 3.1(c)]	Micro-SD	512 MB	1 GHz	26 GPIO	Wi-Fi	65 x 30 mm	Micro-USB cablè	$10
Raspberry Pi 3 Model B+ [Figure 3.1(d)]	Micro-SD	1 GB	1.4 GHz	26 GPIO	Ethernet, Wi-Fi, Bluetooth	85 x 56 mm	Micro-USB cable, PoE	$35

Table 3.1: A comparison of Arduino and Raspberry Pi boards in terms of connectivity and computing

4. RFID Technology

Radio Frequency Identification (RFID) is an automatic technology and identifies tagged objects from environment through radio waves. RFID system is consisted of readers and tags. The tag is a microchip that is attached to an object to identify the reader. The reader communicated with tag through radio waves. The main benefit of using RFID technology is the identification process is done automatically. RFID systems are used for real-time monitoring purpose. The components of RFID system are as follows: tags, reader, and application system. When object with a tag is tagged to the reader, the reader identifies ID number of the tag, which is unique in every tag. ID number is sent to the server, or as in most standard RFID systems, it is stored in the controller for checking whether it is correct ID or not [Figure 4.1].

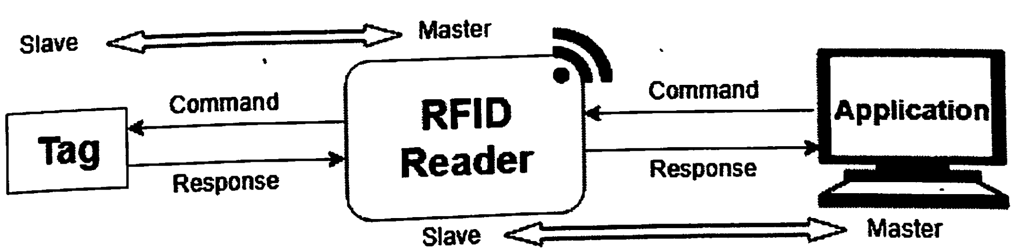

Figure 4.1: Architecture and data flow of an RFID system

A tag is a transponder (transmitter/responder), whereas reader is transceiver (transmitter/receiver). There are two types of tags: active and passive. Active tags are powered by batteries, and can communicate with other active tags. Passive tags have no built-in power source, and they take power from electromagnetic energy transmitted from the reader during identification. Tags are made up of coiled antenna and a microchip. Xiaolin at el. [30] classified active tags into five classes according to its functionality. Active tags can be detected from long distance: up to 30 meters. Maximum distance for passive tag is 6 meters. The advantage of using active tag is its long distance and highest data. However, it costs more expensive than passive tag (around 15-20$ per tag for active, 0.1-0.2$ per tag for passive). The benefit of using passive tag is tag life does not depend on battery, and it is more resistant to physical damage. Disadvantage of passive tag is the read range is limited and communication depends on the antenna size and shape [16]. Norsaidah at el. [14] tested two types of UHF RFID passive tag: AZ-9640 and UPM DogBone for different distances. UPM DogBone is better in terms of detection, and outperformed AZ-9640 in terms of data transfer. AZ-9640 is more compact and discreet. Both types were experimented in the monitoring system. The tags mostly attached to the ID cards, trinkets, wearable devices, etc. In Offline Intelligent Payment System Mifare Classic 1K card was used, which is divided into 16 sectors protecting each sector by two different keys, called key A and key B [6].

Figure 4.2: RFID Passive tag types

RFID reader is responsible for communication with tags within its operation range and send sending the tags' data to server or presenting in application. Attached antenna emits signals to the tag and then receive from it. Reader can be many different sized and has many types. For example, Mifare RC522 reader in Attendance and Information System [12], RS532 RFID reader in Security and Monitoring System [10], PN532 NFC/RFID Controller in Smart Home project [16], ITEAD PN532 NFC in Smart Restaurant system [9], and MFRC522 in Offline Intelligent Payment System. Reader can be affixed in different positions, on the table, in door, in tourniquet, etc.

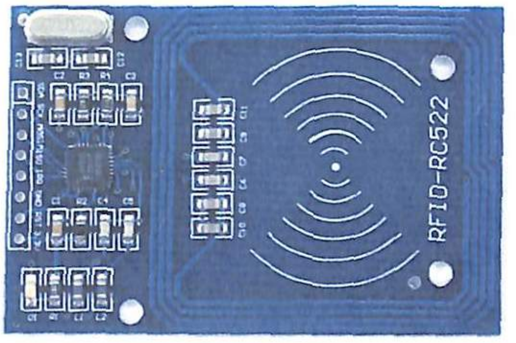

Figure 4.3: RC522 RFID Reader

Data received from tag by reader is presented in an application. The data is used directly when it is tagged in many systems. The data is also stored in server (fog, cloud) for monitoring remotely and analytic purpose. RFID applications are implemented in healthcare, monitoring systems, security, etc. Related systems and projects are discussed in the chapter 2.

5. Attendance Monitoring System

5.1 Architecture of the System

Implementation process of the proposed Attendance Monitoring System (AMS) is based on criteria and metrics such as availability of used equipment,. its cost, and easy programming. The software and hardware requirements, implementation steps are displayed in the Figure 5.1. The architecture of the proposed system is designed and based on the Internet of Things technologies and reviewing previous authors' works. To complete the presented system, software and hardware components are required. RFID tag is attached to card with unique identification number. RFID reader is connected to Raspberry Pi zero embedded computer that is open circuit system by pins, and Micro-USB-to-Ethernet cable and PoE splitter are connected to Raspberry Pi zero board. Micro-USB-to-Ethernet cable and PoE splitter serve to interact with Server via Ethernet cable. Using MySQL, PHP, and XAMPP Server records and data are achieved for browsing in Web-based application that is written by front-end development. Students, instructors, and managing staff are able to view records and data using Web-based application that allows making analytics, sending notifications, and monitoring the performance of the students.

5.2 System Implementation

Steps to upload records and data are as follows: RFID reader (transponder) receives identification number from the tag (responder) and sends it to Raspberry Pi zero connected be GPIO pins. Software installed in Raspbian OS checks whether

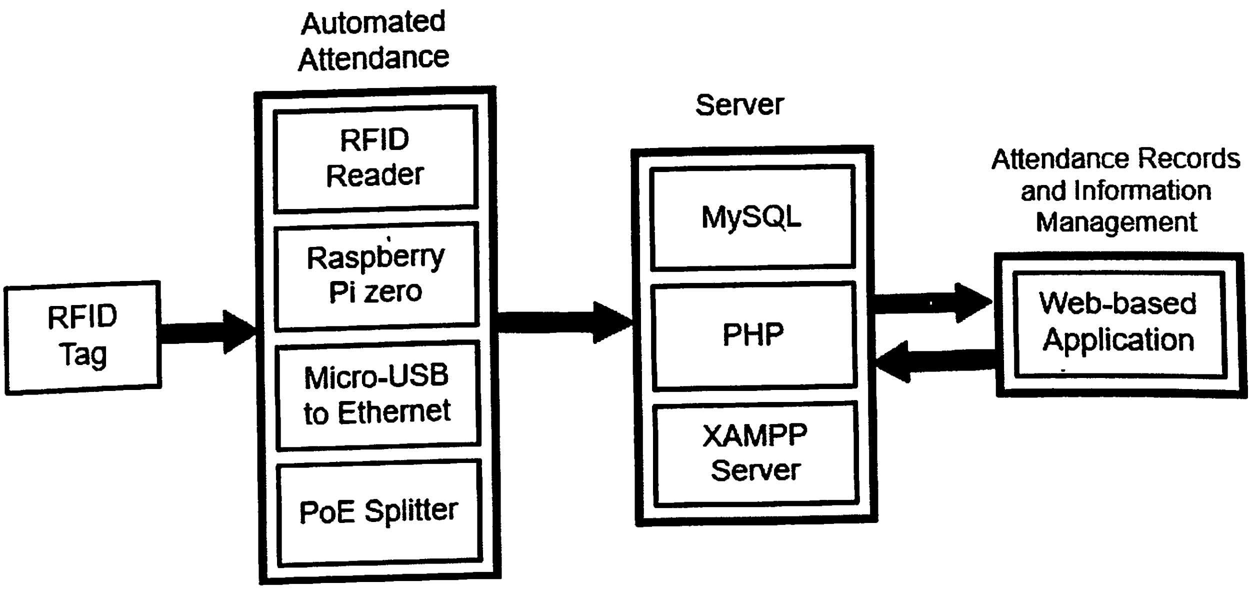

Figure 5.1: Block diagram of the proposed system

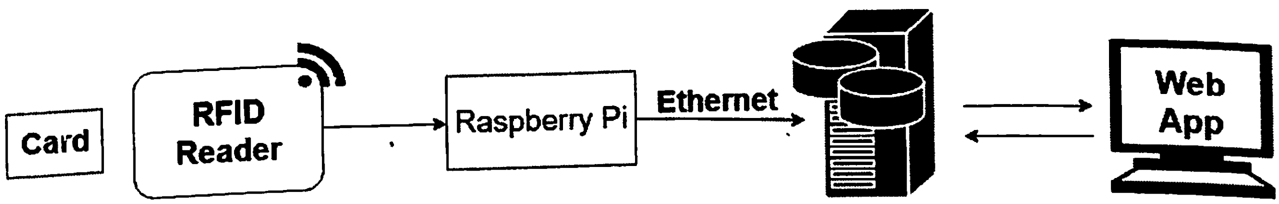

Figure 5.2: System architecture showing the steps of workflow

ID exists in the DB or not. If the ID exists then uploads it to the DB located in the server via Ethernet. Web-based application uses the records and data [Figure 5.2].

RFID reader and Raspberry Pi zero compose monitoring device of the system. RC522 RFID reader is connected to Raspberry Pi zero board by GPIO pins and using Serial Peripheral Interface (SPI) that is used for short-distance communication [Table 5.1]. Red led, Green led, and Buzzer are connected to the board to notify user when a card is tagged. Hardware components for the device of the system costs about US $16 as calculated in the Table 5.2. However, Ethernet cable, switch, hub, etc. are also required for connection to the server.

Figure 5.3 shows connection scheme drawn by Fritzing open-source design tool. Software of the device is written in Python programming language in Raspbian OS.

Raspberry Pi zero board	RC522 RFID module
3.3V	3.3V
Ground	GND
GPIO8	SDA
GPIO11	SCK
GPIO10	MOSI
GPIO9	MISO
GPIO25	RST

Table 5.1: Connection between RC522 RFID Reader and Raspberry Pi zero board

Components	Cost
Raspberry Pi zero	$5
RC522 RFID reader	$2
PoE Splitter	$5
Micro-USB to Ethernet	$4
Overall	**$16**

Table 5.2: Overall cost of the hardware components for the device

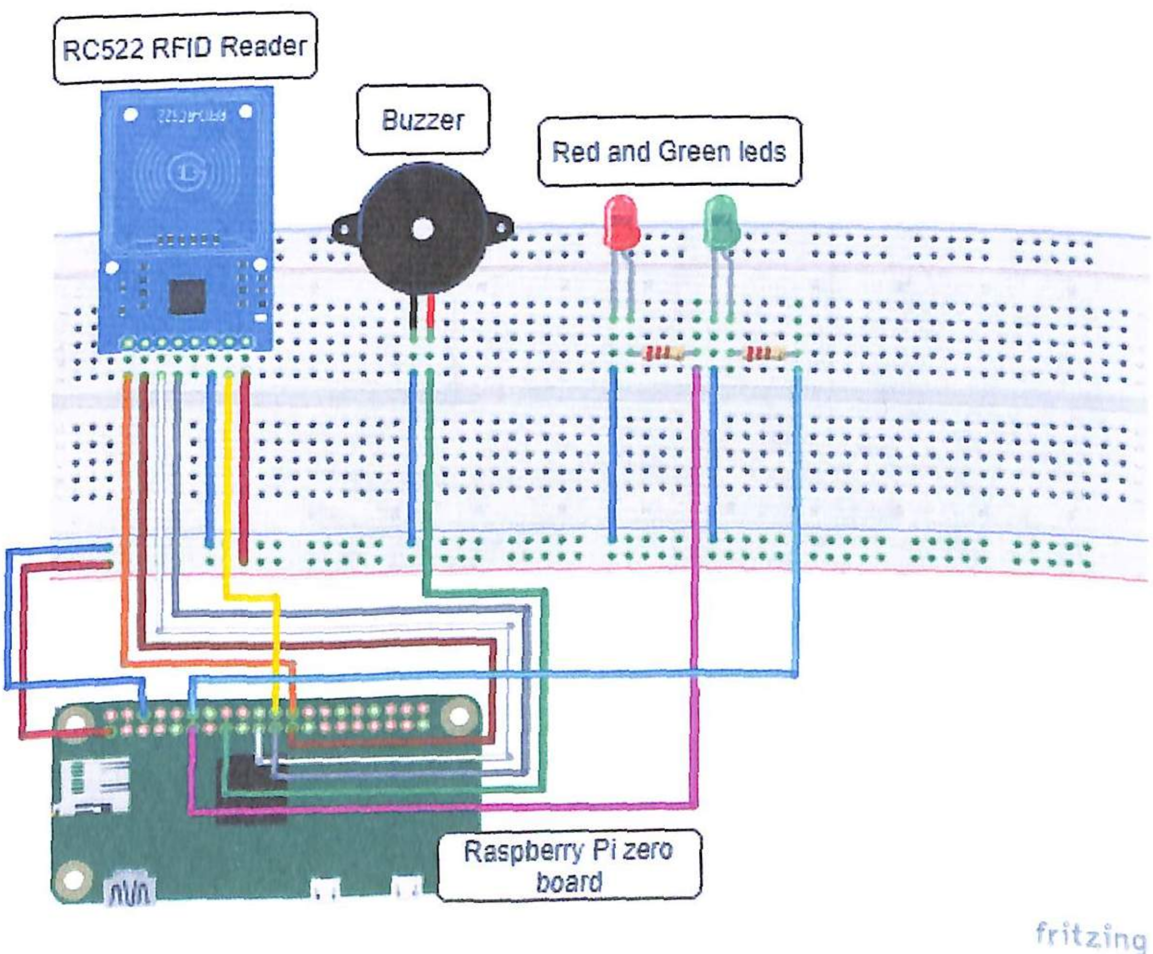

Figure 5.3: RC522 RFID Reader, Buzzer, Red led, and Green led are connected to Raspberry Pi zero board

Hardware of the system works as follows: ID card is tagged to the device it reads identification number from the the card which then checked for existence in database. If the identification number exists in DB then it is inserted to the DB table. Otherwise the device rejects the card. State diagram is shown in the Figure 5.4. Flowchart of the software to the device is shown in the Figure 5.5.

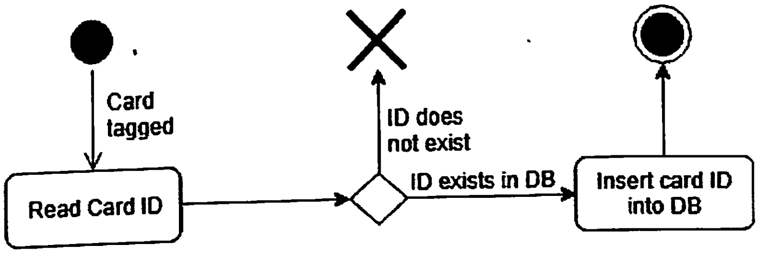

Figure 5.4: State machine diagram of the hardware of the system

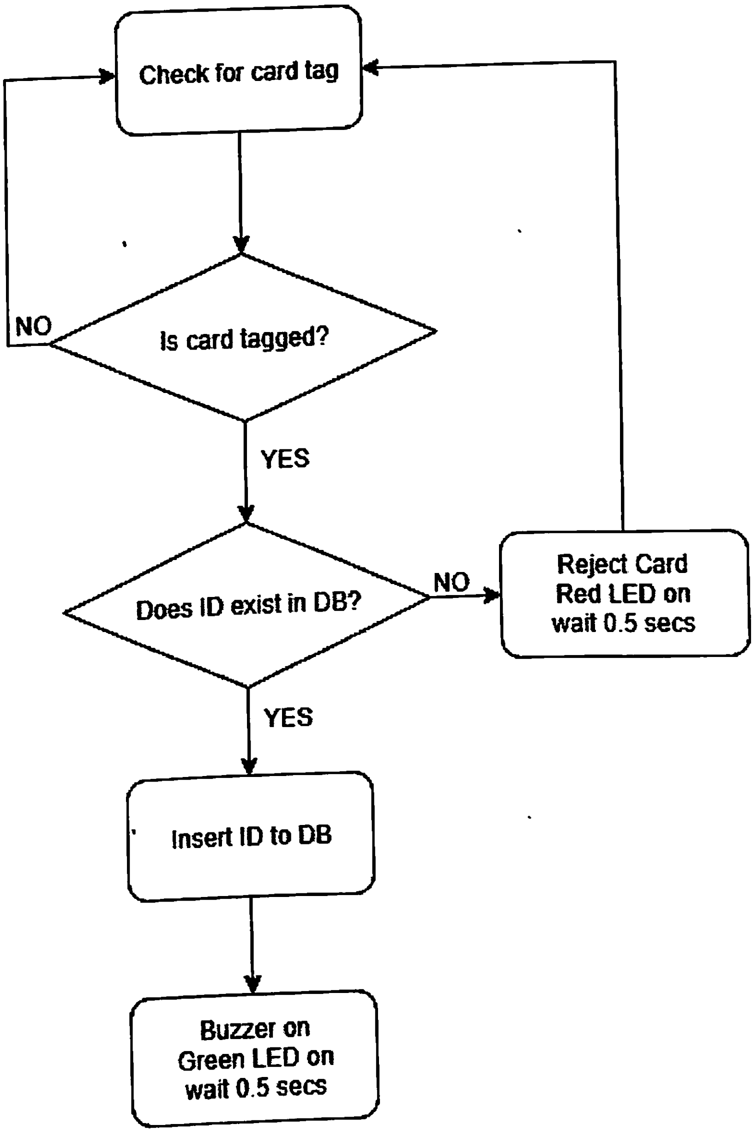

Figure 5.5: Flowchart diagram of the software for running hardware device

MySQL database is installed in XAMPP server. The records and data are fetched using PHP. When the software gets identification number, it uploads it to the database table that is unique for every classroom [Figure 5.6]. Date and time are inserted into the table automatically that uses server time.

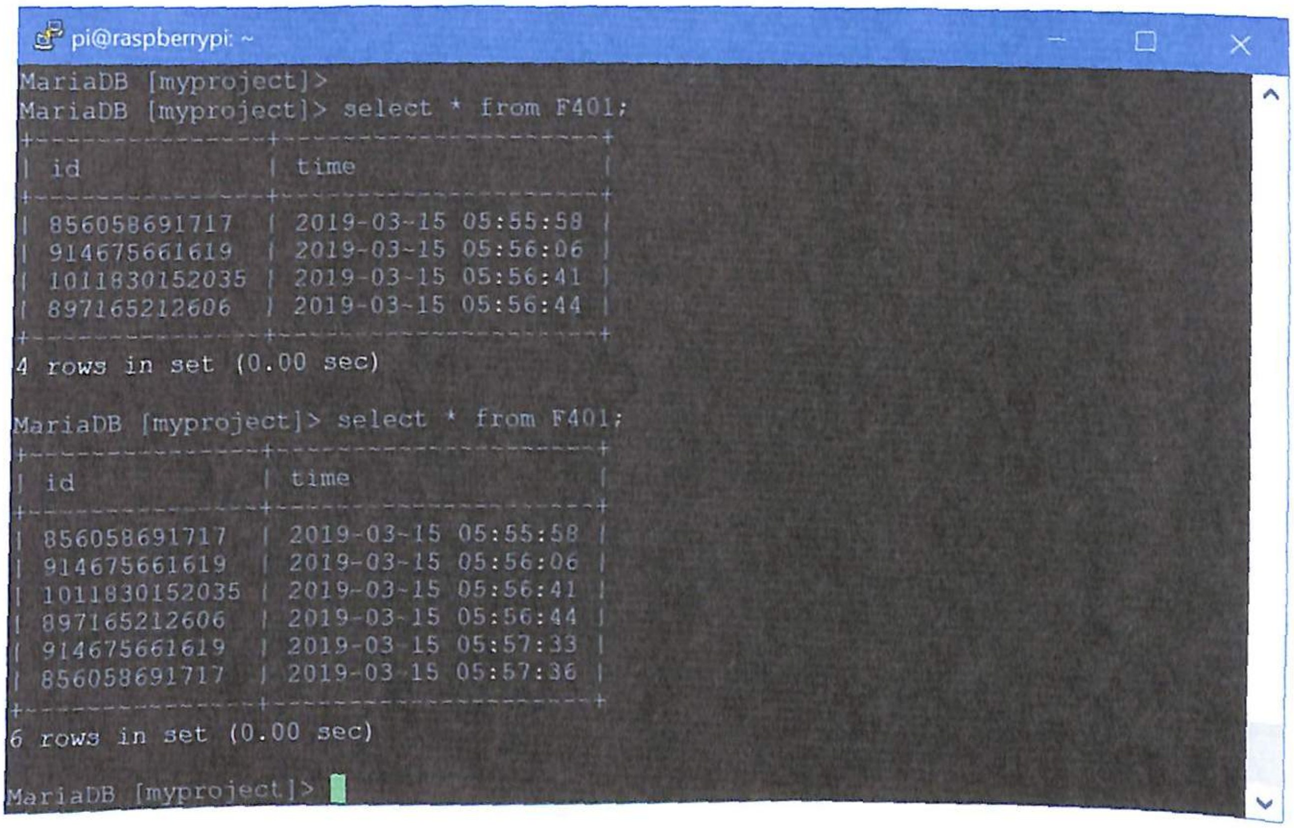

Figure 5.6: ID, Date, and Time are inserted into the MySQL database

Web-based application uses the records and data from the server for monitoring the process. Managing staff, instructor, and student can view the records and the data. They have particular permissions for each of them. Managing staff acts like an administrator. He/She can access all data from the database. Instructor can view his/her and student's attendance rate, time table, change student's attendance state if necessary, and notify student. Student is able to view attendance rate and time table. System also includes Auto Notifier that is able to notify instructor and student if the absence rate gets lower than particular percentage. Use-case diagram for the application is given in the Figure 5.7.

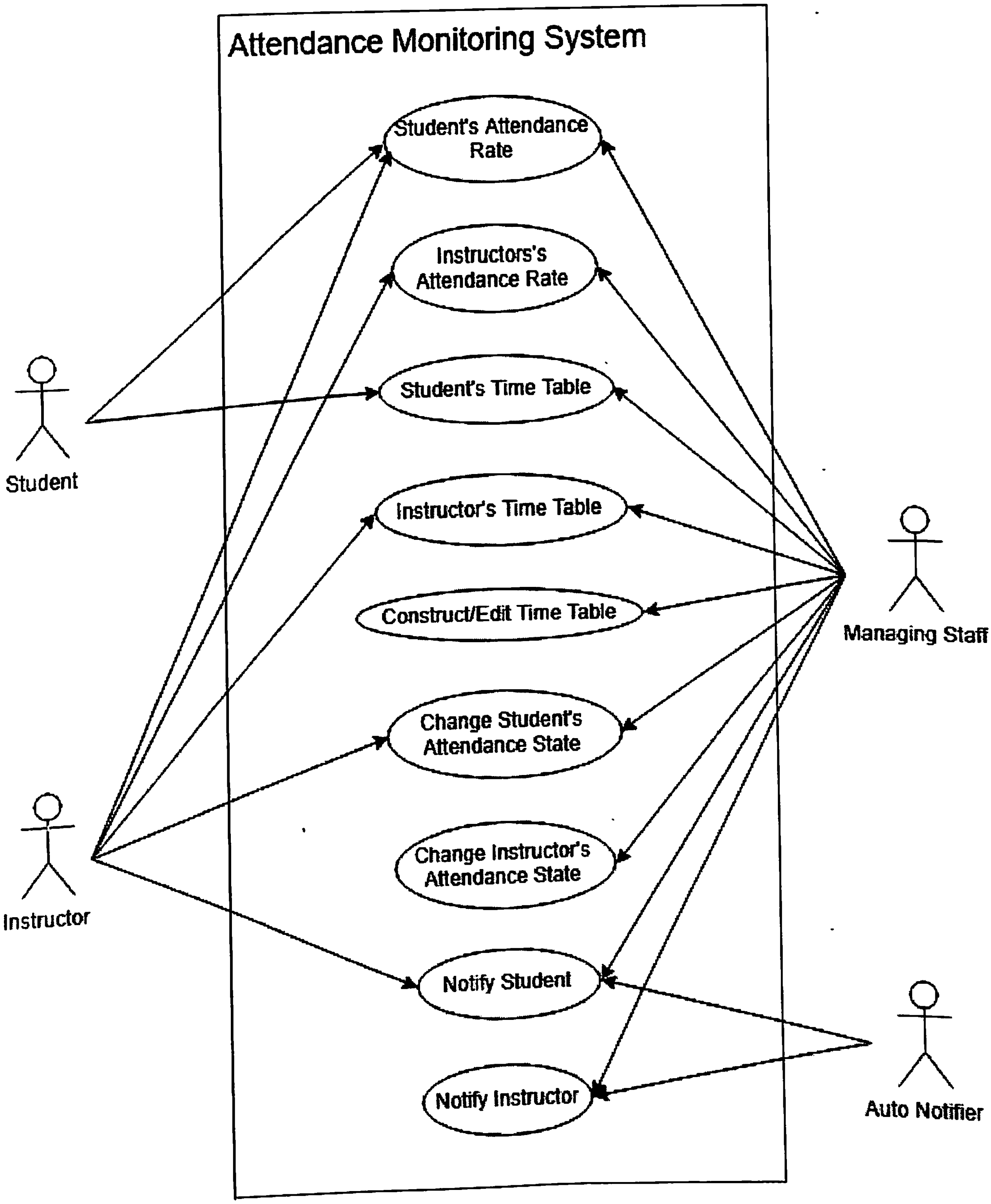

Figure 5.7: Use-case diagram for the application

The application is written using HTML, CSS, JavaScript, and Bootstrap open-source front-end framework. Information about student including name, specialty, and identification number, timetable, attendance, and notifications are covered in the application [Figure 5.8].

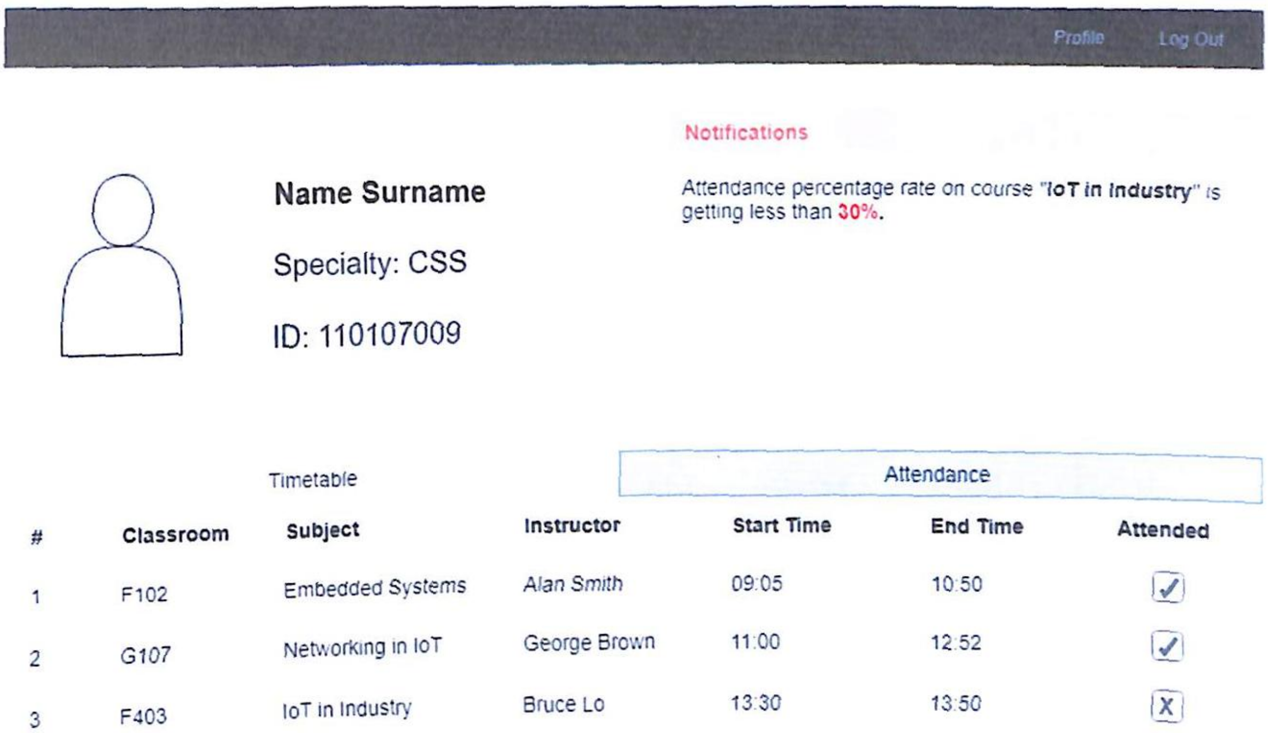

Figure 5.8: User interface for the web-based application of the system

6. Results and Discussion

The proposed system is attaining three objectives; the first one is to check attendance of students automatically using RFID tag which they are using as a student card, the second aim is to inform students about gaps in attendance and timetable, and finally, monitoring instructors whether they come to lesson on time or not. In the traditional method for checking attendance of students, most instructors use papers, excel or excel-based software, or university portal. Survey was done at Suleyman Demirel University where 25 instructors of Engineering and Natural Sciences Faculty participated [Fig. 14]. They were asked questions related to how they student absence report during lessons:

1. What kind of equipment or system do you use for checking attendance of students?
2. Total hours of Lectures in a week?
3. Total hours of Practice/Lab sections in a week?
4. Average number of students participated on Lectures.
5. Average number of students participated on Practice/Lab sections.
6. How many times do you check attendance of students?
7. When do you check attendance of students during lesson?
8. How much time does it take for attendance checking on Lecture?
9. How much time does it take for attendance checking on Practice/Lab sections?
10. How would you like to check attendance of students?

The most of instructors use attendance system on university portal where all students are already registered and the system work automatically. However, the ticking process in done manually by the instructor. About one-third use Excel based software, whereas three of them mark students on paper. One instructor says that he/she did not check an attendance. The reason is it takes too much time for checking. Some of them use both paper and portal, or excel-based and portal [Figure 6.1].

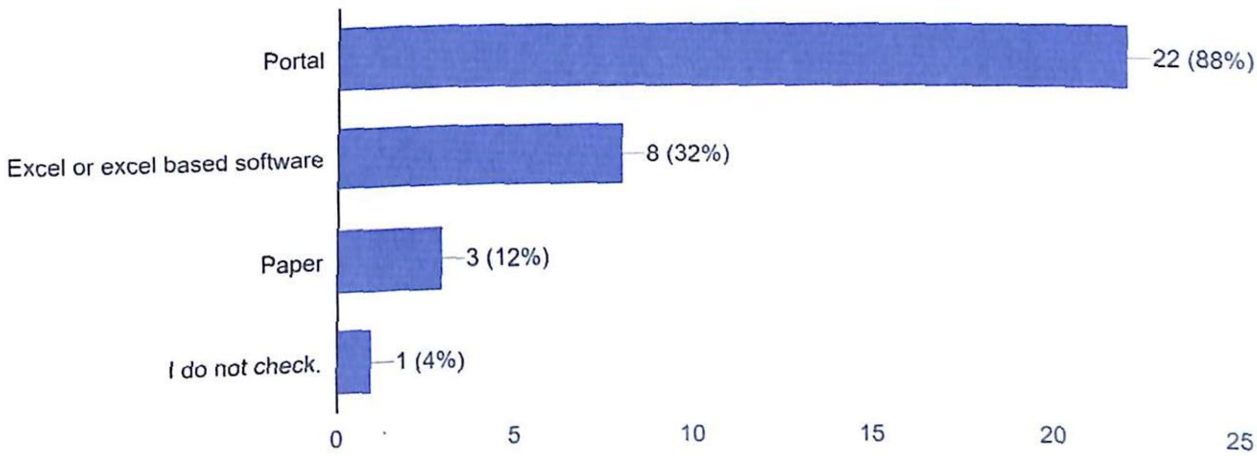

Figure 6.1: How do instructors check an attendance?

According to the survey, quarter of the instructors do not have lectures. Other instructors have 5 hours lectures in a week on average. The biggest number is 10, whereas the least is one. Average number of students in each lecture is different [Figure 6.2]. About 35% of them have less than 40 students, 22% 40-60 students, 30% 60-80 students, and 13% of them have more than 80 students. For practice and lab sections, the number is different, and they have much more hours of classes. 8 hours in a week on average. Some of them have more than 20 hours of practice/lab sections. 16% of them have less than 10 students, 40% 10-20 students, and other 44% have more than 20 students [Figure 6.3].

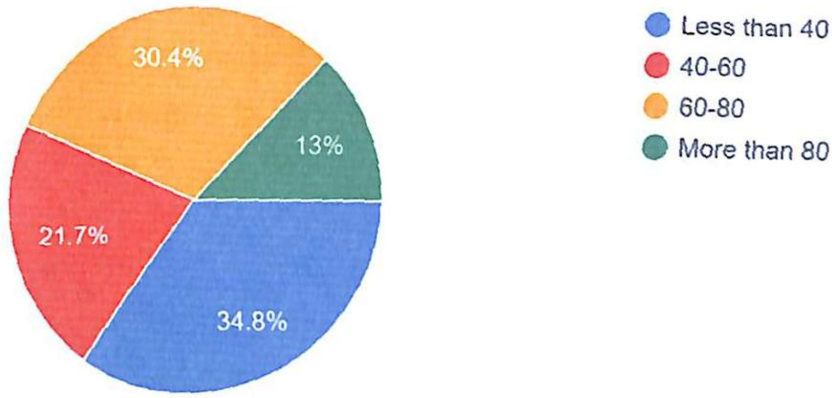

Figure 6.2: Average number of students on Lectures

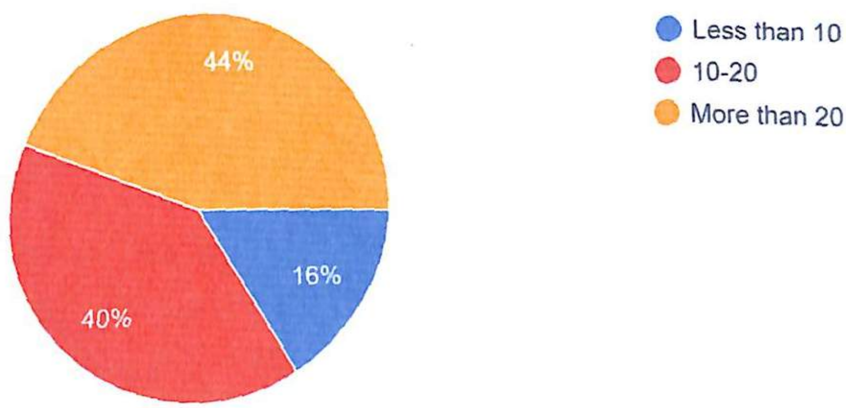

Figure 6.3: Average number of students on Practice/Lab sections

Most of all instructors (64%) check attendance only once during class, whereas 20% check twice [Figure 6.4].

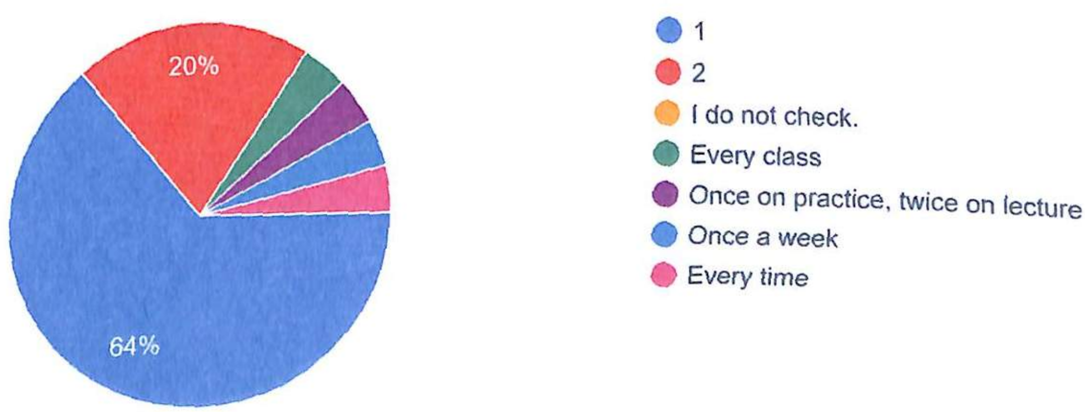

Figure 6.4: How many times is attendance checked?

They were asked for when they check attendance during class [Figure 6.5].

One-fifth of them answered that they checked at first five minutes of class, 12% after fifth minute, 32% after tenth minute, and 16% at the end of lesson. Some of them checked on random time, whereas one of them checked at the beginning and at the end of class.

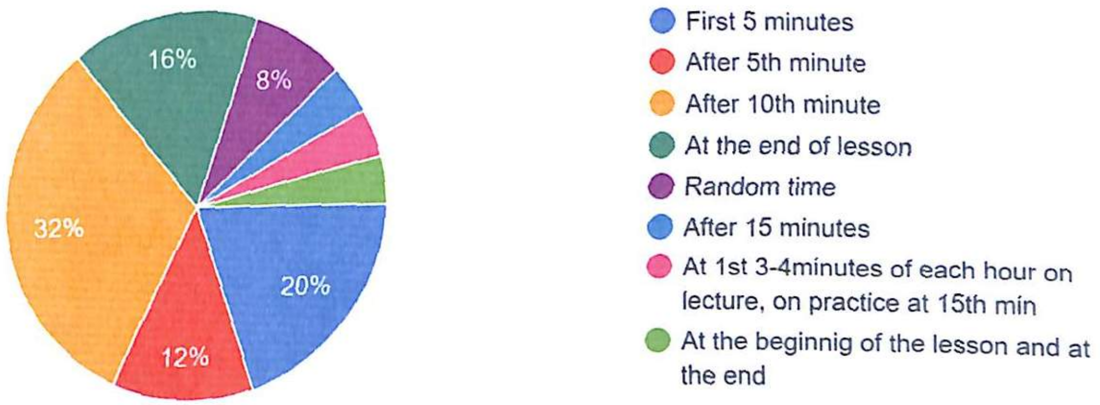

Figure 6.5: When is attendance checked?

When the instructors were asked for how much time did it take for checking attendance during Lectures, most of them (36%) said that the time is one to three minutes [Figure 6.6]. 20% take 3-5 minutes, and 16% take more than 5 minutes. One of them says that students mark themselves on paper. As expected, very big percentage (76%) of instructors say that it takes only 1-2 minutes during Practice/Lab sections [Figure 6.7]. Another 20% replied that it takes 3-5 minutes. One instructor refuses checking attendance.

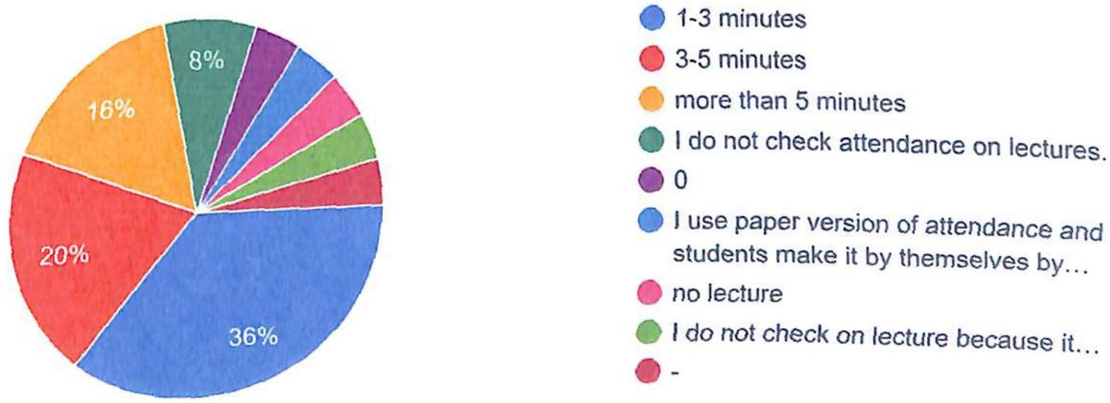

Figure 6.6: How much time does it take for checking attendance during Lectures?

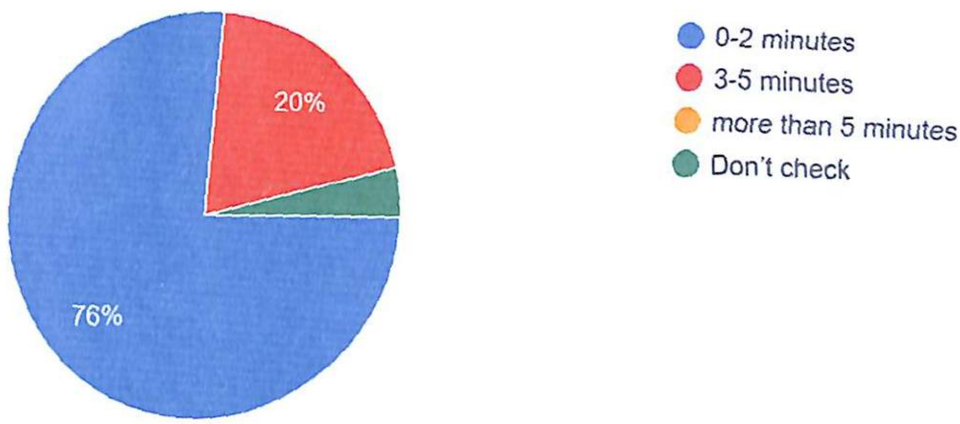

Figure 6.7: How much time does it take for checking attendance during Practice/Lab sections?

Finally, the instructors said that it checking attendance automatically is good approach. This number is 76% [Figure 6.8]. Two instructors want to check manually. However, 3 out of 25 think that attendance is not required.

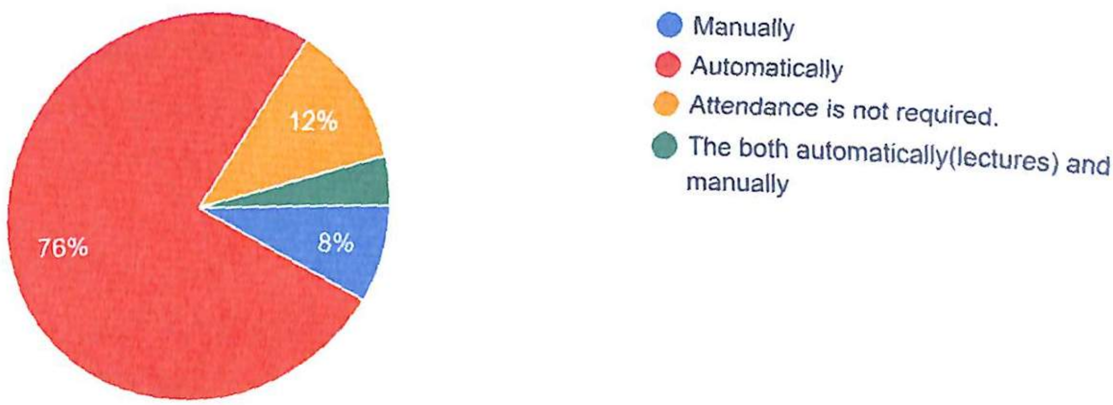

Figure 6.8: How do instructors want the system to be?

According to the study, checking the attendance manually takes much time. Let us assume that marking students takes 3 minutes every time. Twenty-five instructors have total 150 hours of class in a week. Together they lose 450 minutes every week. In a month, this number gets 1800 minutes, which is 30 hours. Other instructors who did not participate on survey also must be mentioned. This costs very much to government, and automatic attendance monitoring system must be developed to solve this problem.

Table 6.1 compares traditional attendance monitoring system to the proposed system where the second one is better in all comparisons. The proposed system does not need human interface, and it checks attendance automatically. The records and data is stored in database that is safer than papers. The data accuracy is high for proposed system.

Parameters	**Human Interface**	**Average time for checking**	**Resources**	**Data accuracy**	**User Friendly**	**Data Security**
Traditional System	Yes	More than 3 minutes	Paper, computer	Low	No	Data can be lost
Proposed System	No	Automatic	Electronic record	High	Yes	Data is stored in DB

Table 6.1: Comparison between Traditional System and Proposed System

On the other hard, automatic attendance system has several types such as biometrics, QR code, barcode, magnetic stripe, and RFID-based attendance systems. These technologies have different needs and requirements. Hasanein et al. [12] compared and discussed the most standard types of automatic attendance systems like barcode, biometric, magnetic stripe, and RFID. RFID does not need control and it has wide functionalities. Data density, and resources and data accuracy is higher than other three types in RFID. In addition, RFID does not require direct contact, and it has no influence direction of reader and data carrier. Barcode and Magnetic stripe fails if there is no slot of communication. RFID has lower cost than biometrics.

Hardware part of any IoT system is very important when it comes to its cost, power, memory, and network. IoT systems should be available and usable with more functions that allows using in more conditions. The hardware of the system is compared to previous authors' systems that used RFID reader and IoT hardware platform. The comparison made by the following usability [Table 6.2 and 6.3]:

1. How does the system transfer captured data?
2. How the device take power?
3. Where is the captured data stored?
4. What kind of additional system is required to check the correctness of data?

Author(s)	Data Storage	Data Transfer	Power	Additional Check
Hasanein et al. [12]	Server	Ethernet cable	Power Supply	No
Ching et al. [7]	Central server	n/a	Power Supply	No
Ishan et al. [13]	Firebase Cloud	n/a	Power Supply	Check weight and height
Tarun et al. [26]	Cloud	n/a	Power Supply	Capture image of classroom
Ping et al. [24]	Cloud	Wi-Fi	3.3 V Power Supply	No
Guixin et al. [11]]	Central Server	n/a	Power Supply	No
Asim et al. [5]	n/a	n/a	Power Supply	No
Joseph et al. [15]	Cloud	Wi-Fi	Power Supply	No
Proposed System	Central Server	Ethernet	Power over Ethernet	No

Table 6.2: Comparison of RFID-based systems of previous authors by technical specifications

The records and data are stored in server in [12], [7], [11], and proposed system that makes communication with device more easily than using cloud. Cloud is better for data safety. When it comes to transferring data in [12] and proposed system used Ethernet cables where data is transported safely without corruption and for long distance. Wireless must be able to use always. Using power supply makes the device on repeatedly. Hasanein et al. [12] used Ethernet cable for data transfer and power supply for powering the device. In this case implementing the device can take much more money for cabling than other authors' systems. Ethernet can be used for both purposes like in proposed system. In [13] and [25] used technologies for additional checking that makes correctness of students' data higher than other systems.

Author(s)	Main Specifications
Hasanein et al. [12]	Student's information displayed in screen and web-based application.
Ching et al. [7]	Student must put ID card into slot; the system is installed in the classroom near the teacher's table to watch.
Ishan et al. [13]	Non-biometric verification that uses W-H fusion function for additional checking to control correctness of data. Uses MQTT protocol to send data.
Tarun et al. [26]	Camera is also used for capturing image in classroom; used image comparison algorithm to count number of attendees.
Ping et al. [24]	Used Node MCU microcontroller for fast wireless connection.
Guixin et al. [11]	Basic information including name, age, course name, venue, etc. are stored in RFIC card.
Asim et al. [5]	Display result on both University TV panels and web-based application.
Joseph et al. [15]	All information is stored in additional memory for checking whether tagged ID exist or not.
Proposed System	Ethernet cable is used for both data transportation and powering.

Table 6.3: Comparison of RFID-based systems of previous authors by commenting their main specifications

In addition, IoT systems should have more functionalities to use for user's aims. The proposed system compared to RFID-based attendance monitoring systems of previous authors according to criteria and metrics discussed in Hasanein et. al. [12]:

1. Does the system contain data management?
2. Does the system have functionality to track student's location and position?
3. Does the system have service to send report or notification?
4. Does the system observe the achievements of students?
5. Does the system provide records and data when error appeared?
6. Does the system support information service for displaying the student's information on the screen?

Table 6.4 shows comparison results according to the questions discussed above. The letter 'Y' stands for 'Yes' meaning the system has this functionality or metrics. Conversely, the letter 'N' stands for 'No' that the system has no such functionality.

Author(s)	System Functionality					
	Data Management	Tracking Students	Sending Reports	Monitoring Records	Maintenance Records	Information Services
Hasanein et al. [12]	Y	Y	Y	N	Y	Y
Ching et al. [7]	Y	N	N	Y	N	Y
Ishan et al. [13]	Y	N	N	N	N	Y
Tarun et al. [26]	Y	N	N	N	Y	N
Ping et al. [24]	Y	N	N	Y	N	N
Guixin et al. [11]	Y	N	N	N	N	N
Asim et al. [5]	Y	Y	N	N	N	Y
Joseph et al. [15]	Y	N	Y	Y	Y	N
Proposed System	Y	N	Y	Y	Y	N

Table 6.4: Comparison of RFID-based system of previous authors by their functionalities

All previous systems support data management. However, only [12] and [5] are enable to track student's location and position using additional technology. The systems [12], [15], and proposed system have functionality to send notification to students warning about absenteeism. This feature helps the students to control their participation. [7], [24], [15], and proposed system monitor achievements of students using records and data that gives further research in their performances on lessons. [12], [26], [15], and proposed system store data in the database for maintaining records and data when an error occurred. [12], [7], [13], and [5] support information service that displays the student's information about course, time, timetable, etc.

7. Conclusion

A student attendance monitoring system is designed and implemented to provide capabilities for tracking student attendance, informing about gaps in timetable, and manage the data to examine student's performance on subjects. In addition, the proposed system eases work of staff where there is no need to take absence records using extra paper works or electronic documents. Application of IoT technology is achieved to support the automated attendance monitoring system for an academic sector using RFID technology and IoT hardware platform. Size of the data to be sent by network is very small that is 9 bytes per one track. The hardware device of the system is low-costed and uses Ethernet cable for both power and transferring data. In a result of comparison, it can be said that Hasanein et al. [12], Joseph et al. [15], and the proposed work have most of the system functionality criteria. Primary goals for future directions, the first one is to develop student information service that will be displayed in screen, the next one is to use more than one RFID reader in a board, third goal is to extend to NFC reader that allows using NFC tags of wearable devices and gadgets, the fourth goal is to examine CoAP, MQTT, and RESTful web services for fast transportation of the data, and final goal is to extend the system by inserting additional mechanism to control card replacements among different students.

References

[1] Barenji Ali Vatankhah and Canberk Degirmenci. "Robot control system based on web application and RFID technology". In: *MATEC Web of Conference 28* (2015). DOI: `10.1051/matecconf/20152804001`.

[2] Bazzi Ali et al. "RFID based paid parking system". In: *International Conference on Current Trends in Computer, Electrical, Electronics and Communication (ICCTCEEC-2017)* (2017), pp. 1238–1241.

[3] Arduino. *Arduino*. URL: `https://arduino.cc/`.

[4] Arduino. *Arduino Yun*. URL: `https://store.arduino.cc/usa/arduino-yun/`.

[5] Majeed Asim and Ali Mahmood. "How Internet-of-Things (IoT) making the university campuses smart? QA higher education (QAHE) perspective". In: *018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC)* (2018), pp. 646–648. DOI: `10.1109/CCWC.2018.8301774`.

[6] Noer Astriany, Hasanuddin Zulfajri B., and Djamaluddin Dewiani. "Implementation of RFID based raspberry pi for user authentication and offline intelligent payment system". In: *2017 15th International Conference on Quality in Research (QiR) : International Symposium on Electrical and Computer Engineering* (2017), pp. 251–255.

[7] Ching Hisang Chang. "Smart classroom roll caller system with IoT architecture". In: *2011 Second International Conference on Innovations in Bio-inspired Computing and Applications* (2011), pp. 256–360.

[8] Miorandi Daniele et al. "Internet of things: vision, applications and research challenges". In: *Ad Hoc Networks* 10 (2012), pp. 1497–1516.

[9] K. B. Eric and W. H. Ya. "IoT based smart restaurant system using RFID". In: *4th International Conference on Smart and Sustainable City (ICSSC 2017)* (2017), pp. 1–6. DOI: 10.1049/cp.2017.0123.

[10] Welbourne Evan et al. "Building the internet of things using RFID". In: *IEEE INternet Computing* (2009), pp. 48–55.

[11] Zhao Guixin and Ql Bei. "Application of the IoT technology in the intelligent management of university multimedia classrooms". In: *Applied Mechanics and Materials Vols* 513-517 (2014), pp. 2050–2053.

[12] Rjeib Hasanein D. et al. "Attendance and information system using RFID and web-based application for academic sector". In: *International Journal of Advanced Science and Applications* 9.1 (2018), pp. 266–273.

[13] Hossain Ishan Arefin et al. "IoT based autonomous class attendance system using non-biometric identification". In: *2018 Joint 7th International Conference on Informatics, Electronics and Vision (ICEIEV) and 2nd International Conference on Imaging, Vision and Pattern Recognition (ICIVPR)* (2018), pp. 268–271.

[14] Gubbi Jayavardhana et al. "Internet of things (IoT): a vision, architectural elements, and future directions". In: *Future Generation Computer Systems* 29 (2013), pp. 1645–1660.

[15] Irawan Joseph Dedy, Adriantantri Emmalia, and Farid Akh. "RFID and IoT for attendance monitoring system". In: *MATEC Web of Science 164* (2018), pp. 1–8. DOI: https://doi.org/10.1051/matecconf/201816401020.

[16] Mihal'ov Juraf and Hulic Michal. "NFC/RFID technology using Raspberry Pi as platform used in smart home project". In: *IEEE 14th International Scientific Conference on Informatics* (2017), pp. 259–264.

[17] Kamel Khechiba. "Design and implementation of microcontroller based controller for direction and speed of a robot using arduino". In: (2016). DOI: 10.13140/RG.2.2.22462.69447.

[18] Singh Kiran Jot and Kapoor Divneet Singh. "Create your own internet of things". In: *IEEE Consumer Electronics Magazine* (2017), pp. 57–68.

[19] Maciej Kranz. *Building The Internet of Things*. Wiley, 2016.

[20] Sowmiya M. and Sabeenian R. S. "Security and monitoring system by using RFID tags and multiple sensors". In: *International Conference on Electrical, Instrumental and Communication Engineering (ICEICE2017)* (2017).

[21] Maksimovic Mirjana et al. "Raspberry pi as internet of things hardware: performances and constraints". In: *1st International Conference on Electrical, Electronic and Computing Engineering* (2014), pp. 1–6.

[22] Nadzir Norsaidah Muhamad, Rahim, and Zubir. "Wireless sersor node with UHF RFID for monitoring system". In: *International Symposium on Antennas and Propagation* (2017).

[23] Raspberry Pi. *Raspberry Pi.* URL: `https://raspberrypi.org/`.

[24] Tan Ping et al. "Teaching management system with applications of RFID and IoT technology". In: *Education Sciences* (2018).

[25] Saimounika T. and Kishore K. "Real time locating system using RFID for Internet of things". In: *International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS-2017)* (2017), pp. 3507–3508.

[26] Sharma Tarun and Aarthy S. L. "An automatic attendance monitoring system using RFID and IoY using Cloud". In: *2016 Online International Conference on Green Engineering and Technologies (IC-GET)* (2016).

[27] Vujovic Vladimir and Maksimovic Mirjana. "Raspberry Pi as a sensor web node for home automation". In: *Computers and Electrical Engineering* (2015).

[28] *What is the Internet of Things.* URL: `http://starproperty.my`. April 2, 2017.

[29] xDevs. *Overlooking for Raspberry Pi 3 model B.* URL: `https://xdevs.com/article/rpi3_oc/`.

[30] Jia Xiaolin et al. "RFID technology and its applications in internet of things (IoT)". In: *2012 2nd International Conference on Consumer Electronics, Communications and Networks, CECNet 2012 - Proceedings* (2012), pp. 1282–1285.