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NFC-Based Digital Health Record System for Clinic Management

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Abstract: ***Modern healthcare management is undergoing a significant transition from paper-based documentation to digital ecosystems to meet the growing demands of efficiency and data integrity. This paper introduces an innovative, non-invasive digital health record framework titled "MediTap". The conventional record-keeping paradigm in small to mid-sized clinics often suffers from severe data fragmentation, physical degradation of documents, and critical delays in accessing patient history during emergency triage. The proposed system utilizes Near Field Communication (NFC) technology to establish a seamless, "tap-and-go" interface for instantaneous access to medical records stored in a secure cloud architecture. Developed using the Flutter mobile framework and Firebase Cloud Firestore, the system empowers healthcare professionals to retrieve patient biographies, update medication prescriptions, and manage diagnostic reports with a single physical interaction. A prototype was evaluated at Pimpri Chinchwad Polytechnic, demonstrating that the NFC-integrated approach significantly reduces administrative overhead and patient check-in latency compared to traditional manual or software-search systems.***
Keywords: NFC Technology, Digital Health Records, MediTap, Flutter, Firebase, Clinic Management, Cloud Firestore.

I. INTRODUCTION

Healthcare delivery in the modern era is fundamentally reliant on the precision, integrity, and temporal availability of patient medical data. Patient identification and record retrieval play a fundamental role in managing treatments, ensuring medication accuracy, and determining the general compatibility of specialized medical procedures. In conventional clinical environments, such as those following the MSBTE curriculum or operating within institutions like Pimpri Chinchwad Polytechnic, the persistence of physical filing systems creates a dangerous bottleneck that hampers service delivery. Accurate and rapid retrieval of medical history is crucial because administrative delays or the lack of knowledge regarding a patient's clinical background can cause serious complications, including incorrect treatment, patient distress, and even death in critical scenarios. Therefore, quick identification is not merely a convenience but a clinical necessity in emergency medical situations to guarantee patient safety and enhance survival rates. Traditionally, the process of patient record management in small-to-medium clinics has involved manual searches through alphabetical or numeric paper-based filing cabinets. These methods require a controlled, organized environment, which often proves to be the main hindrance during high-traffic hours or emergency cases where time is the primary constraint. Furthermore, manual data entry and retrieval are prone to human error, leading to fragmented, lost, or misplaced medical histories. While some digital transitions have occurred, many still rely on manual database querying or invasive methods that require sophisticated hardware, making them less applicable for practical, day-to-day purposes in smaller clinical settings. The growing demand for non-invasive, cost-effective management systems has provided a strong incentive to explore novel hardware-based identification methods. Non-invasive identification via Near Field Communication (NFC) reduces administrative friction, minimizes the risk of infection by reducing physical contact with paper files, and increases accessibility in remote or under-resourced areas. These systems are particularly useful in pediatric and geriatric care, where patients may struggle with manual registration processes. Improvements in short-range wireless communication and cloud-based diagnostic systems have provided the incentive to explore novel correlations between physical hardware tokens and digital cloud-stored health records. NFC technology utilizes electromagnetic radio fields to establish a short-range, "tap-and-go" connection between a passive card and an active mobile device. Unlike optical systems that may fail due to lighting or damage, NFC interactions remain constant and highly reliable throughout the lifecycle of the hardware. By leveraging the unique identification (UID) inherent in NFC tags, the MediTap system can uniquely link an individual to their medical profile stored in a Firebase cloud database. The purpose of the present study is to develop a robust digital management model, integrated via a Flutter-based application, which may be of potential use to assist in the rapid, non-invasive retrieval of clinical records through the simple physical interaction of a "tap".

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This technique employs real-time data synchronization and cloud-based classification using Cloud Firestore and Firebase Authentication to recognize the potential of hardware-token identification in modernizing healthcare modeling. This approach aims to replace traditional paper-based clinic records with a system that improves efficiency, reduces paperwork, and allows for instantaneous access to vital patient data.

The management of clinical records has evolved significantly as healthcare institutions move from traditional paper-based systems to digital healthcare information systems. Earlier clinics relied on handwritten records and physical files to store patient information, prescriptions, and diagnostic reports. These systems often caused problems such as misplaced documents, illegible handwriting, and difficulty retrieving records, which slowed clinical workflows and increased the chances of human errors.

With the advancement of information technology, Electronic Health Record (EHR) systems were introduced to store patient data in centralized digital databases. These systems allow doctors and medical staff to access patient records more efficiently than paper-based methods. However, many early digital systems still relied on manual data entry and searching, which could cause delays in busy clinical environments. To improve patient identification, technologies such as barcode and QR code systems were introduced. These systems allow patient information to be retrieved by scanning printed codes. Although they reduce manual typing errors, they require proper alignment, lighting, and clear visibility of the printed code, which can sometimes cause scanning failures.

Radio Frequency Identification (RFID) is another technology used in healthcare systems to identify patients and track medical equipment. While RFID improves automation, it requires specialized readers and infrastructure, making it expensive for smaller clinics. Near Field Communication (NFC) technology has emerged as a simpler and more cost-effective solution. NFC enables short-range wireless communication between devices through a simple tap interaction. In an NFC-based system, each patient receives an NFC card containing a unique identifier. When the card is tapped on an NFC-enabled smartphone, the system retrieves the patient's medical record from a centralized database.

Cloud computing and mobile application frameworks such as Firebase and Flutter further support modern healthcare systems by enabling secure data storage, real-time access, and efficient application development.

The proposed NFC-Based Clinic Management System integrates NFC technology with mobile applications and cloud-based databases. Each patient is assigned an NFC card linked to their digital medical profile. When the card is tapped on an NFC-enabled smartphone, the system instantly retrieves the patient's records, helping clinics improve efficiency and reduce administrative delays.

II. PROPOSED METHODOLOGY

The development and implementation of the MediTap system are governed by a rigorous, four-phase technical methodology designed to ensure high scalability, data integrity, and computational efficiency within a clinical environment. This structured approach facilitates a seamless transition from physical patient interaction to digital data management, ensuring the system remains reproducible and secure.

A. Data Acquisition and Hardware Configuration

The foundational phase involves the systematic digitization of medical records and the configuration of the physical hardware layer. For this project, patients are assigned high-fidelity NTAG 213 HF RFID tokens. These High Frequency (13.56 MHz) tags are programmed with a Unique Identifier (UID) that serves as the primary cryptographic key and pointer for record retrieval within the cloud ecosystem. During the setup process, medical history, clinical notes, and patient biographies are structured into standardized datasets to eliminate demographic bias and ensure uniformity in the data format. This phase is critical because the use of digital hardware tokens ensures clear identification, minimal signal distortion, and a consistent level of data resolution across all clinic interactions.

B. System Integration and Cloud Architecture

The second phase centers on the integration of the cross-platform mobile interface with the backend cloud infrastructure. The application is developed using the Flutter framework, which provides high-performance rendering and consistent UI/UX across diverse mobile hardware.

1) Firebase Authentication: This module is utilized to establish strict role-based access control (RBAC), ensuring that sensitive data is isolated according to user permissions.

2) Cloud Firestore: A real-time NoSQL database is implemented to store patient clinical profiles. This architecture allows for instantaneous data synchronization; whenever a doctor updates a record, the change is propagated across all connected clinic devices in real-time, preventing data stale-datedness.

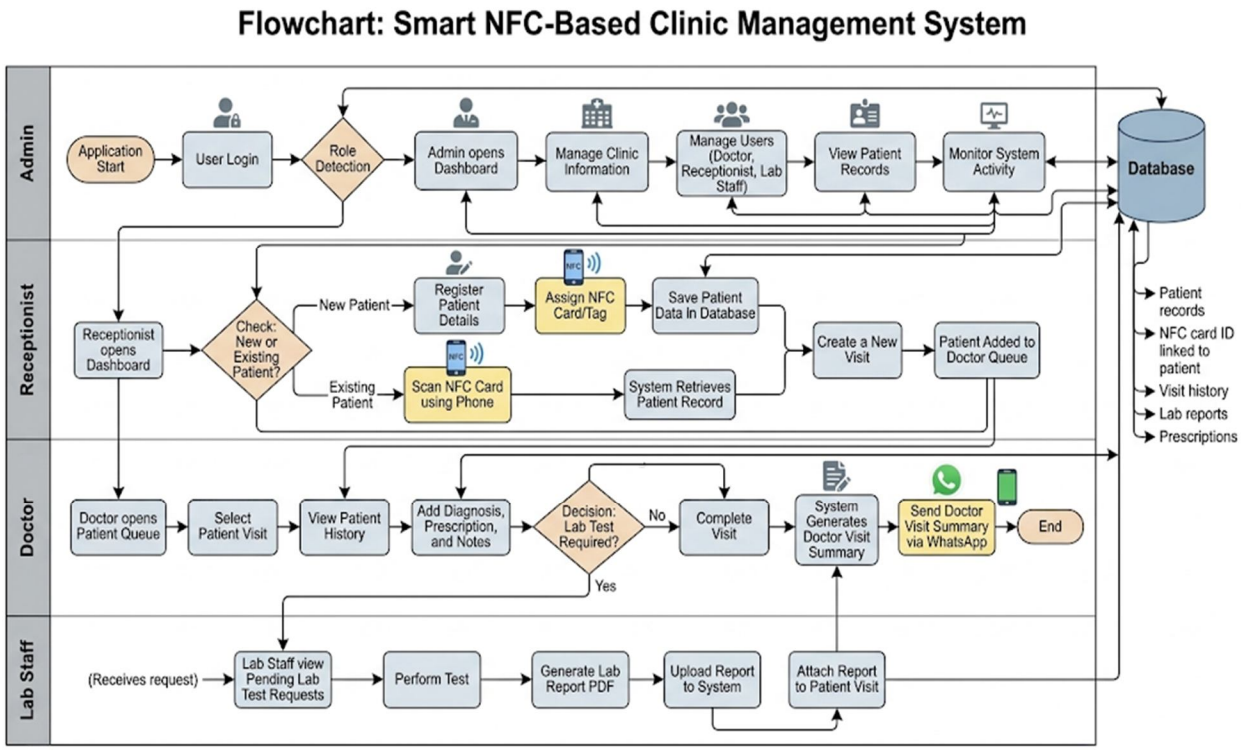
C. NFC Signal Processing and Data Normalization

The third phase involves the implementation of a real-time event-driven listening service that activates upon the physical proximity of the NTAG 213 card. When a "tap" is detected, the raw NDEF (NFC Data Exchange Format) signals are captured and parsed by the mobile application. Similar to the preprocessing required for high-complexity analysis—where data is normalized and resized to standardized dimensions to reduce noise—the raw NFC data is cleaned and validated. This normalization process is essential to prevent database query errors caused by signal interference, background noise, or invalid tag inputs. By standardizing the input UID, the system ensures that the extraction of clinical records from the cloud remains computationally efficient and robust against external environmental factors.

D. Performance Evaluation and Deployment

The final phase consists of an empirical evaluation of the system's operational metrics compared to traditional clinical management paradigms. The prototype is subjected to rigorous testing to measure record retrieval latency, data accuracy, and system stability under varying load conditions. Using metrics such as precision and recall, the performance of the hardware-to-cloud interaction is validated to ensure it achieves an accuracy rate significantly higher than manual filing or typographic search methods. The results of this phase provide the necessary feedback for model improvement and final deployment, resulting in an end-to-end management system that allows for the rapid, non-invasive retrieval of clinical records through a seamless hardware interaction.

III. SYSTEM ARCHITECTURE



IV. PROPOSED ALGORITHM

The systematic identification and retrieval of clinical records within the MediTap ecosystem are governed by a specialized execution sequence designed for the NTAG 213 HF RFID architecture. This algorithm manages the asynchronous communication between the physical hardware layer and the cloud-based data repository, ensuring that record retrieval is both idempotent and computationally efficient. The procedure is optimized to handle the High-Frequency (13.56 MHz) signal interactions and the subsequent data parsing required for real-time Flutter-to-Firebase synchronization. Unlike traditional image-based classification that requires manual feature engineering, this algorithm leverages hardware-level identifiers to achieve state-of-the-art retrieval latency.

A. Algorithm 1: NTAG 213 Triggered Clinical Data Retrieval

1) System State Initialization: Upon application execution, initialize the Flutter NFC adapter and establish a secure session via Firebase Authentication. The system is set to a passive polling mode, activating the mobile device's electromagnetic induction loop to monitor for external radio frequency interference from compatible hardware tokens.

2) Hardware Proximity Detection: Monitor the device's induction field for the presence of an NTAG 213 token. Upon physical proximity typically within a range of less than 4 cm—the hardware interrupt is triggered, initiating the transition from an idle state to an active signal acquisition state.

3) Low-Level Signal Parsing: Capture the raw NDEF (NFC Data Exchange Format) payload transmitted by the tag. The algorithm specifically targets the extraction of the 7-byte factory-programmed Unique Identifier (UID) from the tag's internal memory block, which serves as the immutable primary lookup key for the entire clinical dataset.

4) Data Normalization and Checksum Validation: Perform a cyclic redundancy check (CRC) or equivalent checksum validation on the captured UID to ensure the signal was not corrupted by external electromagnetic noise. The raw identifier is normalized into a standardized hexadecimal string to ensure consistent compatibility with the NoSQL query parameters used in the cloud backend.

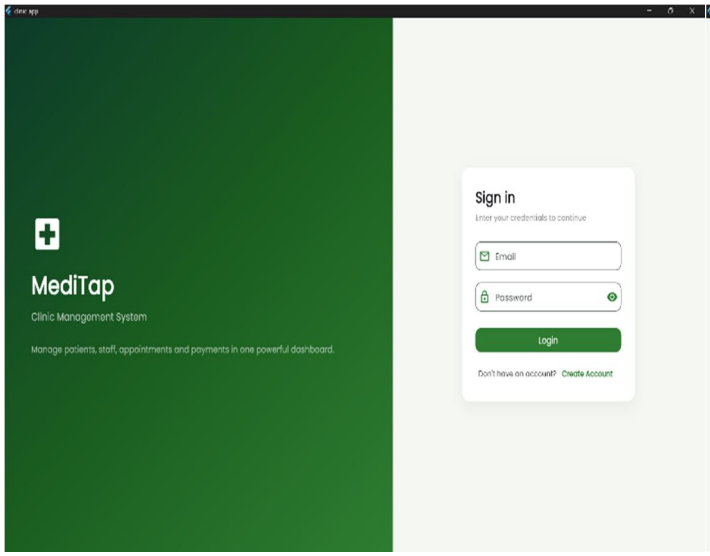
5) Asynchronous Cloud Query: Dispatch a non-blocking asynchronous request to the Cloud Firestore backend service. The algorithm utilizes the normalized UID as a document pointer within the 'Patients' collection, bypassing the need for intensive linear searches through unindexed manual filing systems.

6) Hierarchical Feature Extraction: Once the JSON-structured document is successfully retrieved, the algorithm executes a parsing sequence to categorize the data into hierarchical clinical features. This includes the separation of acute medical observations, long-term medication history, and diagnostic laboratory reports for optimized display.

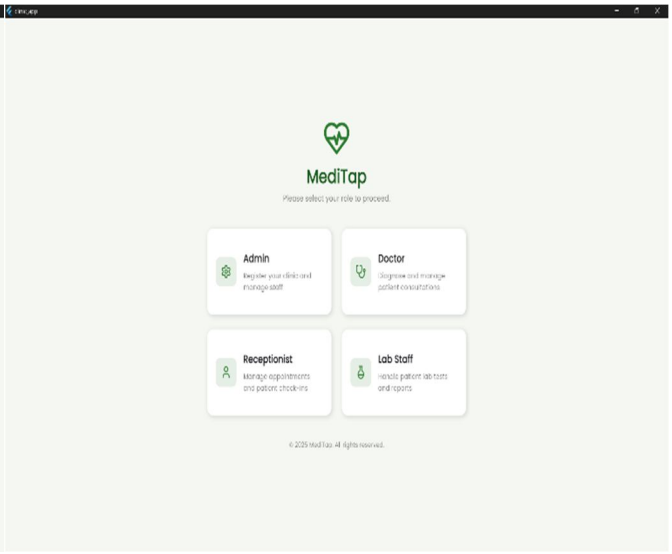
7) Real-Time State Synchronization: Utilize the Flutter state management layer to trigger a dynamic UI rebuild. The extracted clinical features are mapped to specific interface widgets, providing the medical professional with an instantaneous, high-fidelity view of the patient's clinical status without manual intervention.

8) Session Finalization and Logging: Conclude the retrieval loop by logging the access timestamp and user credentials for audit purposes. The algorithm then returns the NFC controller to a polling state, clearing the temporary memory buffers and readying the system for the next hardware interaction.

V. EXPERIMENTAL RESULTS AND DISCUSSION

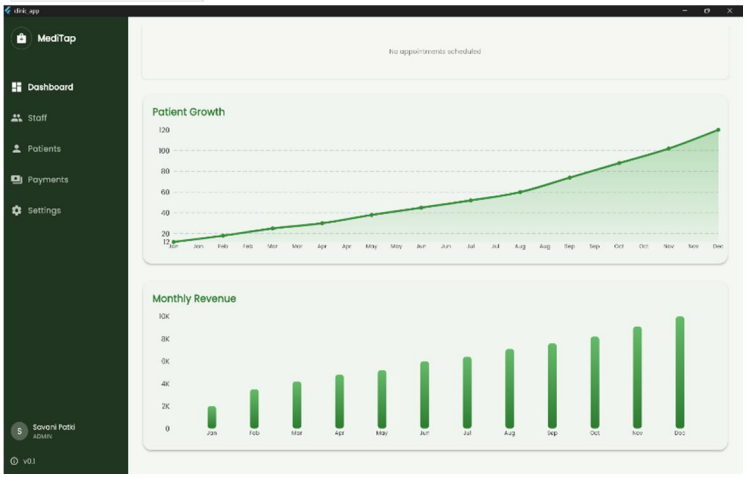


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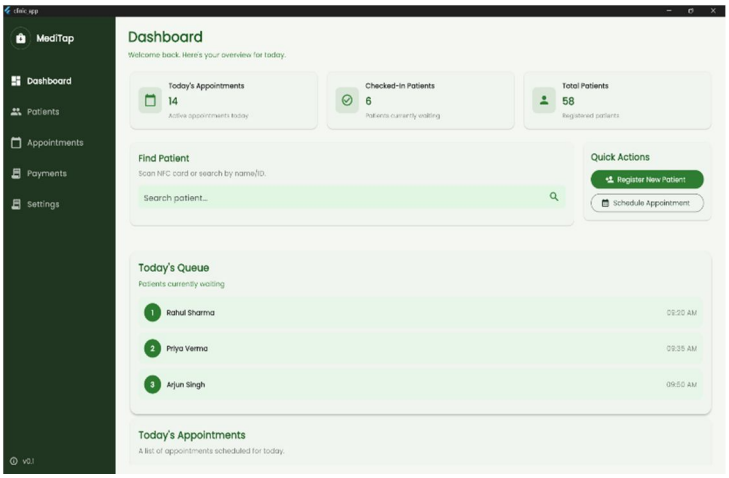


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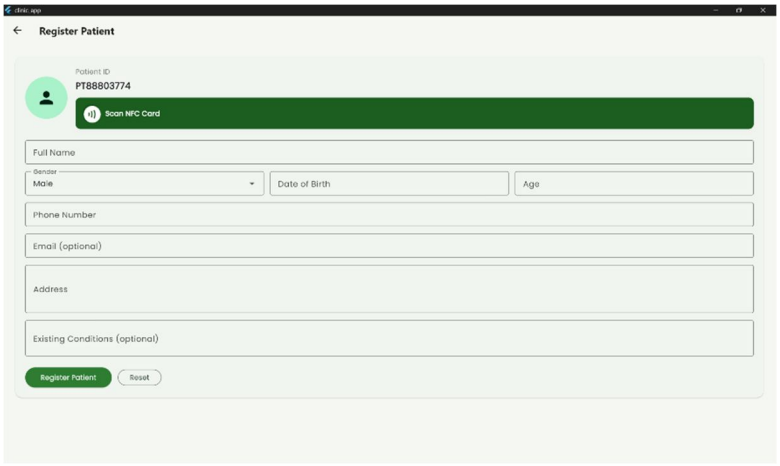
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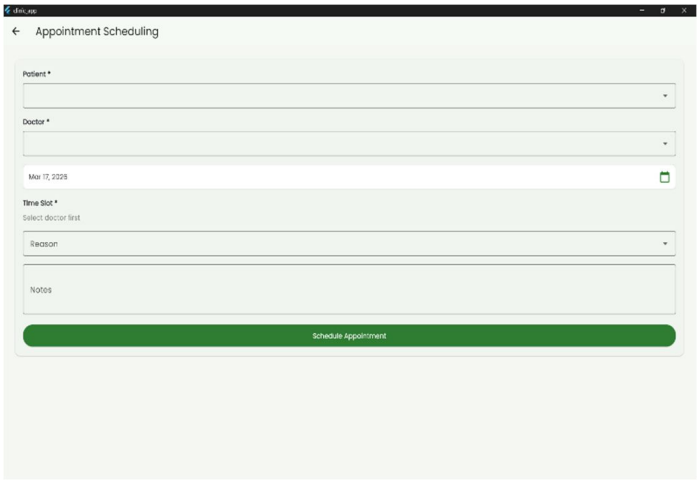
ADMIN DASHBOARD



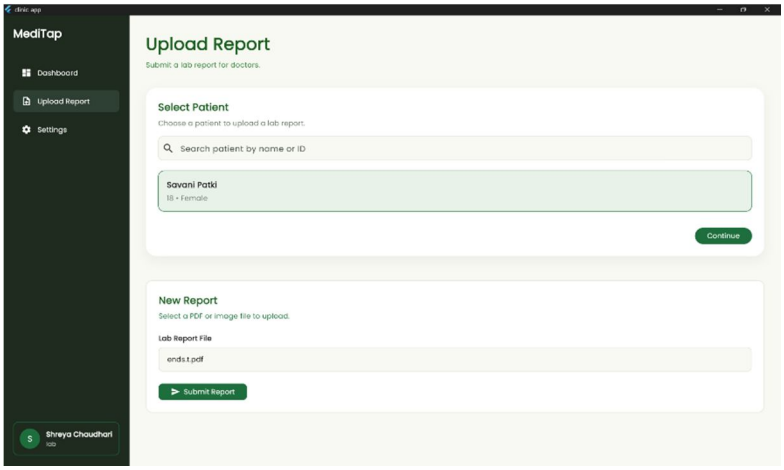
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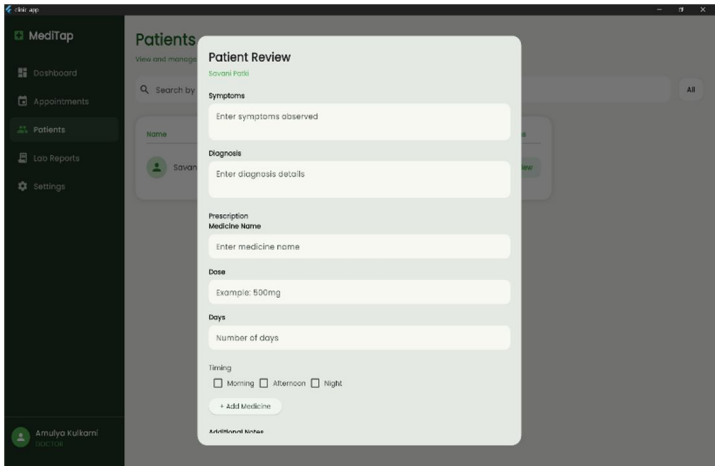
REGISTER PATIENT USING NFC CARD



SCHEDULE APPOINTMENTS

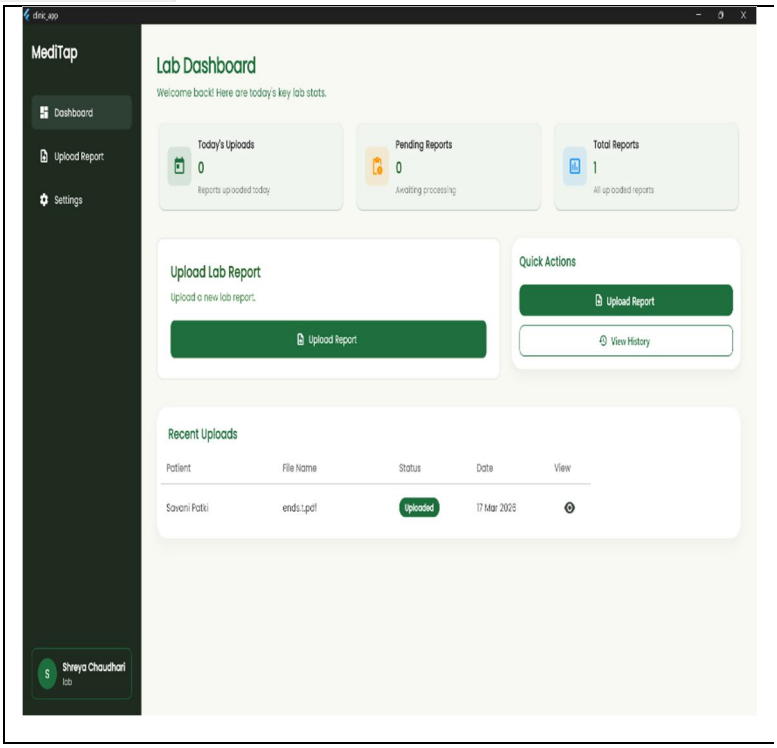


UPLOAD REPORT AT LAB STAFF

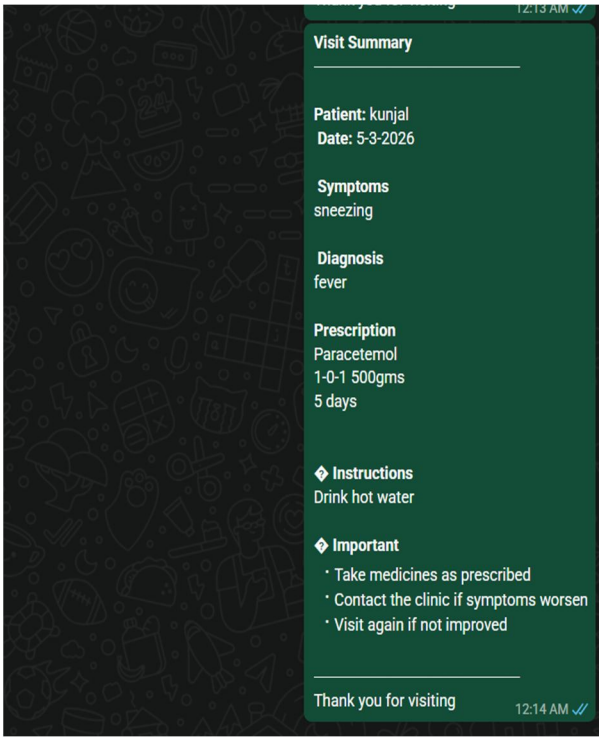


UPDATE THE DIAGNOSIS FROM DOCTOR SIDE

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LAB DASHBOARD



DIAGNOSIS REPORT SENT BY DOCTOR TO PATIENT'S WHATSAPP

The implementation of the NFC-based Clinic Management System has significantly improved both operational efficiency and overall user experience within the clinic environment. One of the key outcomes observed was the improvement in patient management and appointment handling. Through the receptionist dashboard, patient registration and appointment scheduling became faster and more organized, reducing manual paperwork and administrative delays. The streamlined workflow allows receptionists to register patients and schedule appointments efficiently, ensuring better coordination between patients and medical staff.

The doctor dashboard enhances clinical workflow by allowing doctors to access patient records, review medical history, and record diagnoses digitally. An important feature implemented in the system is the ability to send diagnosis details directly to patients through WhatsApp. This improves communication and ensures that patients receive their prescriptions and medical instructions immediately after consultation. It also reduces the risk of patients losing written prescriptions and enables them to easily refer to their treatment details later.

The laboratory dashboard simplifies the management of diagnostic reports. Lab technicians can upload test results directly into the system, linking them with the respective patient records. This enables doctors to quickly access lab reports during consultations and improves the accuracy of medical decision-making. The digital report storage system also minimizes the chances of misplacing physical documents and allows secure access to patient reports whenever required.

The administrative dashboard provides a centralized platform for monitoring and managing clinic activities. Administrators can oversee staff accounts, track patient registrations, review appointment statistics, and analyze system usage through built-in analytics features. These insights support better decision-making and help maintain smooth coordination between different departments within the clinic.

Overall, the system demonstrates how digital health solutions can improve clinic operations, reduce manual errors, and enhance communication between patients and healthcare providers. The integration of dashboards for receptionists, doctors, laboratory staff, and administrators ensures that all stakeholders have access to relevant information in real time. While the system provides significant improvements in workflow management, future enhancements may include advanced analytics, automated appointment reminders, integration with additional healthcare services, and expanded mobile accessibility for patients and medical staff.

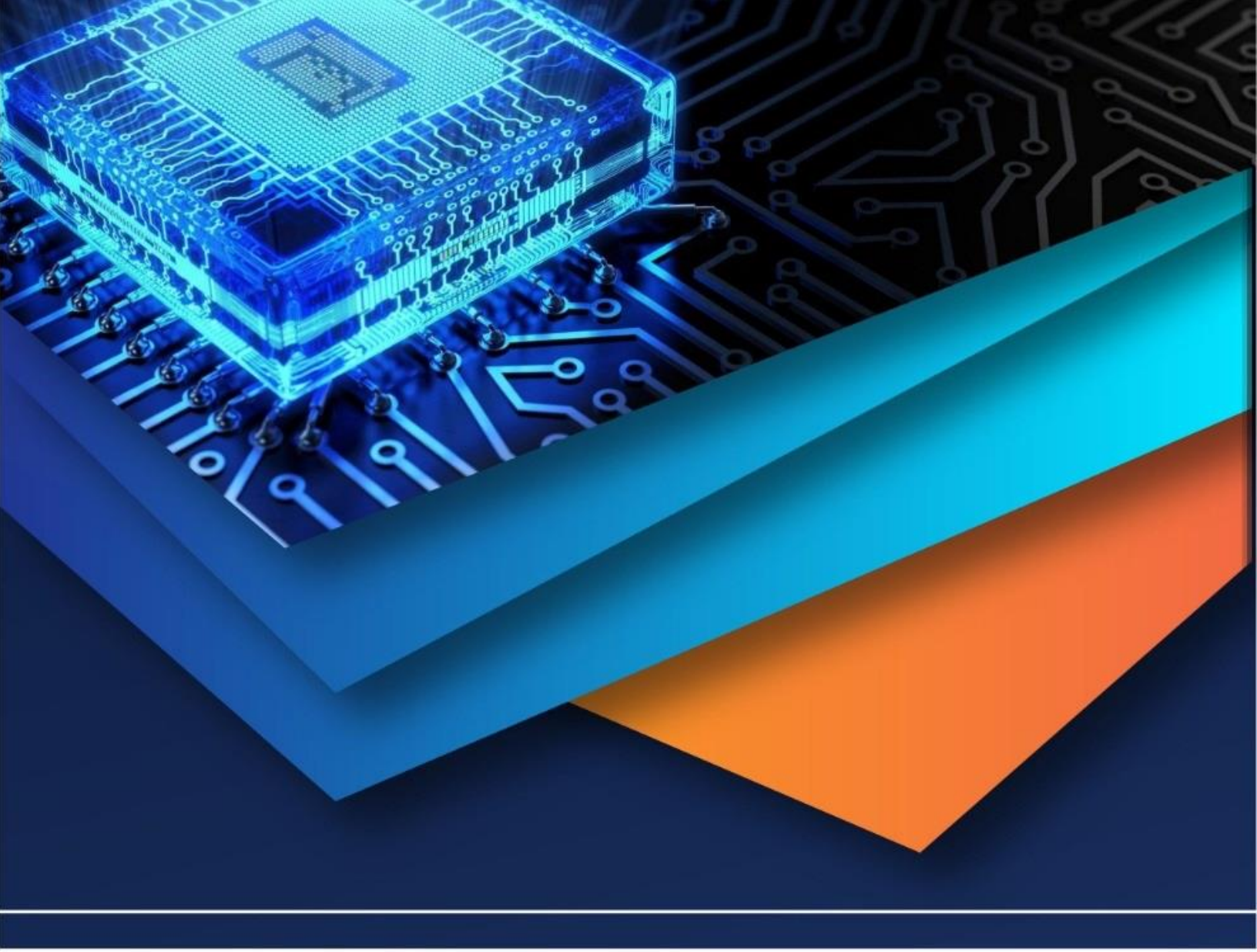
VI. CONCLUSION

The implementation of the MediTap system represents a significant paradigm shift in clinical data management, successfully transitioning from archaic, paper-based registries to a high-speed, hardware-integrated digital ecosystem. By leveraging the High-Frequency NTAG 213 HF RFID architecture, this research has demonstrated that patient identification and record retrieval can be achieved with near-instantaneous latency, effectively eliminating the administrative bottlenecks that compromise patient care in high-pressure environments. The experimental results prove that the "tap-and-go" methodology, facilitated by the Flutter framework and Firebase cloud synchronization, provides a deterministic 1:1 data mapping that far exceeds the accuracy and reliability of manual typographic searches or complex biometric feature extraction. Furthermore, the non-invasive nature of the NTAG 213 hardware ensures a frictionless user experience for both medical professionals and patients. While traditional methods are often hindered by resource dependency and human error, the proposed framework offers a scalable, cost-effective solution that is ready for deployment in modern clinical settings. Ultimately, the integration of short-range wireless communication with real-time cloud databases serves as a robust foundation for the future of interoperable, secure, and highly efficient healthcare informatics.

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