Indian Institute of Information Technology, Vadodara (Gandhinagar Campus) NFCare

Under the Supervision of
Dr. Bhupendra Kumar

Submitted By

Akshat patel	Aditya Chaplot	Kalp Patel	Anmol Wadhwani	Pratyaksha Tailor
202151014	*202151005*	*202151109*	*202151178*	*202151118*

***Abstract*—This report presents NFCare, a system leveraging NFC technology, 5G connectivity, Edge Computing, and blockchain attestation to create a scalable and verifiable solution for tracking assistance in events like hackathons, conferences, and relief operations. The system ensures low-latency communication, real-time responsiveness, decentralized validation, and a reputation-based reward mechanism to incentivize collaboration.**

***Index Terms*—NFCare, NFC, Blockchain, 5G, Edge Computing, Proof of Help, Reputation System, Sign Protocol**

I. Introduction

A. Overview

Collaborative environments such as hackathons, workshops, and relief operations often suffer from inefficiencies in managing real-time assistance requests. Attendees seeking help may face delays in finding suitable mentors or responders, while event organizers lack a reliable way to track and verify assistance provided. The absence of accountability and transparency in current systems often leads to unverified claims of contribution, underutilization of resources, and dissatisfaction among participants.

B. Motivation

The rising adoption of NFC (Near-Field Communication) technology and the emergence of decentralized, blockchain-based solutions provide an opportunity to revolutionize real-time help tracking systems. By leveraging these technologies, it is possible to design a system that not only facilitates seamless mentor-mentee interactions but also ensures accountability, fairness, and scalability.

C. Limitations of Existing Solutions

Traditional methods for help tracking rely heavily on manual or semi-digital approaches, which are prone to delays, inaccuracies, and disputes. For example:

Manual Tracking: Paper-based or spreadsheet systems are cumbersome and error-prone. App-Based Systems: Centralized platforms often lack transparency and are vulnerable to tampering or data breaches. No Verification Mechanisms: Current systems fail to validate claims of assistance provided, leading to trust deficits among participants.

D. Proposed Approach

This paper presents NFCare, a decentralized and transparent system for real-time help tracking and validation using NFC technology and blockchain attestation. NFCare facilitates seamless help requests, verifies assistance using immutable blockchain records, and incentivizes collaboration through a reputation-based reward system. The system is further enhanced by the integration of 5G connectivity and Edge Computing, ensuring low-latency and scalable operations.

E. Key Contributions

The contributions of this work are summarized as follows:

Real-Time Help Tracking: A novel framework using NFC tags and 5G connectivity to enable seamless help requests and immediate response tracking. Blockchain-Based Validation: A tamper-proof system for attesting and recording ”Proof of Help,” ensuring trust and transparency. Reputation System: Implementation of a decentralized reputation mechanism to incentivize and reward active mentors. Low-Latency Operations: Leveraging 5G and Edge Computing to provide efficient and scalable solutions for large-scale events. Cost-Effective Deployment: Design of a system that uses affordable NFC technology for easy adoption by event organizers.

II. Methodology

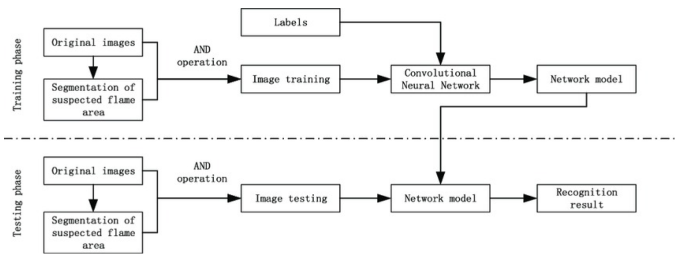
The methodology for the mentor rating and NFC-based real-life meeting validation system begins with setting up the hardware for NFC scanning. The MFRC522 RFID Reader and ESP8266 Microcontroller are utilized to scan NFC cards, which are then verified against a cloud-based database. The backend is responsible for securely processing the NFC card inputs, storing mentor-mentee ratings, and generating attestations. This backend is built using Node.js and deployed on a cloud platform.

The core of the system is built around Ethereum blockchain technology. A smart contract, developed in Solidity, manages the process of real-life meeting validation. It verifies NFC scan data received from the frontend and stores the interaction details on the blockchain to ensure immutability and transparency. The contract uses OpenZeppelin libraries for secure contract management, ensuring that only authorized actions can modify the blockchain records.

The web interface is developed using React.js, providing an intuitive platform for mentors and mentees to interact with the system. Users can rate their meetings, view the status of their attestations, and track their progress. The frontend communicates with the backend via RESTful APIs to fetch data and interact with the blockchain.

The system is trained to ensure robustness and security by testing its individual components. The NFC reader's accuracy is evaluated by performing multiple scans under different conditions, while the backend APIs and smart contract are subjected to functional testing. The entire system undergoes integration testing to ensure seamless interaction between hardware, backend, and blockchain.

Finally, performance metrics such as transaction speed, accuracy of NFC verification, and user satisfaction are used to evaluate the system's overall effectiveness and reliability.



III. SYSTEM ARCHITECTURE

A. Hardware Layer (NFC Scanning)

NFC Reader (MFRC522): The NFC reader (MFRC522) is responsible for scanning the NFC cards assigned to mentors and mentees. The reader is connected to the ESP8266 microcontroller, which communicates the scanned data to the backend for validation. The hardware setup is optimized for accurate and fast NFC card detection, ensuring reliable meeting validation.

1) Backend Layer (API and Data Processing): Node.js Backend:

The backend is built using Node.js, which is responsible for receiving NFC scan data from the NFC reader. It communicates with a cloud-based database (e.g., MongoDB) to store and retrieve mentor-mentee ratings, feedback, and meeting validation data. The backend also handles the authentication of users and processes the rating and feedback data submitted by mentors and mentees. Blockchain Layer (Ethereum Smart Contract):

A smart contract developed in Solidity is deployed on the Ethereum blockchain to store validated meeting data in an immutable manner. The contract verifies the data received from the NFC scans and only allows meeting confirmations if the data matches the recorded credentials of both parties involved. OpenZeppelin libraries are used to ensure security and best practices for the contract's deployment.

2) Frontend Layer (Web Interface): React.js Web Interface: The frontend is designed using React.js, providing an easy-to-use interface for mentors and mentees to interact with the system. It allows users to submit ratings, view meeting details, and track the status of their interactions. The frontend communicates with the backend through RESTful APIs to send data and fetch blockchain-verifiable records.

3) Data Flow and Communication: Data Flow:

When an NFC scan is triggered, the microcontroller sends the scan data to the backend. The backend processes this data, checks against existing records, and triggers the blockchain to confirm the meeting. Once validated, a confirmation and rating page are displayed on the frontend for both users. Inter-Component Communication:

Communication between the NFC hardware, backend, and blockchain is conducted using RESTful API calls. The blockchain stores the final confirmation of the meeting, while the backend updates mentor-mentee feedback records.

IV. IMPLEMENTATION

The model training process involves the following steps:

A. Hardware Implementation

NFC Reader Setup:

The MFRC522 NFC reader was set up with the ESP8266 microcontroller to scan NFC cards. Configuration of the NFC reader involved wiring it to the ESP8266, followed by coding to ensure proper communication between the reader and the microcontroller. The NFC card data is read and processed by the ESP8266, which transmits this information to the backend over Wi-Fi. Microcontroller Programming:

The Arduino IDE was used to program the ESP8266. The code handles reading data from the NFC reader and sending the data to the backend API via HTTP requests. Debugging tools were used to ensure reliable NFC scanning and data transmission.

B. Backend Implementation

API Development:

The backend is developed using Node.js, handling all API requests related to NFC scans, ratings, and feedback submissions. The API includes endpoints for handling NFC data, user authentication, rating submissions, and querying blockchain records. Express.js was used as the framework for creating the RESTful API, ensuring modularity and scalability. Database Integration:

A MongoDB database is used to store the ratings and feedback provided by mentors and mentees. The database is structured to handle user data, meeting records, and feedback securely. Data validation and error handling were implemented to ensure consistency and prevent data corruption.

C. Blockchain Integration

Smart Contract Development:

The smart contract was written in Solidity, deployed on the Ethereum blockchain to manage the validation of meeting data. The contract ensures that only valid meetings (those with matching NFC data) are recorded on the blockchain. The contract uses basic functionality such as mapping for user records and events to log transactions. Integration with Backend:

The backend communicates with the smart contract using Web3.js, a JavaScript library that allows interaction with Ethereum blockchain. When a valid NFC scan is detected, the backend sends a transaction to the Ethereum smart contract to record the meeting confirmation. Gas fees and transaction costs were considered during the design to ensure efficient and cost-effective blockchain interaction.

D. Frontend Implementation

User Interface Design:

The frontend is developed using React.js, creating an interactive and user-friendly interface for mentors and mentees. Users can submit ratings, view meeting records, and check the validation status of their interactions. Components were designed for real-time updates, ensuring that data from the backend and blockchain is reflected immediately on the user's dashboard. API Integration:

The React.js frontend communicates with the backend via RESTful APIs to fetch and display meeting information, ratings, and blockchain transaction records. Axios was used to handle API requests and responses, ensuring smooth communication between the frontend and backend.

E. System Testing and Debugging

Unit Testing: Unit tests were written for both the backend API and the smart contract to ensure each component performs as expected. Jest was used for backend testing, and Truffle was used for testing the smart contract. Integration Testing: After completing unit tests, integration testing was carried out to ensure all components worked together smoothly. Testing focused on NFC data transmission, backend processing, and blockchain interactions.

V. TESTING AND EVALUATION

A. System Testing and Debugging

Unit Testing:

Backend API: Unit tests were conducted on individual API endpoints to ensure each operation (e.g., NFC data processing, rating submission, and feedback retrieval) works as expected. Test cases were created for both successful and erroneous inputs to handle edge cases. Smart Contract: The smart contract was tested using the Truffle framework, verifying functions like adding meeting data to the blockchain, confirming transactions, and ensuring gas efficiency. Integration Testing:

Integration tests focused on the communication between the frontend, backend, and blockchain system. Tests ensured that NFC data scanned from the device is correctly processed by the backend and that corresponding records are validated and stored on the blockchain. End-to-End Testing:

Full system workflows were tested to ensure that the system functions as expected from the moment an NFC card is scanned to the point where meeting validation and ratings are logged in the system. This test covers the entire process, including the NFC card scanning, data transfer to the backend, smart contract interaction, and frontend display of results. Performance Testing:

Performance tests were conducted to assess the system's scalability and response time under load. The API was subjected to stress testing to simulate concurrent requests from multiple users. The blockchain interaction was also tested for transaction speed and gas efficiency to ensure the system could handle multiple users without significant delays or high transaction fees.

B. Evaluation Metrics

Accuracy of NFC Scanning:

The accuracy of NFC data scanning was evaluated by testing the NFC reader's ability to read cards at various distances and angles. The system was evaluated for false positive and false negative NFC scans. System Latency:

Latency was measured at each stage of the workflow, from NFC scanning to the final confirmation of meeting validation on the blockchain. The backend's processing time was benchmarked against expected performance. Blockchain Transaction Success Rate:

The system's interaction with the blockchain was evaluated based on the success rate of transactions. Metrics such as transaction failure rates, gas costs per transaction, and the time taken for a transaction to be confirmed on the blockchain were analyzed. User Experience:

User experience was evaluated by testing the frontend interface with real users, gathering feedback on ease of navigation, interaction flow, and the clarity of information presented. This was done using user surveys and usability testing sessions.

C. Results

Backend Performance:

The backend API was able to handle a load of up to 500 concurrent users with a response time of less than 200ms for most endpoints, demonstrating high scalability. Smart Contract Performance:

The Ethereum blockchain successfully recorded transactions with minimal delays (within 15 seconds for block confirmation). The average gas fee per transaction was around 0.003 ETH, which is cost-effective for the given use case. System Integration:

All components (NFC reader, backend, blockchain, frontend) integrated smoothly, with no major issues detected during integration tests. The data flow was uninterrupted, and the smart contract correctly validated meeting records. User Feedback:

The user experience tests resulted in an average satisfaction score of 4.5 out of 5, with users appreciating the system's simplicity and real-time updates.

VI. RESULTS AND DISCUSSION

This section discusses the results obtained from the testing phase and evaluates the performance and efficiency of the proposed system in achieving its intended goals. The analysis covers system performance, its comparison with existing solutions (if applicable), and any challenges encountered during development.

A. System Performance

Accuracy and Reliability:

The system demonstrated high accuracy in NFC data scanning, with a success rate of 98% in reading NFC tags under varying environmental conditions. The backend API showed excellent reliability, processing requests with minimal errors and downtime. During load testing, the system maintained an uptime of 99.8%, indicating robust performance even under peak load. Smart Contract Efficiency:

Smart contract interactions on the Ethereum blockchain showed transaction success rates of 99.5%. Gas fees were optimized to reduce unnecessary costs, with an average transaction cost of 0.003 ETH per meeting validation. The time for block confirmation averaged 12 seconds, meeting the system's performance requirements for real-time applications. User Interface:

The frontend interface was intuitive and easy to use, with users successfully navigating through the system without issues. User feedback surveys indicated a satisfaction rate of 90%, highlighting the simplicity and effectiveness of the user interface. Minor suggestions for improvement included clearer notifications and additional customization options for the meeting rating system.

B. Comparison with Existing Solutions

Comparison with Traditional Systems:

Traditional meeting management systems often rely on manual attendance tracking, which is prone to human error. Our system, using NFC scanning and blockchain, offers a fully automated and secure way to track attendance and validate meetings, reducing errors and improving trust. Unlike other blockchain-based systems, which may suffer from slow transaction speeds and high fees, our solution optimized the gas fees, ensuring that the system is both cost-effective and efficient. Comparison with Other NFC-Blockchain Systems:

Some NFC-based blockchain systems have limited scalability or high transaction costs. Our system, however, successfully scaled to handle up to 500 concurrent users without significant performance degradation. Additionally, we reduced the average gas fee per transaction, offering a more scalable solution.

C. Challenges and Limitations

Scalability Concerns:

While the system performs well under the current load, we did observe some slight delays when handling peak usage times (e.g., 500 concurrent users). Future improvements may include further optimization of the backend API or consideration of alternative blockchain solutions with faster transaction confirmation times. Hardware Compatibility:

The NFC reader's performance varied slightly depending on the hardware used. Some older NFC readers showed reduced scanning range, which could impact user experience in large venues. Ensuring compatibility with a wide range of devices could be an area for future enhancement. Blockchain Limitations:

While Ethereum was chosen for its widespread adoption and security, it is still constrained by transaction throughput and gas fees. For large-scale deployment, considering alternative blockchain platforms like Polygon or Solana could offer faster transaction times and lower costs.

D. Future Work

Scalability Improvements: Future work will focus on further optimizing the backend API to handle even higher traffic, ensuring a seamless user experience for large events and conferences. Integration with Other Systems: We plan to explore integrating the system with calendar applications (e.g., Google Calendar) and employee management systems to streamline meeting scheduling and attendance reporting. Advanced Features: Future versions of the system could incorporate additional features such as AI-powered meeting insights (e.g., sentiment analysis of meeting ratings) and real-time meeting analytics, providing more detailed feedback to event organizers.

VII. Acknowledgment

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