Implementation of RFID-based Lab Inventory System

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***Abstract*—Radio Frequency Identification (RFID) is one of the enabling technologies for IoT. RFID is a computerizing recognition process field that has steadily gained momentum in recent years. It is now being recognized as a technique to improve data handling processes, complementing other data capture technologies in many ways. Numerous devices and accompanying systems have been created to meet a wide range of applications. Given its effectiveness and affordability, short-range surveillance and monitoring can benefit greatly from RFID technology.**

This paper aims to show an example of how RFID technology can be used as an inventory management tool in university labs where a large number of equipment is a challenge that faculty have to face every day. The developed system allows students to virtually see which labs are present in the university and the equipment present in them. Secondly, they can apply for usage of a particular piece of equipment between a time slot, and it can be authenticated by that RFID tag present next to computerizing recognition process field that has been scanned before usage.

***Index Terms*—Internet of Things (IoT), Radio Frequency Identification (RFID), Inventory Control**

I. Introduction

Things that can be managed online are referred to as IoT. The rising demand for connection and control across a wide range of gadgets and devices has led to a rapid expansion of the Internet of Things (IoT) market over the past few years. To enable dependable remote connection and data transfer in a wireless environment, effective connectivity is the primary criterion applied to current IoT devices[1].

This goal is accomplished by using processing-capable sensors on these items and serving technologies that connect to the network and exchange data. Due to the integration of numerous technologies, including widely used computers, sophisticated embedded systems, and hardware sensors, the sector has undergone changes[2].

Each institution has a large number of laboratories as well as a large number of tools, kits, and other items that both students and instructors use. Keeping track of all the laboratory inventories is essential. Usually, fat dead-stock registers are used for this. It is an extremely time-consuming and arduous operation. There is frequently no provision in place to produce a regular or yearly report on how inventories are being used. Sometimes, items are taken out of the lab without being entered in the inventory register, and other times, they are even stolen, costing the institution money and ultimately the students' money. Sometimes the inventory register is lost and all of the records are erased. This system does not provide inventory security. All of these problems make the system unreliable, unsafe, and ineffective[16].

The Internet of Things (IoT) concepts urge us to imagine vast, open networks of numerous sentient things that may interact with one another and their surroundings, share data and resources with the cloud, and respond to environmental changes. 75 billion gadgets might be connected to the Internet of Things by 2025. Radio Frequency Identification (RFID) is one of the IoT's enabling technologies (RFID)[3][4].

Small electrical gadgets with a chip and an antenna are referred to as RFID. It gives that object a special identification number. The RFID device needs to be scanned in a similar way to the bar code or magnetic strip to retrieve the identifying data. From an energy perspective, there are three different types of RFID tags: passive, semi-passive (battery-assisted passive, or BAP), and active.

Passive tags often use HF (High Frequency) and LF (Low Frequency) frequencies. Better range, a quicker read time, and less energy are (very simply) RFID LF's advantages over

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HF. However, HF allows the card and reader to communicate in both directions. Identification is given, as well as the information kept in the sectors[5][6].

The paper is organized as follows: Section II discusses the entire system design, which includes the technologies and the hardware components that have been used. In Section III, the proposed methodology is explained. This explains how the system is interconnected to its various components. Section IV discusses the obtained results and lastly, Section V concludes the paper.

II. System Design

A. Hardware

IoT device solutions that are robust, affordable, and low-power are necessary to advance the technology's applications. A compact form factor is another necessity for an IoT device; the wider the device's application space, the smaller and lighter it must be. A microprocessor and a wireless communication module, or a combination of both, are components of every IoT-based device. There are a lot of modules available, but the majority of the devices that are now on the market are either very expensive or big and heavy[7].

1) ESP32: The former microcontroller ESP8266 was replaced by a new gadget called ESP32. The ESP32 gadget is a potent microcontroller with integrated Wi-Fi and Bluetooth that is made to be the ideal choice for Internet of Things devices. It is simple to integrate ESP32 onto a custom PCB and construct a space-saving gadget thanks to the published circuit of the module ESP-WROOM-32. For testing and teaching purposes, the board ESP32-DevKitC is a ready-to-use, breadboard-friendly option[8][9].

2) MRC522: The 13.56MHz Mifare card detection MRC522 module is a Serial Peripheral Interface (SPI) breakout board device made up of an MRC522 IC. Mifare is ideal for the job because it is an RFID tag brand that is frequently used in daily life. The fundamental idea behind an RFID module is the transmission of an electrical signal to cards and the reception of data—the memory content of the card—that is transmitted back from the card[10].

B. Front-end Development

We would define front-end development as the graphical user interface of a particular website, using tech stacks such as HTML, CSS, and JavaScript so that the users can view and interact with the website. The main objective here is to ensure that when any user opens up the website, he/she is able to view the information in a format that would be easy to read. Here, we determine where the images would be placed, what the navigation should look like, and how do we present the website. Below are the tech stacks that we have used for our website:

1) HTML: HyperText Markup Language (HTML) is used to show documents on an online browser. Browsers receive markup language documents from an online server or local storage and render the documents into transmission web content. Markup language describes the structure of an online page semantically and originally enclosed cues for the looks of the document.

2) CSS: Cascading Style Sheets (CSS) is a cascading language that can be used to describe the presentation of a document written in a markup language like HTML. CSS describes how a particular element should be rendered on the screen. CSS is one of the core languages of the open web and it is standardized across web browsers. CSS is used to style and lay out web pages.

3) Bootstrap: Bootstrap is a free and open-source framework that helps us in responsive front-end web development. It is an HTML, CSS, and JavaScript library that simplifies the development of web pages. The main purpose of adding it to our project was to apply Bootstrap's layout. It provides a basic style definition for all the HTML elements. The most significant bootstrap feature is its containers. The container is a layout component and every other element is placed inside it.

4) React: A free and open-source front-end JavaScript library, React enables us to build user interfaces based on the UI components. It can be used as the base in the development of a single-page, mobile, or server-rendered application. Also, React usually requires the use of some additional libraries for client-side functionality.

C. Back-end

The back end of our website is crucial in bringing all the project's components together and giving it life. The back end is in charge of managing the database, dealing with any API calls, transferring data to the front end, and receiving data from NodeMCU. We were able to meet the project's requirements thanks to various diverse libraries supporting Node.js. The project's database is MongoDB.

1) Node.js(v16.14.1): A back-end JavaScript run-time environment that is open-source, cross-platform, runs on the V8 engine and executes JavaScript code outside of a web browser. It was created to help create scalable network applications. Using Node.js, programmers may create command-line tools and server-side scripts that generate dynamic web page content before the page is transmitted to the user's web browser.

2) Express: Express is a back-end web application framework for Node.js, released as free and open-source software under the MIT License. It is designed for building web applications and APIs. Its features are robust routing, concentrating on high-performance and HTTP helpers (redirection, caching, etc).

3) MongoDB: Document-oriented database application MongoDB is cross-platform and open source. MongoDB is a NoSQL database application that employs documents that resemble JSON and optional schemas. Field, range query,

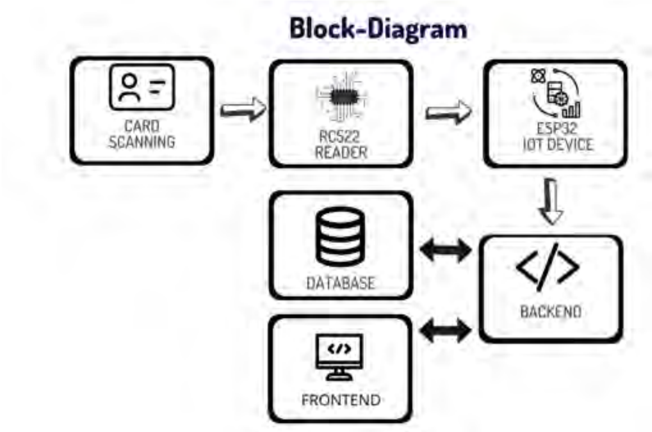

Fig. 1. Block Diagram

and regular expression searches are supported by MongoDB. Queries can include user-defined JavaScript functions as well as the ability to return specified document fields.

III. Methodology

Due to some connection issues, while using the ESP8266 [4], ESP32 was used to interface with the MRC522. According to RFID system theory, unless it is utilized for data transfer, just the first 4 bytes of the first data block of the first sector of an RFID card are typically used for identification to reduce the time necessary to discern the contents of a card. The term ”Unique Identifier” refers to these four bytes (UID). The reader will only record the UID bytes whenever a card is waved. Following the capture of this data, it will be transferred via the SPI communication protocol, which is a native protocol for both MFRC522 and ESP32[11].

A 2MB flash memory is attached to the ESP32 microcontroller. ESP module is more dependable for specialized tasks than most microcontrollers because it is theoretically faster and has larger flash memory. Because the microcontroller has Wi-Fi firmware built-in, it can connect to Wireless Access Points and browse the internet. After completing the necessary security checks and connecting to a modem or mobile hotspot, the ESP32 will be given an IP address, indicating that it is now capable of sending IP packets. The modem will send these packets to the Internet Service Provider over DSL, where they will be routed on a sub-net and enter the internet. The code uses the WiFiClient library to connect to the network.

Following a series of programs, the ESP32 will convert the data into an IP packet after identifying a card and send it to a database that the website can access. Following a series of programs, the ESP32 will convert the data into an IP packet after identifying a card and send it to a database that the website can access. The ESP32 will additionally ask the database for a list of RFID UIDs that are pre-written before beginning to distinguish between the detected card and the pre-written request is accepted and a component is issued, a query is generated that acts as a proof for the component ted when the RFID card is read so the lab assistant can track its usage. This is accomplished using the NTPClient library which connects to the internet to allow the ESP32 to read the current date and time.[12]

The server part should provide two main services. The first service concerns communication with the client part. A specific client (ESP32) contacts the server always when an RFID card is detected by the RFID reader. Accordingly card ID, current time, and current date query are sent to the database. The server acknowledges or rejects access requirements to the query. The second service concerns access management. The server part should provide a user-friendly way to configure access for specific users identified by their RFID card. All necessary data are stored in the MongoDB database. To create a centralizer-appropriate access system JSON schemas are needed. There are four major databases. First is the User database which stores all user information like full name, UID, identification, and type – to distinguish between students and lab assistants or other employees. A user database is used for extracting specific student, admin, or set of student data. The second is Component data which stores the details of each component present in the lab. The third is the request database where the request query is sent by students which are stored under the specific lab and its lab assistant. And lastly, we have our Journal database where after a request is accepted and a component is issued, a query is generated that acts as a proof for the component which is issued to a specific student.[13]

The process is that the student has to visit the website. On the website, the student has to select the component from the lab they prefer. After selecting the component a calendar will appear on the screen. The student now has to request a slot by selecting the time period and date. After this process is done, a request is generated under the lab assistant request page. The lab assistant will now see the request and allot the component by scanning the specific tag which is attached. The date and time of the reading are packed into a message and the Journal database. The Boolean data type (returnData) in the Journal database will remain false if the component is not returned to the lab. To return the component the student or the lab assistant has to scan the RFID tad again. The scan will update the data in the Journal database by changing the Boolean value to true.[14]

IV. Result

This system produced a GUI with two main functions i.e. showing the equipment present in the numerous labs an institute has and slot booking for the equipment available in the labs' inventory. It also shows the information regarding the apparatus present. The ab assistant can also regularly update if the hardware is facing any issues. Since there are multiple quantities of a single instrument. the assistant can also state on the website which particular instrument is usable and which equipment is facing problems.[15]

Once the RFID tag or card is read, it shows the serial number of the card/tag in decimal and hexadecimal format. the decimal format and the date and time of the reading are

Fig. 2. Website Homepage

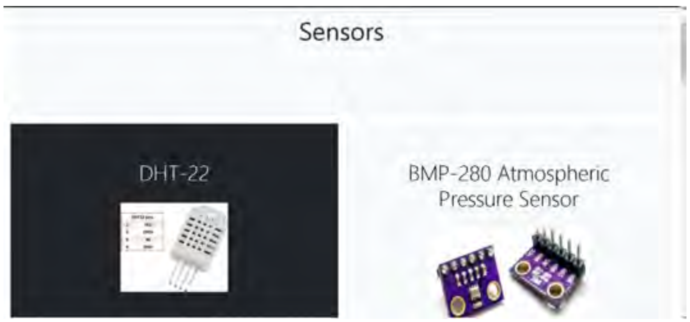

Fig. 3. Equipment present in a lab

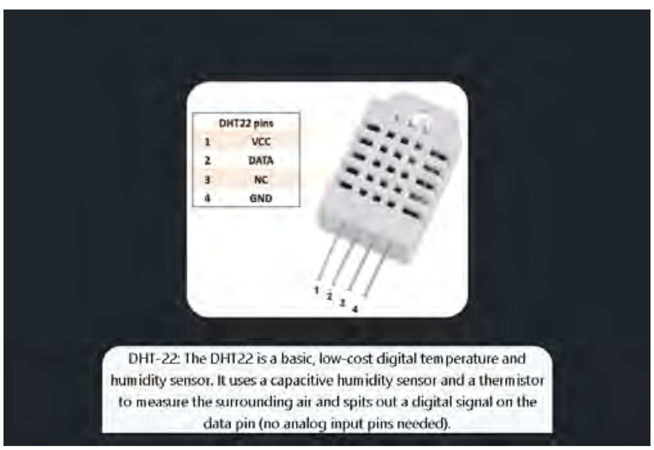

Fig. 4. Description of the equipment

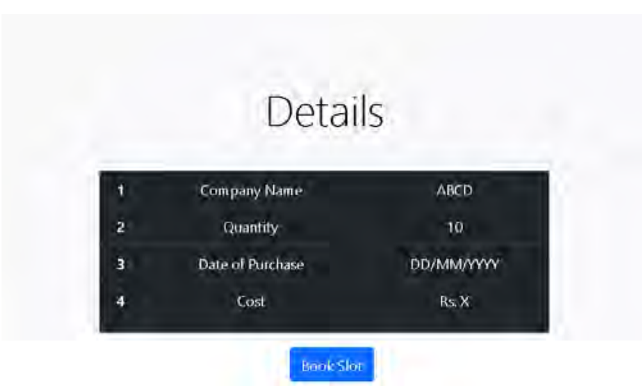

Fig. 5. Details regarding equipment and slot booking option

Fig. 6. Read data shown on MongoDB

packed into a message and then sent to the MongoDB backend with the help of HTTPClient. It should then relate to the pre-recorded RFID serial numbers and find a match to show which apparatus' card/tag was read.[16][17]

V. Learning Outcomes

We learned about integrating technologies for practical solutions through the implementation of IoT with RFID systems. We learned about the criteria for students and colleges through To. To develop the best website for the student and the college, we looked at university websites when designing this one. Another technical learning outcome was the connection of the ESP module with our back-end system using the HTTP client library. This project also helped us attain knowledge on working with Arduino modules, NodeMCU modules, and Raspberry Pi and interfacing them with different sensors.

VI. Conclusion and Future Work

The paper demonstrates the development of an RFID-based inventory management system to track lab equipment automatically and stop unauthorized checkout of lab equipment from the university's lab. The system tags the equipment with robust battery-free RFID tags and uses a contactless card or tag for user authentication. The created system can be enhanced in the future by employing more effective RFID tags and antennae that can display the equipment's proximity, which may then assist in creating reliable machine-learning algorithms for precisely localizing lab equipment across the university.

This project can be taken forward by using long-range tags, which have a larger reading radius. By using it, we can have a room limit for the equipment and track them, if they are taken out of the room. This project can also be expanded for use throughout the campus by adding a few web pages for the different colleges on the campus.

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