IOT-Enabled Smart Library Control System With Concurrent NFC Tag Monitoring

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Abstract- *The NFC Library Management System is an innovative and efficient solution designed to streamline library operations by leveraging NFC (Near Field Communication) technology. The system focuses on two primary functionalities: Attendance Tracking and Book Borrowing Management, making library interactions seamless and automated. When students scan their NFC tags, their attendance is automatically recorded in the system, ensuring accurate tracking by avoiding duplicate entries for the same day. Additionally, the system maintains a count of unique attendance days for each student. For book management, students can borrow or return books by scanning NFC tags associated with both their account and the book. The system records borrow dates, calculates due dates, and dynamically manages fines for overdue returns. The backend is developed using Node.js and Express.js, with MongoDB serving as the database. The frontend, built using React.js, provides a user- friendly interface to monitor attendance and manage library records. Integration with Arduino Uno R4 WiFi enables real- time NFC data transmission to the backend. Furthermore, an SMS notification feature is implemented using Twilio API to alert students about overdue books, accumulated fines, and upcoming due dates. This project aims to replace traditional, manual library management processes with an automated system that reduces errors, enhances efficiency, and improves the overall user experience.*

Keywords: *Arduino, Attendance Tracking, Book Management, IoT, Library Automation, MERN Stack, NFC Technology, Real- time Monitoring, SMS Notifications*

I. INTRODUCTION

The NFC Library Management System is an innovative solution designed to automate and streamline library operations using Near Field Communication (NFC) technology. Traditional library management systems rely heavily on manual record-keeping, paper-based methods, and barcode scanning, which create operational bottlenecks, result in human errors, and consume significant staff time. These legacy systems struggle with duplicate entry detection, real-time inventory management, and automated fine calculations for overdue books.

This system addresses these challenges by focusing on two main functionalities: Attendance Management and Book Borrowing and Returning. Students scan their NFC tags to mark their attendance, ensuring precise logging and preventing duplicate entries for the same day. By scanning NFC-enabled student IDs and book tags, the system tracks borrowed books, calculates due dates, and monitors fines for overdue returns automatically.

The system integrates SMS notifications to alert students about upcoming due dates, accumulated fines, and other important updates. It enhances operational efficiency and minimizes manual intervention, reducing errors and providing real-time insights for students and administrators. The solution is built on the MERN stack (MongoDB, Express.js, React.js, Node.js) for its robust backend, responsive frontend, and seamless integration. Additionally, Arduino-based NFC readers are used to capture data from NFC tags, enabling efficient real- world interactions. The Arduino Uno R4 WiFi connects directly to the backend server via WiFi, eliminating the need for additional communication hardware.

A. Objectives

The primary objectives of the NFC Library Management System are:

- Automate attendance processes and maintain accurate, real-time records of student visits to the library
- Streamline borrowing and returning processes with NFC technology and ensure proper tracking of books and inventory management
- Automate fine calculation for overdue books and notify students of pending fines via SMS until the book is returned methods, increasing operational complexity.

- Minimize human errors in library operations and provide a scalable solution capable of handling large datasets and user interactions
- Leverage IoT and NFC for seamless data capture and use SMS notifications to enhance user communication and engagement

B. Advantages

The proposed system offers several advantages:

- Automated attendance and book transaction management eliminates manual processes, reducing human error and ensuring accurate real-time tracking
- NFC-based scanning provides instant feedback, allowing students to complete library transactions within seconds, eliminating long queues
- Automated fine calculation and SMS notifications keep students informed about due dates and overdue books, reducing administrative workload
- Real-time inventory management enables staff to instantly track book availability and location, preventing losses and improving library operations
- Enhanced security through NFC encryption and authentication protocols protects user data and prevents unauthorized book removal

II. LITERATURE SURVEY

A comprehensive review of existing research in NFC-based library management systems reveals various approaches and implementations.

Suhartono and Karya (2017) introduced NFC technology for campus library services where NFC tags are embedded in student ID cards and books for automated check-in and check-out operations. The authors implement a handheld NFC reader connected to a central server that updates book status and user records in real-time. The system significantly reduces circulation time and manual errors compared to barcode systems but requires dedicated hardware and lacks integration with web-based dashboards or automated fine calculation features.

Nizam and Malik (2024) proposed a hybrid library system combining NFC cards for user authentication and QR codes for book identification to streamline library transactions. The system automatically logs borrowing and return activities when users tap their NFC card followed by scanning book QR codes. The approach improves transaction accuracy and reduces manual data entry but depends on dual identification

Kurmi and Patil (2014) presented a smartphone-based NFC library automation system where NFC-enabled Android phones act as readers to interact with NFC tags attached to library books. Users tap their phones on book tags to perform self-service issue/return operations connected to a central server via internet. The model eliminates the need for dedicated NFC hardware and empowers users with mobile autonomy but primarily focuses on circulation without integrating attendance management or fine calculation.

Brian and Arockiam (2017) introduced an IoT-based smart library system with NFC tags for secure book tracking and anti-theft mechanisms. The system uses networked NFC readers connected to a cloud server to continuously monitor book movements and generate alerts for unauthorized removal. While effective for theft prevention and basic inventory control, the model does not extensively cover student-centric features such as automated attendance or detailed fine management.

Patel, Gupta, and Verma (2019) explored various NFC applications in modern libraries including smart shelving, self- checkout kiosks, and membership card integration. The authors analyze NFC's advantages over traditional RFID and barcode systems such as secure short-range communication, smartphone compatibility, and cost-effectiveness.

The review of existing literature indicates that while several NFC-based library systems exist, most focus on specific aspects. There is a gap in comprehensive systems that integrate attendance tracking, book management, automated fine calculation, real-time dashboards, and SMS notifications into a unified platform. This proposed system addresses these limitations.

III. SYSTEM ANALYSIS

1. Existing System

The existing library management systems generally employ basic manual record-keeping techniques and paper-based methods to track student attendance and book transactions. While these measures provide a foundational level of library operations, they often fall short in detecting duplicate entries, managing real- time inventory, and automating fine calculations for overdue books. Manual systems create operational bottlenecks by overwhelming library staff with administrative tasks, resulting in delays, human errors, and loss of crucial transaction information.

2. Limitations of Existing System

The limitations include implementation costs for smaller institutions requiring hardware and software investment, compatibility issues between new NFC devices and existing library software, manual intervention needed when network or device malfunctions occur, training requirements for users and staff to effectively utilize NFC technology, high-speed internet connectivity requirements for real-time data processing, and inability of barcode systems to prevent duplicate check-ins without manual verification.

C. Proposed System

The proposed system is a fully automated, IoT-enabled library management solution using NFC technology to detect student attendance and book transactions in real-time. When a student scans their NFC-enabled ID card, the system automatically records their attendance, preventing duplicate entries through intelligent validation. A web-based dashboard provides real-time updates on attendance records, book availability, and transaction history for both students and librarians.

The Arduino Uno R4 WiFi microcontroller controls NFC reader operations, sending data to the backend server for processing and storage via its built-in WiFi capability. The MERN stack powers the complete application, connecting to the IoT network for remote monitoring and control. Automatic SMS notifications are sent to students via Twilio API, alerting them about due dates, overdue books, and fine amounts.

D. Advantages of Proposed System

Students and library staff benefit from automated processes that eliminate manual record-keeping and reduce waiting times at library counters. The system reduces human error through automated validation and database constraints. It requires minimal maintenance once deployed, with low-power NFC tags requiring no batteries. Real-time inventory tracking and automated fine calculations ensure accurate book availability status and transparent financial transactions. SMS notifications keep students informed, reducing administrative workload. The web-based dashboard provides accessibility from any device. The scalable architecture can accommodate growing book collections and student populations.

IV. SYSTEM REQUIREMENTS

1. Hardware Requirements

- Arduino Uno R4 WiFi with integrated ESP32-S3 module for WiFi connectivity
- RFID-RC522 module operating at 13.56 MHz frequency
- MIFARE Classic 1K NFC tags for student ID cards and book identification
- Power Supply (USB Port, Battery Pack, or Wall Adapter)
- WiFi Router for internet connectivity
- Buzzer for audio feedback, LED indicators, jumper wires, and breadboard

2. Software Requirements

- Operating System: Windows 10+, macOS, or Linux Ubuntu 20.04+
- Visual Studio Code for web development, Arduino IDE for microcontroller programming
- Programming Languages: JavaScript (ES6+), C++ for Arduino firmware
- Frontend: React.js with Material-UI for responsive design components
- Backend: Node.js with Express.js for RESTful API development
- Database: MongoDB for NoSQL data storage
- Package Manager: npm for dependency management
- Version Control: Git with GitHub
- Twilio API for SMS notifications
- Dependencies: Mongoose, Axios, Body-parser, CORS, Socket.io, Dotenv, Node-cron

V. SYSTEM DESIGN

1. System Architecture

The system architecture consists of three main layers. The Hardware Layer comprises the Arduino Uno R4 WiFi connected to the RC522 NFC Reader via SPI protocol. This layer reads NFC tag UIDs and transmits them to the server via HTTP POST requests over WiFi. The Backend Layer, built with Node.js and Express.js, processes incoming requests, validates data against MongoDB database, manages business logic for attendance tracking and book transactions, calculates fines, and triggers SMS notifications through Twilio API. The Frontend Layer, developed with React.js, provides a responsive web-based dashboard accessible to students and librarians. Socket.io enables real-time updates.

2. Hardware Components

Arduino Uno R4 WiFi serves as the central microcontroller unit featuring a 32-bit processor and integrated ESP32-S3 module for WiFi connectivity. It

interfaces with the RFID reader, reads data from NFC tags, and uses built-in WiFi to send data directly to the backend server.

The RC522 is an RFID module based on the MFRC522 chip operating at 13.56 MHz frequency. It generates an electromagnetic field to detect and communicate with passive NFC tags. When a student taps their card, the RC522 reads the unique UID and sends it to Arduino via SPI protocol.

NFC tags are passive storage devices containing a microchip and antenna but no battery. They are powered by the magnetic field generated by the reader. Student tags are embedded in ID cards, while book tags are adhesive stickers attached to books.

3. System Workflow

System Initialization: Arduino Uno R4 WiFi powers on and automatically connects to the pre-configured WiFi network. Backend Node.js server starts by loading environment variables, connecting to MongoDB database, and initializing Express routes. React frontend loads and establishes Socket.io connection.

Attendance Tracking: Student taps NFC ID card on RC522 reader. Arduino reads UID and sends HTTP POST request to backend. Backend queries MongoDB to find student record and checks for existing attendance entry for current date. If new entry, creates attendance record and increments counter. Arduino provides feedback via buzzer and LED. Dashboard updates in real-time.

Book Borrowing: Student scans ID Card to create temporary Active Session. Student then scans Book's NFC Tag. Backend validates book availability, overdue fines, and borrowing limit. Creates transaction record, updates book status to "Borrowed", calculates due date, and triggers SMS notification.

Book Returning: Student scans Book Tag to return. System retrieves transaction record and calculates fine based on days late. Updates transaction with return date and fine amount. Updates book status to "Available". Sends SMS with fine details if applicable.

VI. CONCLUSION

The NFC-Based Library Management System successfully demonstrates the efficiency of integrating IoT and modern web technologies for modernizing library operations. By combining Arduino Uno R4 WiFi with RC522 NFC readers, the MERN stack, and Twilio SMS API, the system automates attendance tracking and book transactions in real time, drastically reducing manual work and eliminating human errors. Duplicate attendance entries are prevented through intelligent date-based validation. Automated fine calculations ensure transparent and dispute-free financial transactions. SMS notifications keep students informed without requiring librarian intervention.

Librarians benefit from a comprehensive web-based dashboard providing visibility into library operations, real-time inventory tracking, attendance analytics, and transaction history. Built entirely with open-source tools and affordable hardware, the solution is both cost-effective and scalable. The modular architecture allows easy expansion with additional NFC readers, integration with existing student information systems, and adaptation to various library sizes. This project establishes a solid foundation for future innovations in smart library management and demonstrates the practical application of IoT, web development, and database technologies in solving real-world operational challenges.

Future Enhancements:

- AI Fine Waiver Recommendation System analyzing attendance patterns and borrowing history
- Real-time Noise Monitoring with edge ML models for maintaining quiet study environment
- Facial Recognition for touchless authentication and enhanced security
- Mobile Application using React Native for iOS and Android access to library services
- Predictive Analytics for personalized book recommendations based on borrowing patterns
- ERP Integration for unified student data management across institutional systems
- QR Code Backup System for damaged or non-functional NFC tags
- Geofencing alerts for overdue books when students are physically near the library

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