Université Abou Bekr Belkaid
Tlemcen Algérie
جامعة أبي بكر بلقايد
تلمسان الجزائر

People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

Abou Bekr Belkaïd University – Tlemcen

Faculty of Sciences

Department of Computer Science

Graduation Thesis

For the Acquisition of the Master's Degree in Computer Science

Under the ministerial decree 1275

Option: Information and Knowledge System (S.I.C)

Theme

SanuPass

Intelligent Digital Medical Passport with Real-Time Geo-Medical Tracking

Cross-Platform Mobile Ecosystem for the Secure Portability of Health Data

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Academic Year: 2025 / 2026

Acknowledgments

I would like to express my deep gratitude to everyone who contributed, directly or indirectly, to the realization of this work.

First, I extend my thanks to my supervisor for her monitoring of this project.

I also thank the entire faculty of the Computer Science Department for the quality of the teaching provided during my university curriculum. Their knowledge and pedagogy formed the fundamental foundation upon which my LMD training is built.

My thoughts also go to my classmates for their mutual aid, constructive exchanges, and the stimulating working environment shared during these years of study.

A special thank you to my family, who has always supported me with love, patience, and trust. Their constant presence by my side has been an inexhaustible source of motivation and determination.

Finally, I express my gratitude to the members of the jury for the honor they do me by agreeing to evaluate this work.

Dedications

To my dear parents, for their unconditional love, their sacrifices and their unwavering support.

To my brothers and sisters, for their understanding and constant encouragement.

To all my teachers, from primary school to master's degree, who passed on to me knowledge and the passion for learning.

To my friends and classmates, for the shared moments and the bonds created.

To all those who believe in digital innovation serving healthcare in Algeria.

— Zeansni Riad

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List of Abbreviations

Abbreviation	Meaning
API	Application Programming Interface
B2C	Business to Consumer
CCP	Compte Courant Postal (Postal Current Account)
DA	Algerian Dinar
ECCP	Electronic Compte Courant Postal
GPS	Global Positioning System
IA	Intelligence Artificielle (Artificial Intelligence)
mHealth	Mobile Health
NoSQL	Not Only SQL
PFE	Projet de Fin d'Études (Graduation Thesis Project)
QR Code	Quick Response Code
REST	Representational State Transfer
RIB	Relevé d'Identité Bancaire (Bank Account Statement)
RIP	Relevé d'Identité Postale (Postal Account Statement)
SDK	Software Development Kit
S.I.C	Systèmes d'Information et de Connaissances (Information and Knowledge Systems)
TTL	Time To Live
UID	Unique Identifier
UI	User Interface
UX	User Experience

GENERAL INTRODUCTION

1 Project Context

In recent years, the rapid rise of mobile technologies and ubiquitous computing has profoundly transformed the global healthcare sector. It has become extremely simple for individuals to monitor their physiological data, manage their appointments, and access digital solutions instantly. In the field of medical informatics, this evolution has catalyzed the growth of **mobile health** (mHealth) and personalized digital credentials, enabling seamless data portability beyond traditional institutional boundaries.

On an international scale, solutions such as **Apple Health Records**, **Google Health**, and the **Dossier Médical Partagé (DMP)** in France have demonstrated the feasibility of patient-centric digital health ecosystems. These platforms offer unified access to clinical data, facilitate care coordination, and improve the continuity of medical information.

It is in this global context of digital empowerment and health tracking accessibility that the idea of the **SanuPass** project was born. Inspired by these highly performant international solutions, SanuPass is designed as a **decentralized digital medical passport**, patient-centric and equipped with **advanced geo-medical capabilities**. The project is part of an effort to modernize healthcare systems through secure, state-of-the-art software solutions, placing vital clinical data directly in the hands of the citizen.

2 Problem Statement

Despite the progress made in hospital information systems, the management of personal health data remains highly fragmented. Crucial medical files — clinical history, allergy logs, vital emergency information — are traditionally isolated within physical documents or siloed databases belonging to specific medical facilities.

When a patient travels to different regions or requires urgent care outside their main medical network, this lack of real-time data accessibility and interoperability can lead to:

- Potentially dangerous **diagnostic delays**,
- **Medical errors** due to the absence of critical information (allergies, ongoing treatments),
- Costly and time-consuming **redundant examinations**,
- The inability to quickly **locate** the nearest specialized healthcare facility.

Moreover, existing e-health solutions rarely combine the security of medical records with **real-time geographic awareness**. Finding a nearby specialized medical center matching the patient's immediate clinical needs remains a manual and inefficient task, revealing a **critical technical gap** between secure profile portability and active geographic tracking.

3 Objective

The main objective of our project, **SanuPass**, is to design and develop an innovative cross-platform mobile ecosystem that functions as a **secure digital medical passport** with integrated **geo-medical tracking** capabilities. More specifically, we aim to deliver an engineering solution that is:

- **Simple and intuitive** for the patient, with a modern dark mode interface and fluid animations,
- **Secure and compliant** with data protection standards, using a cryptographically secure access token system with a limited lifetime (2-hour TTL),
- **Optimized for spatial analysis**, allowing the real-time localization of the nearest hospitals, pharmacies, and care centers via geodesic distance calculations (Haversine formula),

- **Intelligent**, integrating an AI-powered health alerts module to detect drug interactions and allergy conflicts.

This master's thesis presents all the stages of design, architectural modeling, and technical implementation of the SanuPass platform, structured into **five chapters**:

- **Chapter I: State of the Art** — analysis of existing mobile health systems, review of international digital passports, and identification of the shortcomings of current local systems.
- **Chapter II: Design of SanuPass** — user needs identification, functional and non-functional requirements, UI/UX mockups, and UML modeling.
- **Chapter III: Realization of SanuPass** — system architecture, technological choices (Flutter, Firebase, Dart), technical structure, and security mechanisms.
- **Chapter IV: Implementation of the Platform** — visual identity, patient and doctor interfaces, and demonstration of key features.
- **Chapter V: Business Model Canvas** — socio-economic feasibility, value proposition, and scalability matrix.

CHAPTER I

STATE OF THE ART

Analysis of international medical portability solutions and diagnosis of local systemic shortcomings

1.1 Introduction

Engineering modern medical software demands a comprehensive preliminary investigation of existing information systems and data architectures. Within health informatics (e-Health), examining how clinical data is transferred, stored, and retrieved reveals critical system vulnerabilities, particularly regarding patient credential security and interoperability failures.

This chapter establishes a detailed state-of-the-art review of medical portability paradigms worldwide before contrasting them with the specific challenges of the Algerian healthcare sector. Through structured comparative analysis, this work highlights the clinical and technical rationale for developing SanuPass, an autonomous, geo-localized mobile medical passport.

1.2 Basic Concepts

To establish a coherent semantic and technical foundation for the SanuPass architecture, this section formalizes the core principles operating at the intersection of cross-platform development, health data security, and geospatial analysis.

1.2.1 Digital Medical Passport

A digital medical passport serves as a **secure and portable container of emergency clinical credentials**—such as blood type, critical allergies, chronic conditions, active treatments, and surgical history—decentralized and managed directly by the patient. In contrast to conventional, siloed health records, this architecture prioritizes **user autonomy**, allowing individuals to store, carry, and instantly share their verified profile using an **encrypted QR Code** during emergencies.

Three architectural pillars sustain this paradigm:

- **Portability**: local cache architectures ensure offline data availability on the patient's mobile terminal,
- **Sovereignty**: the patient retains absolute authority over credential visibility duration and accessor authorization,
- **Interoperability**: utilizing a standardized QR Code combined with temporary tokens decouples data sharing from proprietary hospital networks.

1.2.2 Mobile Health (mHealth)

Mobile health (mHealth) denotes the ecosystem of software applications deployed on mobile devices to facilitate physiological telemetry, remote medical consultations, and portable clinical documentation. Data from the World Health Organization (WHO) projections suggest the global mHealth market will reach **$311 billion by 2027**, expanding at a compound annual growth rate (CAGR) of **29.2%** [9].

The primary barrier to universal adoption remains **interoperability**: the technical capacity of heterogeneous software environments to exchange and parse semantic data structures without altering the underlying clinical information.

1.2.3 Cross-Platform Development (Flutter)

Cross-platform software engineering enables developers to target multiple operating systems (iOS, Android, and Web) using a **single source code** base. Google's **Flutter** framework leverages the **Dart** programming language and the modern **Skia/Impeller** rendering subsystem to compile high-performance native machine code, bypassing intermediate JavaScript runtimes.

Table 1.1. Comparison of cross-platform mobile development frameworks

Criterion	Flutter	React Native	Xamarin
Language	Dart	JavaScript/TSX	C#
Rendering engine	Skia/Impeller (native)	JS Bridge	Native
Performance	$\approx$ Native	Interpreted	Native
Hot Reload	Yes	Yes	Limited
Platforms	iOS, Android, Web, Desktop	iOS, Android	iOS, Android
Community	$>$ 165K GitHub stars	$>$ 119K stars	$\approx$ 14K stars

1.2.4 Geographic Information Systems (GIS)

Geographic Information Systems (GIS) integrate hardware, software, and spatial datasets to capture, archive, manipulate, and analyze coordinates on the Earth's surface. Within e-Health frameworks, geospatial pipelines calculate **geodesic proximity** in real time to locate nearest medical providers.

To execute these spatial distance computations, SanuPass implements the **Haversine** formula:

$$\boxed{d = 2R \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi_1) \cdot \cos(\varphi_2) \cdot \sin^2\left(\frac{\Delta\lambda}{2}\right)}\right)} \tag{1.1}$$

where $R = 6,371$ km represents the mean radius of the Earth, φ denotes latitude, and λ denotes longitude, both parameterized in radians.

1.2.5 Cloud Firestore and Firebase

Firebase provides a Backend-as-a-Service (BaaS) infrastructure developed by Google, aggregating utility services such as federated authentication, real-time database endpoints, object storage, and static web hosting. SanuPass utilizes **Cloud Firestore**, Firebase's document-oriented NoSQL database, to handle synchronized, real-time data persistence between mobile frontends and cloud storage.

The following architectural attributes of Firestore are vital for SanuPass:

- **Real-time synchronization**: client-side data updates propagate instantly via web sockets or long-polling mechanisms,
- **Offline persistence**: local caches ensure application responsiveness and read/write operations during network disconnects,
- **Collection Groups**: these enable cross-collection queries across distributed subcollections, facilitating global queries such as resolving active access tokens,
- **Security Rules**: Declarative security policies establish granular, document-level authorization constraints directly at the database layer.

1.2.6 Access Token Cryptography

Securing clinical records during ad-hoc sharing in SanuPass relies on generating **temporary 6-digit access tokens** using Dart's `Random.secure()` API, which interfaces with a cryptographically secure pseudo-random number generator (CSPRNG). The system assigns each token a **TTL (Time To Live) of 2 hours** and validates it using a collision-free global index scan over Firestore's `collectionGroup` constructs.

1.3 Existing Mobile Health Solutions

Several prominent international frameworks support personal health record aggregation and clinical data portability:

- **Apple Health Records**: embedded within the iOS environment, this system allows patients to aggregate clinical records directly on their devices by querying healthcare providers using the HL7 FHIR standard.
- **Google Health**: Google's initiative focused on consolidating disparate wellness and clinical datasets into unified, interoperable schemas.
- **DMP (Dossier Médical Partagé)** — France: a centralized national electronic health record system, overseen by the French Assurance Maladie, allowing authorized clinicians to access client histories subject to explicit patient consent.
- **MySejahtera** — Malaysia: a national public health application deployed during the COVID-19 pandemic, which integrated immunization credentials and contact tracing systems.
- **NHS App** — United Kingdom: the centralized digital portal for the National Health Service, enabling patients to retrieve diagnostic records, coordinate clinical appointments, and manage prescriptions.

1.4 Situation in Algeria

The Algerian digital health landscape exhibits significant disparities compared to international standards. Crucial structural and operational deficits include:

- **Fragmentation of clinical documentation**: the absence of a unified national electronic health record means patient data remains isolated within separate public and private clinics, lacking any standardized inter-institutional synchronization mechanism.

- **Dominance of paper-based workflows**: physical health booklets, handwritten prescriptions, and printed lab results represent the dominant medium, introducing high risks of loss, transcription errors, and physical degradation.
- **Impended critical care access**: emergency medical personnel face severe obstacles when attempting to retrieve emergency patient profiles (e.g., drug allergies, blood types) during the initial, critical minutes of trauma response.
- **Absence of medical spatial directory services**: the lack of real-time geospatial directories prevents citizens from dynamically identifying on-duty clinics, emergency centers, pharmacies, or specific medical disciplines.

The SanuPass architecture addresses these national challenges by providing a sovereign, mobile-first solution tailored to local clinical dynamics.

1.5 Comparative Study of Solutions

To contextualize the technical positioning of SanuPass, the following table presents a comparative study of the main existing solutions:

Table 1.2. Comparative study of digital health solutions

Feature	Apple Health	DMP (France)	MySejahtera	SanuPass
Medical Record	Yes	Yes	Limited	Yes
Emergency Sharing	Yes (Medical ID)	Doctor consent	No	Yes (QR + Token)
Geolocation	No	No	Yes (COVID-19)	Yes (Real-time)
Interaction Detection	No	No	No	Yes (Client/Server AI)
Cross-platform	No (iOS only)	Web / Mobile	Mobile	Yes (Flutter)
Offline Mode	Yes	No	Yes	Yes

1.6 The Need for SanuPass

Contrasting Algerian clinical practices with international architectures reveals an **urgent developmental gap**. Addressing this requires providing citizens with a robust digital tool designed to:

- Store and carry vital health credentials locally in a secure, digital format,
- Facilitate ephemeral sharing of emergency profiles with medical responders via secure QR Codes,
- Determine the nearest healthcare facilities, clinics, and pharmacies using real-time geospatial positioning,

- Process clinical data to warn users of potential adverse drug-drug interactions,
- Coordinate medication schedules and schedule clinical appointments,
- Retrieve and review historical consultations, treatments, and prescriptions,
- Navigate the user interface natively in Arabic, French, or English.

Developing the **SanuPass** ecosystem addresses these localized challenges, adapting successful global design architectures to the specific socioeconomic and structural requirements of Algeria.

1.7 Conclusion

Evaluating current digital health solutions highlights established global standards for medical passports while exposing the complete absence of equivalent infrastructure in the Algerian health ecosystem. This comparative baseline demonstrates the value of the SanuPass platform, which bridges these local operational gaps by merging secure, offline medical record portability with real-time geospatial intelligence.

CHAPTER II

DESIGN OF SANUPASS

Identification of needs, UML modeling and user interface design

2.1 Introduction

Having evaluated existing solutions and dissected the unique constraints of the digital healthcare market, we commenced a comprehensive design phase. This structural formulation served as a bridge translating our conceptual vision into a concrete, executable software framework. Specifically, the process delineated the system architecture, primary functionalities, and user interface paradigms, while simultaneously addressing critical protocols for security and medical data preservation. Ultimately, these design decisions established the technical bedrock required to develop the SanuPass platform.

2.2 UserNeeds

The operational scope of SanuPass encompasses two primary user demographics: **patients** and **doctors**. Each user profile imposes distinct functional demands that the platform must address to achieve utility.

2.2.1 Patient Needs

- Establishing and maintaining a personal **digital medical passport** compiled of vital statistics (blood group, documented allergies, chronic conditions, current pharmacological treatments, and surgical history),
- **Generating a secure, dynamic QR code** embedded with a transient access token to permit data sharing with verified healthcare professionals,
- **Identifying and navigating** to proximate healthcare institutions, pharmacies, and clinics utilizing an integrated interactive map,
- Receiving **intelligent notifications** warning against potential drug-drug interactions and allergic conflicts,

- Administering **medication schedules** and tracking clinical appointments,
- Reviewing historical consultation records and comprehensive logs tracking who accessed their data,
- Retaining complete sovereignty over personal data through a **kill switch** that instantly revokes all active permissions,
- Navigating the interface in multiple languages, specifically **French, Arabic, and English**.

2.2.2 Doctor Needs

- **Scanning patient QR codes** to access authorized digital medical passports during clinical consultations,
- Entering a fallback **6-digit access code** to locate patients manually when scanning is impractical,
- Examining comprehensive **clinical records** such as patient histories, allergies, and therapeutic interventions,
- **Appending new clinical encounters** to the patient record, detailing diagnoses, pharmaceutical prescriptions, and relevant observations,
- Reviewing the patient's longitudinal **consultation timeline**,
- Receiving instantaneous, real-time **access confirmations** coordinated by the system's handshake mechanism.

2.2.3 Non-Functional Requirements

- **Security**: Enforcing robust encryption on sensitive fields, utilizing Firebase Authentication, and implementing ephemeral access tokens,
- **Performance**: Minimizing latency to ensure response times remain below 2 seconds for geospatial search queries,
- **Availability**: Guaranteeing offline usability through local Firestore caching mechanisms,
- **Scalability**: Architecting a cloud-based infrastructure capable of handling rapid, exponential user registration,
- **Accessibility**: Standardizing a multilingual user interface (FR/AR/EN) that supports right-to-left (RTL) rendering for Arabic,
- **Portability**: Engineering cross-platform compatibility across iOS, Android, and web environments from a singular codebase.

2.3 User Interface Design (UI/UX)

To cultivate a refined, accessible, and intuitive user journey, we structured the interface around several fundamental design paradigms:

- **Vibrant Dark Mode**: Employing a cohesive palette structured around deep blue gradients, accented by teal and gold, which minimizes visual fatigue while projecting a premium aesthetic.
- **Glassmorphism**: Leveraging Flutter's `BackdropFilter` and `ImageFilter.blur` modules to introduce frosted glass styling to UI containers.
- **Google Fonts Typography (Outfit)**: Deploying the modern sans-serif typeface Outfit to optimize readability across varying display densities.

- **Micro-animations**: Incorporating fluid UI transitions by utilizing the `Animated Positioned` widget paired with a `Curves.easeOutBack` velocity curve.
- **Haptic Feedback**: Delivering tactile confirmations through subtle physical vibrations during crucial actions like QR scanning and data validations.

2.4 UML Modeling

The Unified Modeling Language (UML) serves as the standard notation for depicting software architectures visually. In this project, we align UML diagrams with the **Unified Process (UP)** lifecycle methodology to construct structural and behavioral models of the SanuPass platform.

2.4.1 Use Case Diagrams

To represent the functional boundaries and actors' interactions clearly, the system's use cases are separated into three focused models: the Patient Space (Figure 2.1), the Doctor Space (Figure 2.2), and the Premium Payment Process (Figure 2.3).

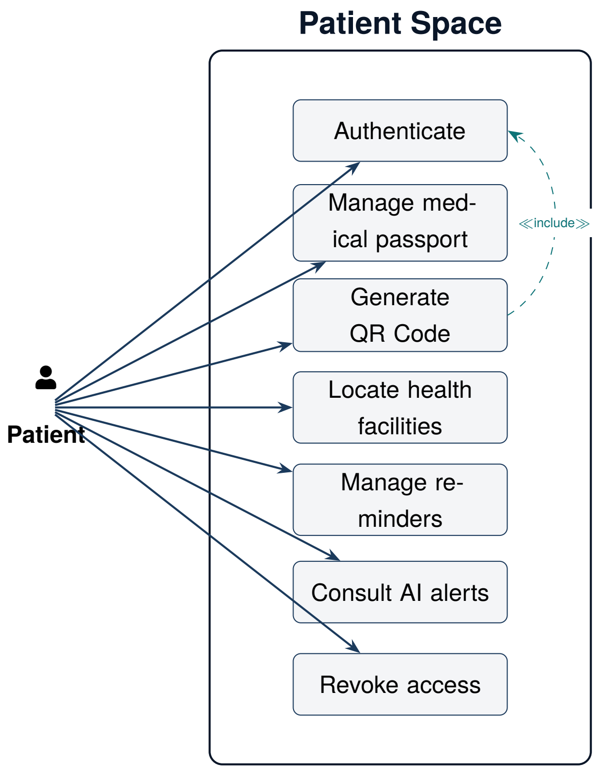

Figure 2.1. Use case diagram of the Patient Space

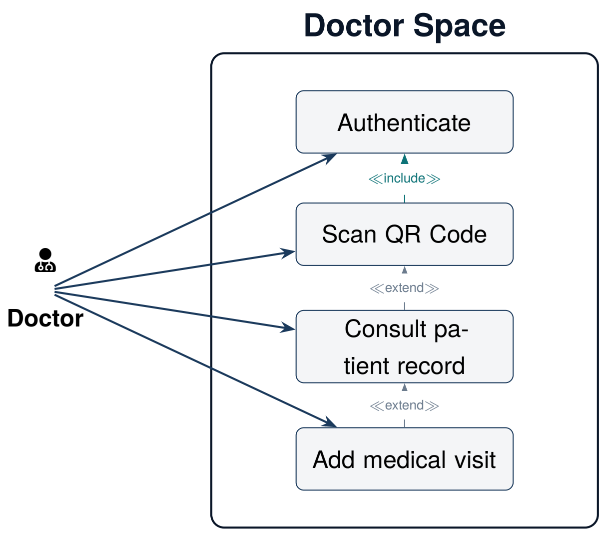

Figure 2.2. Use case diagram of the Doctor Space

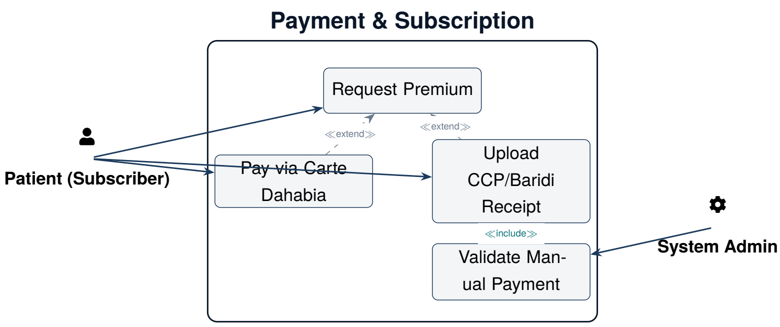

Figure 2.3. Use case diagram of the Premium Payment Process

2.4.2 Class Diagrams

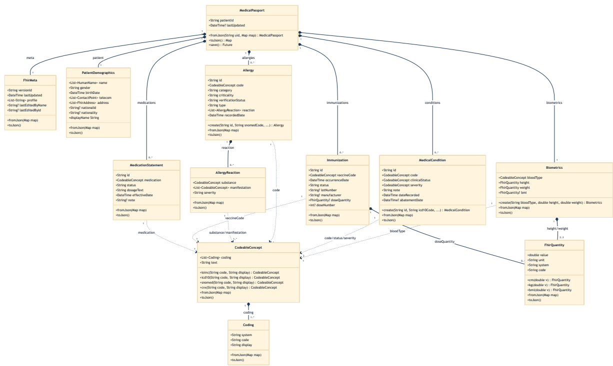

Figure 2.4. Core Domain Model Class Diagram (FHIR R4)

This diagram represents the core clinical data structures of the SanuPass platform, modeled in compliance with the HL7 FHIR R4 interoperability standard. The `MedicalPassport` acts as the aggregate root, encapsulating the patient's demographics, metadata, and biometrics. It maintains compositions of key clinical entities, including chronic medical conditions (ICD-10 coded), allergies, immunizations (CVX coded), and active medication statements (RxNorm coded). By utilizing the `CodeableConcept` and `Coding` structures, the system ensures that all clinical data is semantically mapped to international medical terminologies, enabling seamless integration with global health networks.

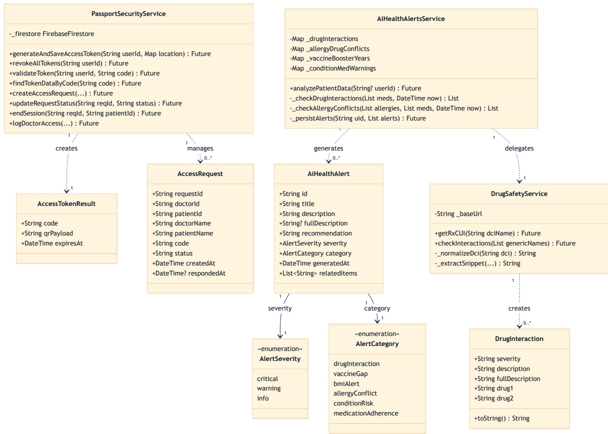

Figure 2.5. Security, Access Control, and AI Safety Services Class Diagram

This diagram details the architectural components responsible for system security, access control, and real-time clinical safety. The `PassportSecurityService` orchestrates the cryptographic QR handshake, generating transient `AccessTokenResult` payloads and managing the lifecycle of `AccessRequest` instances between patients and doctors. In parallel, the `AiHealthAlertsService` acts as a rule-based expert system, analyzing the patient's passport data to generate `AiHealthAlert` notifications (categorized by severity and type). For drug-to-drug interactions, it delegates processing to the `DrugSafetyService`, which queries external clinical databases to construct `DrugInteraction` schemas, ensuring patient safety before any medical visit is finalized.

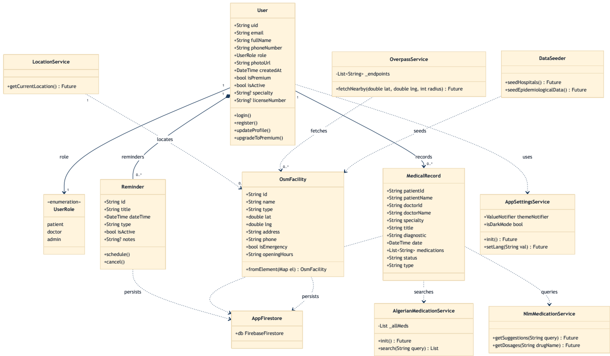

Figure 2.6. User Management, Geolocation, and Platform Services Class Diagram

This diagram illustrates the user management, geolocation services, and supporting platform infrastructure. The central `User` entity is bound to specific roles (`patient`, `doctor`, `admin`) that govern system permissions. The platform integrates OpenStreetMap geographical data, modeling physical health facilities via the `OsmFacility` entity. Supporting services include `LocationService` for GPS positioning, `OverpassService` for geospatial queries, and medication database services (`AlgerianMedicationService` for local DCIs and `NlmMedicationService` for global suggestions). The `AppFirestore` service provides database abstraction, supporting clean data operations across the ecosystem.

These structural diagrams define the relationship schemas across the SanuPass ecosystem, organized into three distinct architectural domains. Figure 2.4 presents the FHIR R4-compliant Core Domain Model, depicting the **MedicalPassport** aggregate root and its composed health record entities. Figure 2.5 models the security, cryptographic token exchange, and real-time AI-driven health safety and conflict verification services. Figure 2.6 defines the User management entities, geospatial facility models, and core background platform utilities. Together, they map the inheritance, composition, association, and dependency dynamics that govern system execution.

2.4.3 Firestore Data Model

To facilitate low-latency read and write operations, the Cloud Firestore database is organized under a denormalized NoSQL schema, structured as detailed in Table 2.1.

Table 2.1. Schema architecture and collections design within the Cloud Firestore database

`Collection`	**Description**	**Key Fields**
`users`	User profiles (UID-keyed)	email, fullName, role, bloodType, allergies, photoUrl
`users/{uid}/access_tokens`	Temporary access tokens	code, qrPayload, expiresAt, isActive
`access_requests`	Doctor→patient access requests	doctorId, patientId, status, createdAt
`reminders`	Medication reminders & appointments	title, dateTime, type, userId
`hospitals`	Medical points of interest	name, type, lat, lng, rating

2.5 Compliance with Security Standards

To guarantee privacy and protect sensitive healthcare information, we embedded core security protocols directly into the system's foundational design:

- **Firebase Authentication**: Managing secure identity services and token validation (supporting email/password pairs and Google OAuth federated sign-in).
- **CSPRNG-Based Ephemeral Tokens**: Utilizing the secure random generator `Random.secure()` to generate collision-resistant, 6-digit access codes.
- **2-Hour TTL (Time-To-Live)**: Restricting vulnerability exposure by enforcing the automatic expiration of active tokens after two hours.
- **Atomic Kill Switch**: Enabling patients to immediately invalidate all active access grants through a Firestore batch operation.
- **Firestore Security Rules**: Enforcing granular, document-level access controls to prevent unauthorized database read or write attempts.
- **Local Biometric Authentication**: Securing physical access to the application via fingerprint scanning and Face ID, facilitated by the `local_auth` package.

2.6 Wireframes

We modeled the user interface layouts based on the guidelines of **Material Design 3**, deploying a premium dark-theme layout to enhance usability. The core interaction workflows are structured as follows:

- **Patient Workflow**: Registration → Authentication → Personal Dashboard → Medical Passport Administration → QR Code Generation → Geospatial Medical Mapping.
- **Doctor Workflow**: Authentication → QR Code Scan → Manual Code Verification fallback → Record Examination → Encounter Documentation.

2.7 Conclusion

In summary, the design phase of the SanuPass system facilitated a thorough mapping of user needs, resolved system architecture components, and defined interactive workflows through UML modeling. This analytical blueprint provided the necessary engineering framework for subsequent implementation phases, maintaining strict alignment between functional criteria, cybersecurity standards, and our UI/UX objectives.

CHAPTER III

REALIZATION OF SANUPASS

System architecture, technological choices and technical structure of the platform

3.1 Introduction

TRANSLATING the SanuPass concept into a functional system demands a technological foundation tailored specifically to the unique constraints of mobile health applications. To guarantee robustness, modularity, and long-term maintainability, the system architecture relies on a carefully structured software model paired with modern, industry-standard mobile development technologies.

3.2 SanuPass System Architecture

The structural design of SanuPass revolves around a **hybrid architecture**. This ecosystem integrates a cross-platform Flutter frontend, a suite of Python-based administration utilities, and a Firebase cloud infrastructure backend:

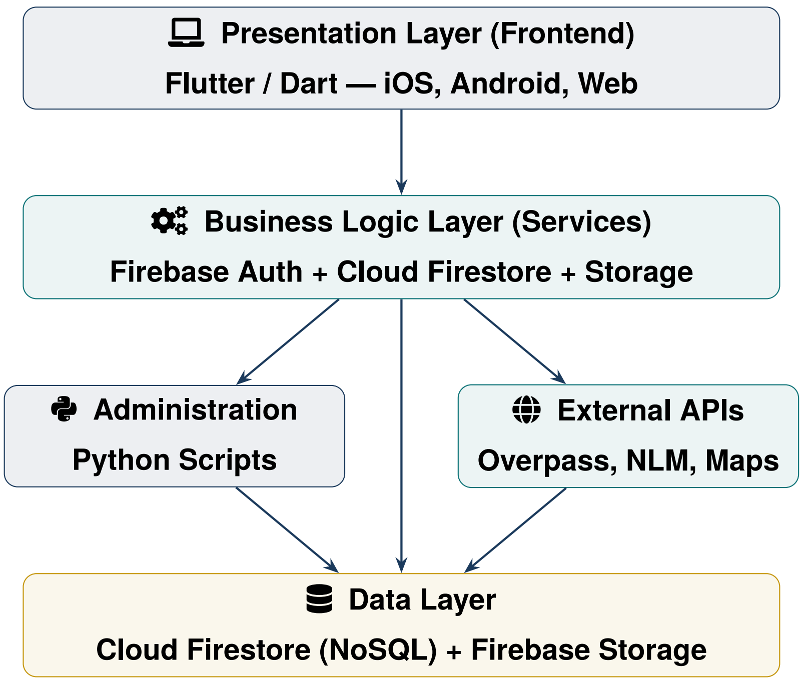

Figure 3.1. SanuPass system architecture

Presentation Layer: This layer comprises the Flutter application, compiled natively to target iOS, Android, and web environments. It governs UI rendering, user interactions, local animations, and real-time frontend communications with Firebase.

Business Logic Layer: Firebase services (including Authentication, Firestore, and Storage) handle user credentials, manage transient access tokens, coordinate live synchronization, and manage secure file uploads. Specialized Dart services, such as `PassportSecurityService`, `OverpassService`, and `AIHealthAlertsService`, codify the application's domain rules and logic.

Data Layer: Cloud Firestore serves as the primary NoSQL datastore, facilitating seamless offline persistence, real-time sync capabilities, and strict document-level security rules.

3.3 Choice of Tools and Languages

Developing an interconnected mobile ecosystem like SanuPass requires a meticulous selection of technologies to ensure high performance, security, and cross-platform portability. This section details the technological stack selected for the Flutter frontend, the Python backend administration utilities, and the integration of various external APIs.

3.3.1 Mobile Development Technologies

The client-facing application is built on Google's cross-platform framework, Flutter. Table 3.1 displays the critical dependencies and packages powering the frontend, alongside their respective roles in the system:

Table 3.1. Technological stack of the SanuPass application

Technology	Role in SanuPass
Flutter 3.8+	Cross-platform development framework (iOS, Android, Web)
Dart	Programming language with native AOT compilation
Firebase Core 4.5	Firebase services integration SDK
Firebase Auth 6.2	Authentication (email, Google Sign-In)
Cloud Firestore 6.1	Real-time NoSQL database
Firebase Storage 13.1	Storage for profile photos and medical documents
flutter_map 8.2	OpenStreetMap interactive map
Geolocator 14.0	Retrieval of GPS position
qr_flutter 4.1	QR Code generation
mobile_scanner 7.2	QR Code scanning via camera
local_auth 2.3	Biometric authentication (fingerprint, Face ID)
http 1.2	HTTP requests to external APIs (Overpass, NLM)

3.3.2 Administration Tools (Backend)

To streamline administrative oversight, initialize database states, and perform security audits on Firestore collections, we developed several Python scripts. Table 3.2 outlines these utilities and their functions:

Table 3.2. Python administration tools

Script	Description
`seed_firestore.py`	Initial database seeding with test data
`seed_passport.py`	Creation of demonstration medical passports
`reseed_default_db.py`	Complete database reset
`diag_firestore.py`	Diagnostic and verification of data consistency
`audit_dbs.py`	Security audit of Firestore collections
`ai_med_conflict.py`	Server-side drug conflict detection
`seed_doctor_scans.py`	Simulation of doctor access for testing

3.3.3 External APIs and Integrations

SanuPass leverages several third-party services and APIs to support geolocation and drug interaction checking. Table 3.3 compiles these integrations alongside their operational parameters and timeout settings:

Table 3.3. External APIs integrated into SanuPass

API	Usage in SanuPass	Timeout
Overpass (OSM)	Geospatial queries to retrieve medical POIs (hospitals, pharmacies, clinics) within a 5 km radius	10s
NLM RxNav	Autocompletion of medication names (`/spellingsuggestions.json`) and dosage resolution (`/drugs.json`) with SCD/SBD filtering	5s
NLM Interactions	Verification of multi-drug interactions via RxCUI (`/interaction/list.json`), HIGH severity only	5s
FDA openFDA	Cross-verification of interactions client-side via `DrugSafetyService`	5s
Google Maps	Launching of native GPS navigation to the selected health facility (Safe Route)	N/A

Resilience Strategy: To handle network interruptions gracefully, each integrated API service follows a **try-API-first, fallback-local** design pattern. For example, the `NlmMedicationService` falls back on a local database of 8 common medications (such as Metformin, Ramipril, Ibuprofen, and Paracetamol) immediately if a connection timeout occurs.

3.3.4 Development Tools

The development and deployment workflow relied on the following toolchain:

- **Visual Studio Code**: The primary IDE equipped with Dart and Flutter extension suites.
- **Android Studio**: Utilized for local Android virtualization, emulation, and profiling.
- **Firebase Console**: The portal for backend configuration, real-time database monitoring, and analytics.
- **Git & GitHub**: Version control and collaborative source code management.

3.4 SanuPass Technical Structure

3.4.1 Structure of the Flutter Application

The directory and file organization of the Flutter application follows a clean-architecture model to decouple models, widgets, and services. Table 3.4 presents the complete file tree and describes the purpose of each component:

Table 3.4. File structure of the Flutter application

`File / Directory`	**Description**
`lib/main.dart`	Entry point, Firebase configuration, theme, routing
`lib/models/`	

Table 3.4. File structure of the Flutter application

File / Directory	Description
medical_passport.dart	Data model of the medical passport (JSON/Firestore serialization)
lib/screens/	
login_screen.dart	Login screen with animations
signup_screen.dart	Registration with validation
patient_dashboard_screen.dart	Main patient dashboard
doctor_dashboard.dart	Doctor dashboard
detailed_passport_screen.dart	Detailed view of the medical passport
edit_medical_passport_screen.dart	Passport editing
passport_token_screen.dart	Generation and display of the QR Code
ai_alerts_screen.dart	AI alerts on drug interactions
profile_screens.dart	User profile and settings
reminders_and_passport.dart	Medical reminders and passport components
add_visit_screen.dart	Form to add a medical visit (doctor)
lib/services/	
passport_security_service.dart	Generation/validation of access tokens
overpass_service.dart	Overpass geospatial queries
ai_health_alerts_service.dart	AI analysis of drug-drug interactions
drug_safety_service.dart	Medication safety check
nlm_medication_service.dart	NLM RxNorm search
algerian_medication_service.dart	Algerian medication database
app_settings_service.dart	Application settings

Table 3.4. File structure of the Flutter application

File / Directory	Description
mock_payment_service.dart	Simulation of Carte Dahabia/Baridi Mob transactions
lib/widgets/	
glass_container.dart	Reusable glassmorphism widget
medical_alert_banner.dart	Medical alert banner
geomed_avatar.dart	Personalized user avatar
fade_page_route.dart	Animated page transition
lib/l10n/	Internationalization files (FR, AR, EN)

3.4.2 Simulation of the Premium Payment System (Mock Banking)

Integrating live production APIs for national payment services in Algeria (such as Algérie Poste's Carte Dahabia or bank transfer networks like Baridi Mob) requires official administrative approvals, merchant credentials, and commercial security certificates. Because these keys were unavailable for the academic prototype phase, we developed a mock banking integration layer to simulate payment validation and state transitions.

3.4.2.1 Core Simulation Logic

The mobile application coordinates all subscription validation processes through the `MockPaymentService`. This class encapsulates simulated banking gateways, handling both synchronous card verification flows and asynchronous manual receipt verification.

- **Carte Dahabia (Instant Payment)**: Simulates online transactions by capturing the user's 16-digit card number, CVV2 code, and expiration date. Upon submitting, the system displays an OTP (One-Time Password) confirmation modal.
- **Baridi Mob / CCP (Manual Verification)**: Enables users to upload a photographic capture of their transaction confirmation or cash deposit receipt. The subscription status transitions to `pending_verification` until approved by the administrator.

3.4.2.2 Subscription Verification and Gateway Responses

To systematically validate all possible error states and success paths during demonstrations, the `MockPaymentService` maps predefined transaction scenarios to specific input card patterns or simulation codes:

0. **Successful Transaction (HTTP 200 OK)**: If the card number ends with `1234` or the input verification OTP is `1234`, the mock gateway returns a transaction success payload. The patient's user profile document in Firestore is instantaneously upgraded with the status field `"isPremium": true`, granting immediate access to advanced AI alerts.
0. **Refusal for Insufficient Funds (HTTP 402 Payment Required)**: If the card number ends with `0000` or the OTP is `0000`, the service simulates a transaction decline due to insufficient funds. The app displays an interactive error banner suggesting alternative payment methods.
0. **Gateway Timeout and Network Errors (HTTP 504 Gateway Timeout)**: Entering a card ending in `9999` triggers a simulated network latency delay of 5 seconds, followed by a gateway connection timeout error. This verifies the robustness of the client-side retry logic and error recovery banners.

Additionally, if the user inputs an incorrect security OTP three times consecutively, the `MockPaymentService` triggers a temporary account-level cooldown (5 minutes), simulating standard banking anti-fraud security protocols.

3.5 Data Security

Given the high sensitivity of patient medical data, security serves as a fundamental pillar of the SanuPass system design. We implemented security measures across multiple layers:

3.5.1 Secure Sharing Protocol

The delegation of access rights to a patient's medical passport runs on a secure four-step handshake protocol:

0. **Generation**: The mobile application initiates the request by generating a cryptographically secure 6-digit code via `Random.secure()` (CSPRNG). The probability of a collision among n concurrent active users is calculated as follows:

$$\boxed{P(\text{collision}) = 1 - \prod_{k=0}^{n-1} \frac{10^6 - k}{10^6} \approx \frac{n^2}{210^6}} \quad (3.1)$$

   For $n = 1,000$ active users, $P \approx 0.05\%$. To mitigate collisions, the backend implements up to five retry attempts validated through a `collectionGroup` query.

0. **Storage**: The system records the generated token within the Cloud Firestore database under the path `users/{uid}/access_tokens`, applying a strict **2-hour Time-to-Live (TTL)**. The resulting QR Code encapsulates the following URI schema:

   `sanupass://access?uid=$userId&code=$code`

0. **Validation**: When a physician scans the QR Code using the built-in `mobile_scanner` utility, the system checks whether the document exists, verifies that the `isActive` flag is set to `true`, and ensures that the `expiresAt` timestamp remains in the future relative to `Timestamp.now()`. Expired tokens are immediately invalidated.

0. **Handshake**: A request document containing the physician's credentials (`doctorId`, `doctorName`) is created in the global `access_request` collection. A `StreamBuilder` on the patient's device detects this entry, prompts the patient for confirmation, and logs the authorized access event in `logDoctorAccess` to maintain an immutable audit trail.

3.5.2 Atomic Kill Switch

Patients retain absolute control over their data, allowing them to revoke all active medical access rights instantly via the `revokeAllAccess(userId)` method. This mechanism leverages a Firestore `WriteBatch` to execute the deactivations atomically, writing changes to the `isActive`, `expiresAt`, and `revokedAt` fields in a single transactional write. This database update propagates to all connected clients in less than 500ms.

3.5.3 Double-Layer Drug Safety Architecture

To detect drug-drug interactions, SanuPass employs a **double-layer** security architecture:

- **Client-Side Layer** (utilizing `DrugSafetyService` and `AIHealthAlertsService`): Performs initial checks inside the Flutter runtime environment to screen for user allergies, therapeutic duplications, and immediate contraindications.
- **Server-Side Layer** (running via the `ai_med_conflict_watcher.py` script): Monitors data changes through the Firebase Admin SDK and queries the NLM RxNav API to screen for interactions of **HIGH** severity, logging any issues under the path `users/{uid}/medical_alerts`.

A `MedicalAlertBanner` widget listens to the `medical_alerts` subcollection via a `StreamBuilder`, immediately rendering a red warning banner if the database receives a critical alert.

3.6 Internationalization System (i18n)

SanuPass features a comprehensive internationalization architecture driven by the `AppLocale` class, spanning 1,210 lines of code and mapping **over 400 localization keys** across all application views.

Table 3.5. Languages supported by SanuPass

Language	Coverage	Direction	Keys
French	Main language, 100% of screens	LTR	400+
Arabic	Complete translation, Algerian month names (*Janfi, Fifri*. . .)	RTL	400+
English	Complete interface, default fallback	LTR	400+

This engine leverages a reactive `ValueNotifier<String>` within `AppLocale`, letting the `AppLocale.t(key)` method supply the translated string corresponding to the active locale dynamically. To render localized UI assets, flag elements are drawn programmatically using a `CustomPainter`; for instance, the Algerian flag's star and crescent are mathematically calculated using a `PathOperation.difference` operation.

3.8 FHIR R4 Compliance

To ensure seamless integration with broader digital health networks, the medical passport data model aligns with the **FHIR R4** (Fast Healthcare Interoperability Resources) specifications, referencing international terminology standards:

Table 3.6. Medical codification standards used in SanuPass

Standard	Domain	Usage Example
SNOMED CT	Clinical terms	Diagnoses, symptoms, procedures
ICD-10	Disease classification	Type 2 diabetes, Hypertension
LOINC	Laboratory observations	Blood types, lab results
RxNorm	Medications	Metformin 500mg, Ramipril 5mg
CVX	Vaccinations	COVID-19 Pfizer, Seasonal flu

Adhering to these classification standards guarantees the necessary semantic **interoperability** for sharing medical records with external hospital systems and clinics.

3.9 DZ-Pharma Database

SanuPass features a built-in medication registry via the `AlgerianMedicationService`, loaded asynchronously from a local database file at `data/meds.json`. This database maps the following drug details:

- **Commercial and generic (INN)** nomenclatures.
- **Dosages** and associated pharmaceutical delivery formats.
- Official **Algerian Public Price (PPA)** indices.
- High-resolution **packaging images**.

The application queries this database using a case-insensitive substring search across three primary fields (`name`, `generic`, and `commercial_name`), capping the results list at 15 items. To minimize app launch times, the service implements a lazy initialization scheme that defers database loading until requested.

3.10 Limitations and Future Work

While the current release meets the design goals, several opportunities exist for future development:

- **Centralized database architecture**: Although Cloud Firestore provides exceptional read/write speeds, transitioning to a PostGIS spatial database could optimize complex geospatial operations.
- **System interoperability**: Extending full integration to HL7 FHIR servers would allow direct data exchanges with institutional healthcare systems.
- **Edge artificial intelligence**: Integrating lightweight, on-device machine learning models would enable offline health pattern forecasting and predictive diagnostics.

- **Commercial deployment**: Launching the client applications on the Google Play Store and Apple App Store once the pilot testing phase completes.

3.11 Conclusion

Developing SanuPass has successfully translated theoretical architecture into a robust, responsive, and visually polished software solution. Combining the cross-platform capabilities of Flutter with Firebase backend operations and third-party geospatial services has yielded a highly performant application tailored to modern mobile health environments. Ultimately, this iteration establishes a secure, extensible foundation ready for large-scale clinical deployment.

CHAPTER IV

IMPLEMENTATION OF SANUPASS

Visual identity, user interfaces and feature demonstration

4.1 Introduction

SanuPass functions as a mobile health management ecosystem designed to empower Algerian patients through the secure portability of their medical records. Several core structural and functional attributes distinguish this platform:

4.1.1 A Cross-Platform Mobile Application

Engineered using the Flutter framework and the Dart programming language, the client application compiles natively across iOS, Android, and web architectures. Its functional scope encompasses:

- A digitized medical passport coupled with dynamic, secure QR Code generation,
- An interactive geo-medical mapping system providing real-time location tracking for health facilities,
- An intelligent, AI-driven alert engine for detecting adverse drug-drug interactions,
- Integrated utilities for scheduling pharmaceutical reminders and clinical appointments,
- A dedicated practitioner portal featuring integrated QR scanning and rapid patient file extraction,
- Comprehensive multi-language support localized in French, Arabic, and English (FR/AR/EN).

4.1.2 Premium Design System

The aesthetic and user experience framework of SanuPass relies on:

- A dark-mode layout themed around professional medical color schemes (incorporating deep blue, teal, and gold accents),
- Glassmorphism techniques that render frosted glass aesthetics via `BackdropFilter` widgets,
- The Outfit typeface from Google Fonts to optimize textual legibility,
- Fluid motion profiles parameterized by custom easing curves (specifically `easeOutBack`),

- Precise haptic feedback triggered during vital user actions.

4.2 Visual Identity

Portraying the portable nature of health data, the moniker **SanuPass** merges the term "**Sanu**" (evoking health and the French *santé*) with "**Pass**" (denoting a passport). The logo synthesizes a stylized protective shield and a cartographic marker, visually uniting the dual thematic pillars of this initiative: robust data security and spatial mapping.

Figure 4.1. SanuPass application logo

The selected color system aims to communicate specific professional values:

- **Deep Blue (#0A1628)**: projects systemic reliability, clinical professionalism, and technical depth,
- **Medical Teal (#0D7377)**: represents health, general wellness, and technological ingenuity,
- **Gold (#D4A843)**: underscores premium design standards and precise execution.

4.3 SanuPass Interfaces

4.3.1 Authentication Pages

4.3.1.1 Login Page

The entry gateway features a dark-themed user interface, integrating:

- Input fields for email and passwords backed by real-time input verification,
- A Google Sign-In button designed for expedited authentication,
- A dynamic load state utilizing an animated transition framework (`AnimatedPositioned` coupled with `Curves.easeOutBack`),
- Direct routes for user onboarding and credential recovery processes,
- Native multilingual layout adjustment where all textual items dynamically conform to the active locale.

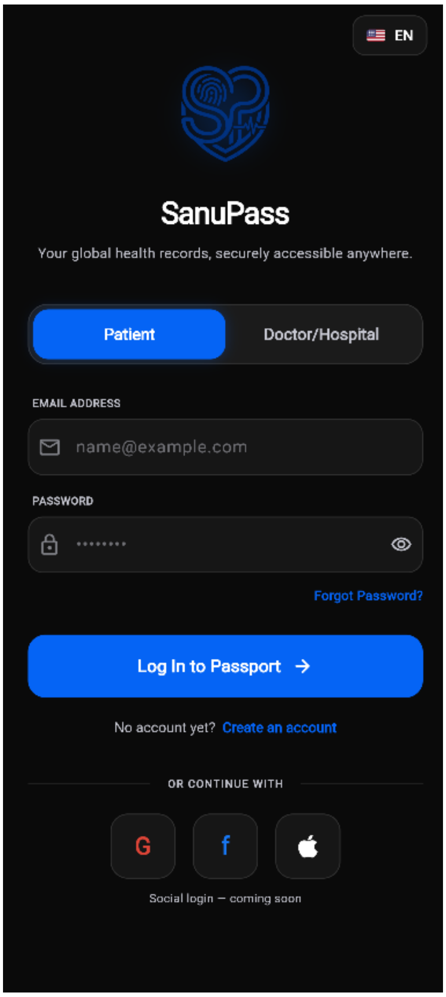

Figure 4.2. SanuPass mobile login interface

4.3.1.2 Registration Page

The onboarding portal enforces security through the following features:

- Explicit role selection dividing workflows between patients and practitioners,
- Structured entry fields for full names, emails, and passwords, the latter supported by a real-time entropy indicator,
- A phone number validation component equipped with an international country selector and corresponding flag icons,
- Dual-layer validation executing processes on both client-side interfaces and backend servers,

- Seamless user provisioning managed by the Firebase Auth engine.

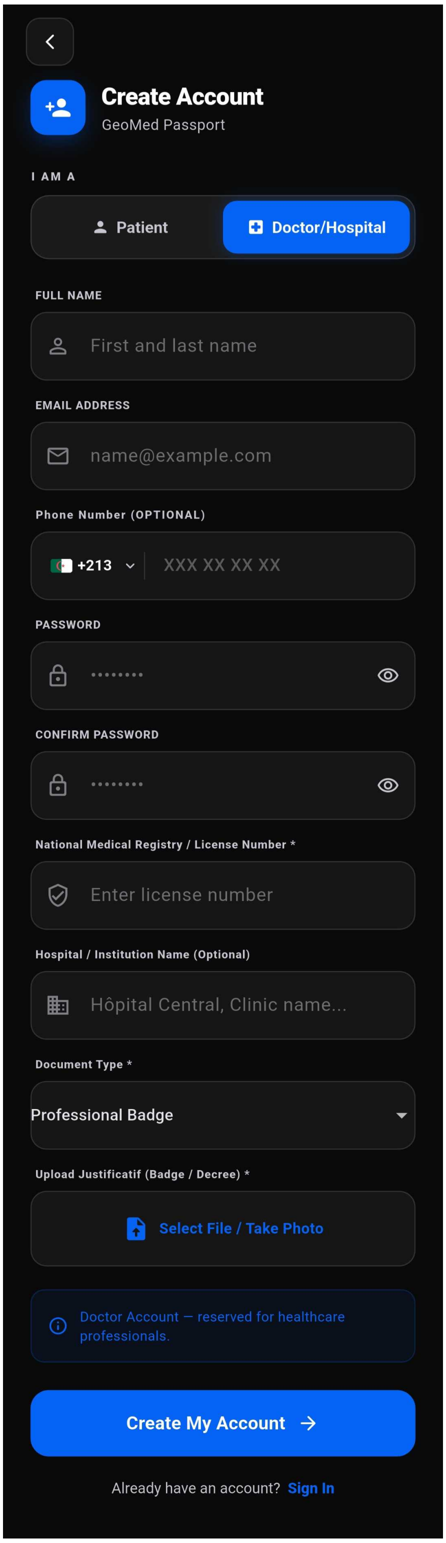

Figure 4.3. SanuPass mobile registration interface

4.3.2 Patient Pages

4.3.2.1 Patient Dashboard

The central landing portal acts as the focal operational hub for the patient, presenting:

- A customized header block containing user avatars, names, and time-aware greeting modules (e.g., morning and evening modes),
- A high-level overview card hosting vital medical indicators like blood typologies and verified allergies,
- A centralized schedule tracker highlighting near-term pharmaceutical administration times and clinical visits,
- A geospatial navigation component pointing out adjacent medical establishments,
- Active, real-time warning indicators generated by the AI interaction parser,
- A comprehensive, chronological log detailing previous clinical evaluations and patient record access events,
- Tab-based navigation utilities to jump across functional screens.

Additionally, when a clinical visit is completed, the patient can submit post-visit recovery feedback (Cured, Recovering, or Still Sick) directly through the dashboard to assist practitioners in monitoring their progress.

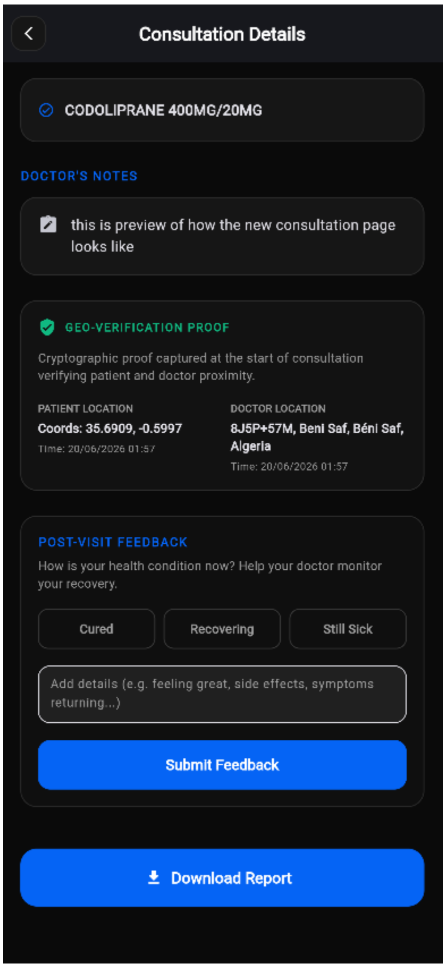

Figure 4.4. Post-visit recovery feedback interface

4.3.2.2 Detailed Medical Passport

The medical passport screen presents complete patient health data in a structured, highly legible design:

- **Core biometric indicators**: blood categorization, height, weight, and automated body mass computation,
- **Allergenic profiles**: a prioritized list utilizing distinct colors to indicate threat severity levels,
- **Chronic pathology tracking**: a register of confirmed chronic illnesses matched to their initial diagnosis timelines,
- **Active pharmacotherapy**: names of drugs, dosage profiles, intake intervals, and automated safety checks,
- **Surgical background**: historical records detailing operational procedures alongside chronological data,
- **Emergency contact details**: family or contact names, relationships, and direct-calling shortcuts,
- **Data modification tool**: entry point enabling users to update personal parameters.

The platform computes the Body Mass Index (BMI) automatically via the following mathematical expression:

$$\boxed{\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}} \tag{4.1}$$

The software interprets the resulting value based on the World Health Organization (WHO) standards outline in Table 4.1:

Table 4.1. WHO BMI classification

BMI	Classification
< 18.5	Underweight
$18.5 - 24.9$	Normal weight
$25.0 - 29.9$	Overweight
≥ 30.0	Obesity

4.3.2.3 QR Code Generation

Within the security token generation module, the patient can trigger the following actions:

- Request a newly generated 6-digit numeric passkey,
- Render a dynamic QR Code embedded with the structured locator string `sanupass://access?uid=&code=`,
- Monitor the active validity window prior to token expiration, governed by a 2-hour TTL constraint,
- Execute an immediate, global revocation of all active access permissions using the integrated **Kill Switch**,
- Display the access code for manual transposition when optical scanning proves impractical.

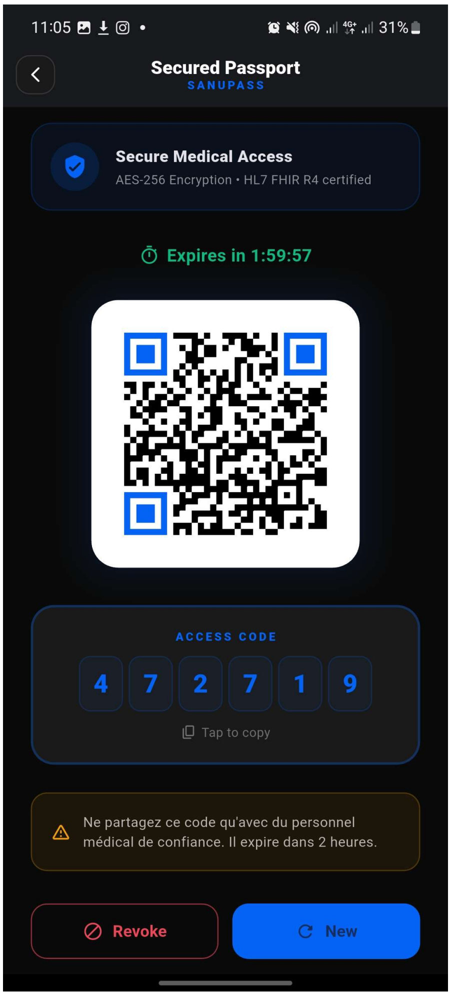

Figure 4.5. Patient temporary QR and access code

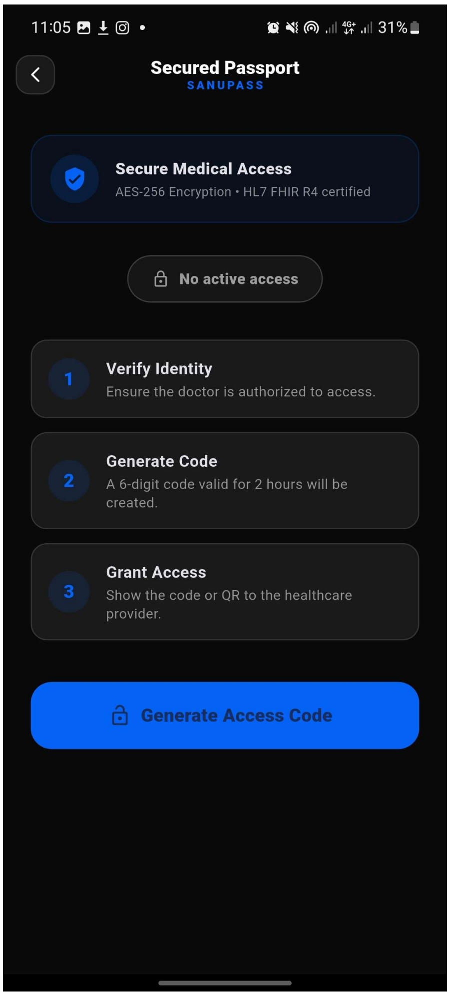

Figure 4.6. Patient medical data access rules

During an active session, to prevent unauthorized visual inspection of files, the patient's dashboard is locked by a security overlay. The patient has the ability to unilaterally terminate this access at any moment via the integrated kill switch.

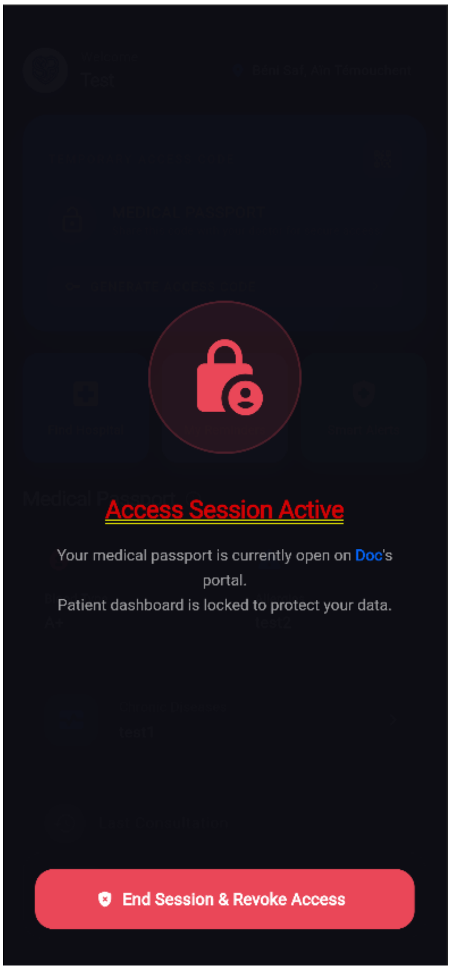

Figure 4.7. Patient active session lock overlay

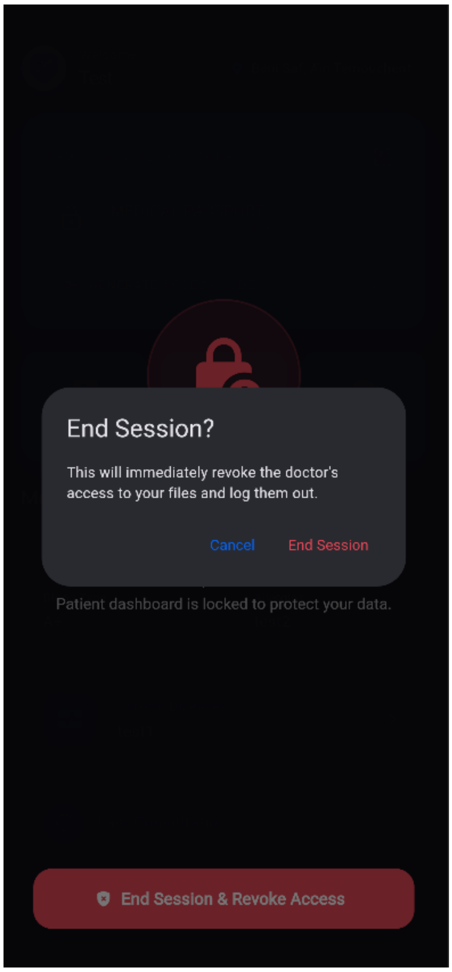

Figure 4.8. Active session revocation confirmation

4.3.2.4 Geo-Medical Map

The spatial intelligence module enables the patient to perform several operations:

- Monitor their coordinates in real time using device-level GPS tracking,
- View hospital facilities, clinics, pharmacies, and analysis labs represented by color-specific map icons,
- Filter map elements by facility taxonomy (including hospitals, pharmacies, private clinics, and diagnostic labs),
- Filter geographical datasets through text-based search fields,
- Determine geodesic distance using the Haversine formula for each identified clinic,

- Activate the **Safe Route** routine, which launches turn-by-turn routing via Google Maps or Apple Maps,
- Access granular details for each center, including its name, address, calculated distance, and user ratings.

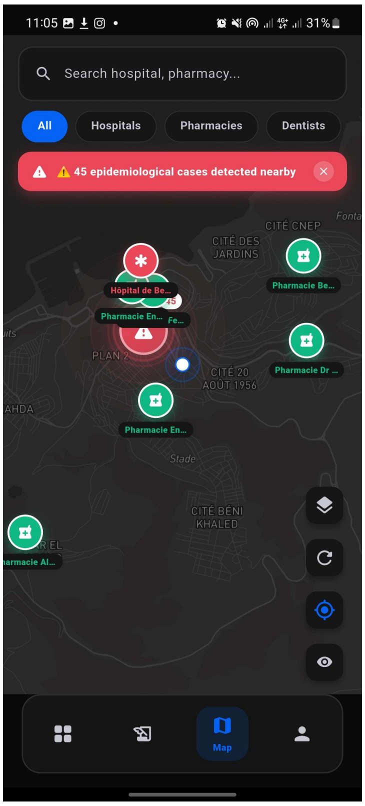

Figure 4.9. Interactive geo-medical map of health centers

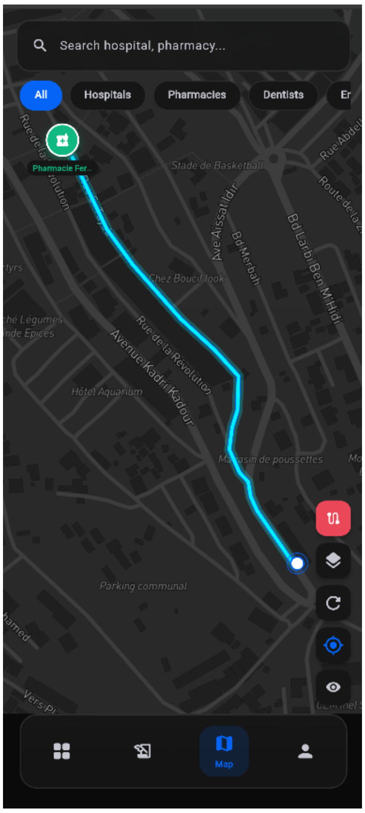

Figure 4.10. Safe routing to health centers

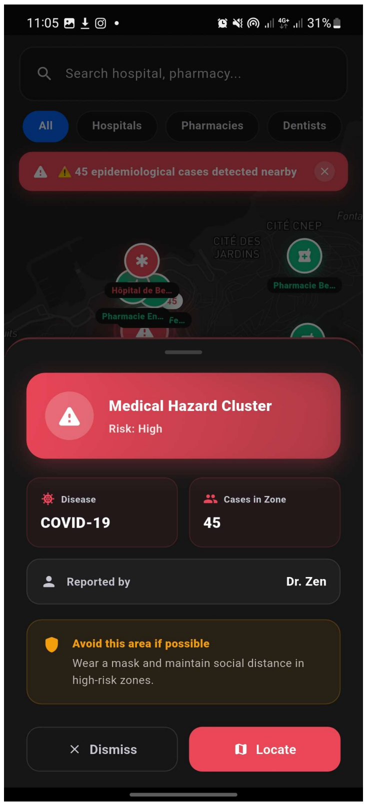

Figure 4.11. Regional health or illness warnings

4.3.2.5 AI Alerts

The clinical safety system automatically evaluates the active records within the patient profile, flagging:

- Dangerous **drug-drug interactions** occurring between current therapeutic agents,
- **Allergic contradictions** linking proposed pharmaceuticals with documented patient hypersensitivities,
- **Pathological contraindications** linked directly to active chronic conditions,

- **Therapeutic redundancies** where identical biochemical agents are prescribed under alternative brand names.

The system classifies these warnings into three distinct priority levels: **Critical**, **Warning**, and **Information**.

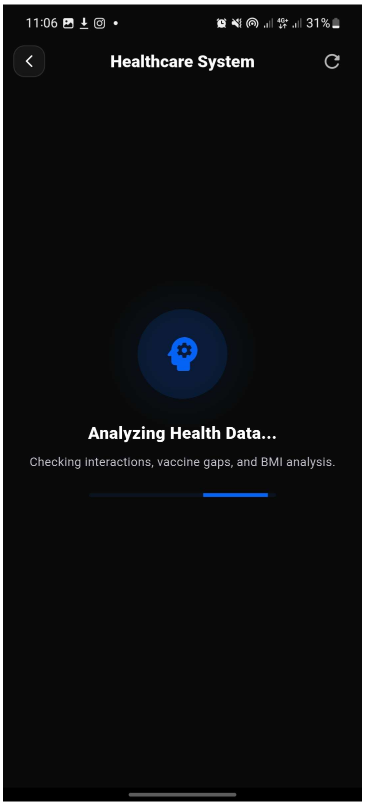

Figure 4.12. AI drug conflict scanning phase

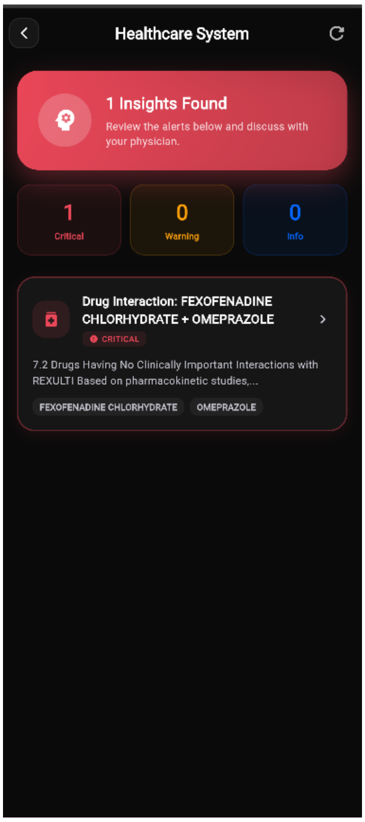

Figure 4.13. Detected drug interaction alerts

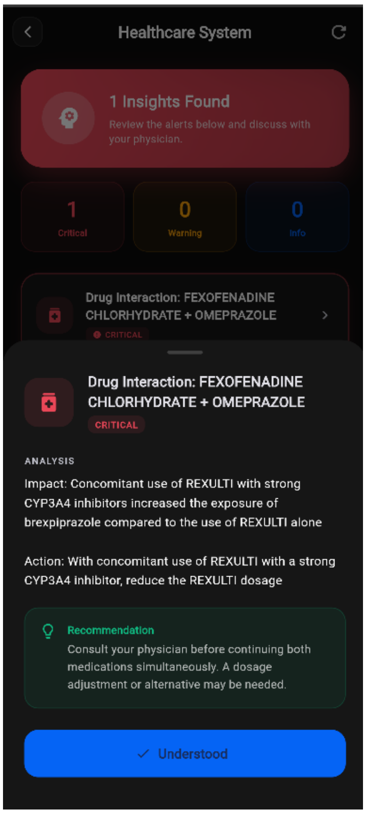

Figure 4.14. Detailed drug conflict explanation

4.3.2.6 Medical Reminders

To support treatment adherence, the notification engine schedules:

- **Medication compliance alerts** configurable on daily or weekly periodicities,
- **Clinical consultations** mapped to explicit dates, times, and facilities,
- **Routine screenings** such as laboratory blood panels or vaccine booster schedules.

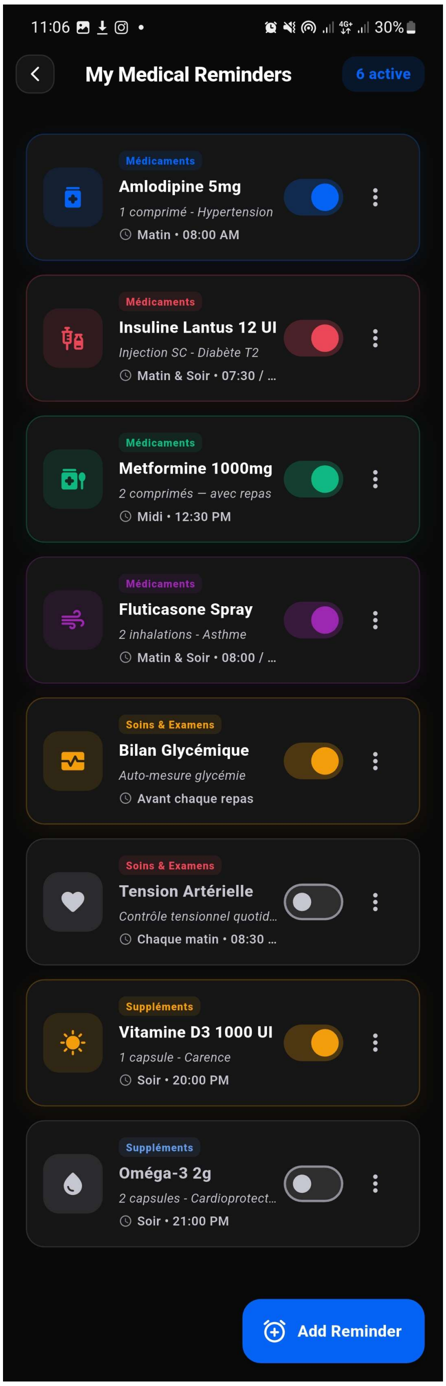

Figure 4.15. Medication and appointment reminders management

4.3.2.7 Settings and Profile

The preference dashboard acts as the administration terminal for user accounts and system configuration:

- **Identity Parameters**: tools to modify user profiles, phone numbers, and profile avatars,
- **System Security**: modules for credential updates and biometric sensor management,
- **Emergency Directory**: contact lists populated with trusted individuals, supporting direct telephonic dialing,
- **UI Adaptations**: switches for theme appearance (dark/light toggles), push notification channels, and active localization (Arabic, French, English).

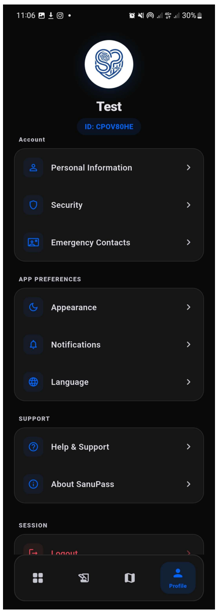

Figure 4.16. Application settings and user profile interface

4.3.3 Doctor Pages

4.3.3.1 Doctor Dashboard

The practitioner workspace provides clinical management tools, featuring:

- **QR Scanner Component**: a parsing module utilizing the `mobile_scanner` library to scan patient tokens,

- **Manual Bypass Field**: a text entry element accepting the 6-digit numeric passkey as a scanning fallback,
- **Global Registry Query**: a `collectionGroup` query searching for corresponding patient documents without requiring the patient's UID,
- **Patient Consultation Log**: a history tracking previously accessed records along with chronological data and verification statuses,
- **Practice Metrics**: statistical modules showing daily consultation counts and total patient visits.

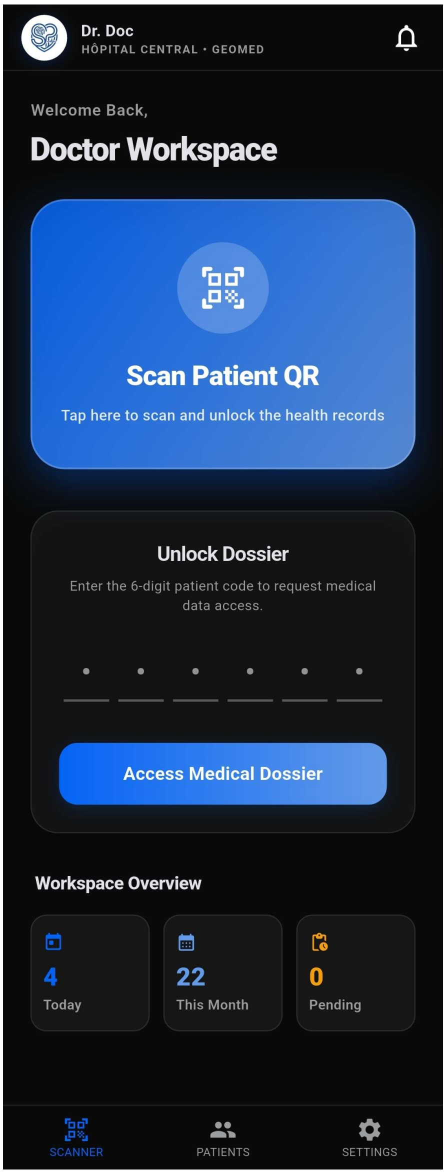

Figure 4.17. Doctor home page with integrated QR scanner and responsive PIN fields

Practitioners can also access their patient registry and review previously recorded consultations and history.

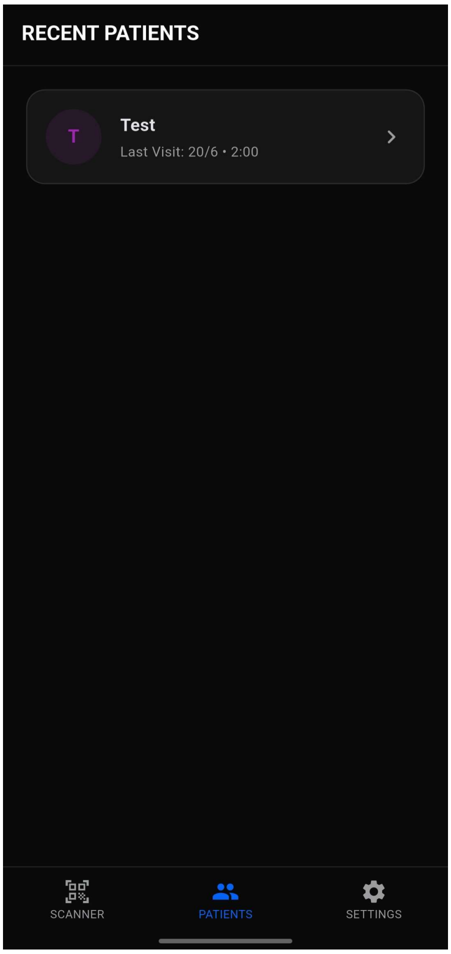

Figure 4.18. Doctor recent patients registry tab

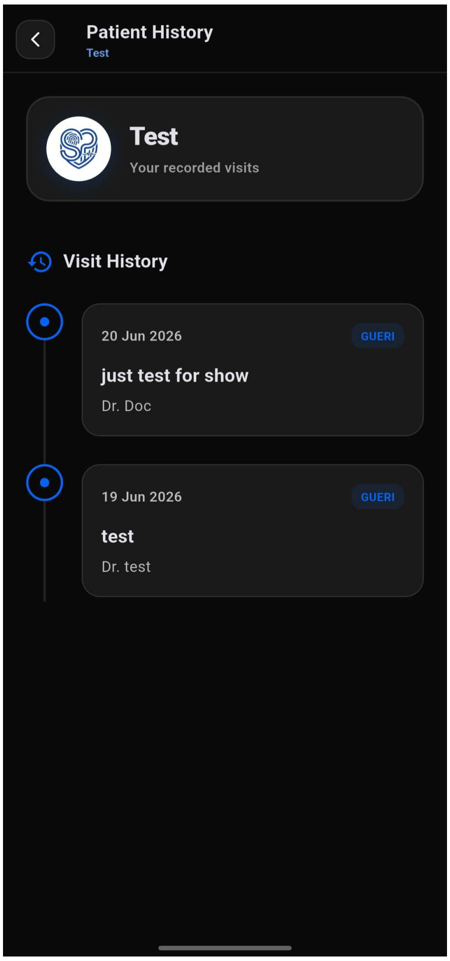

Figure 4.19. Patient consult visit history timeline

4.3.3.2 Patient Record Consultation

Following successful token validation and explicit patient authorization, the doctor gains access to:

- The entire medical passport dataset presented in a read-only layout,
- A historical record of previous clinical consultations,
- An entry form to **record a new visit**, inputting diagnoses, prescription charts, and notes,
- An automatic, immutable **audit log** documenting the precise access window of the practitioner.

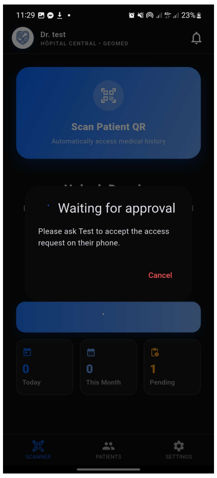

Figure 4.20. Doctor waiting for access

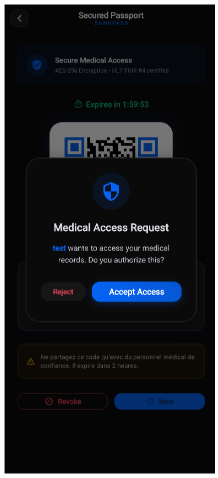

Figure 4.21. Access request overlay on patient screen

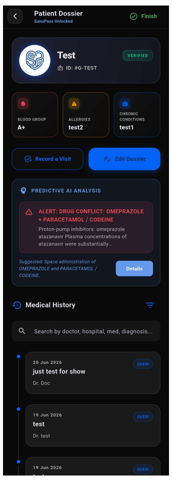

Figure 4.22. Consultation of patient dossier with AI warnings

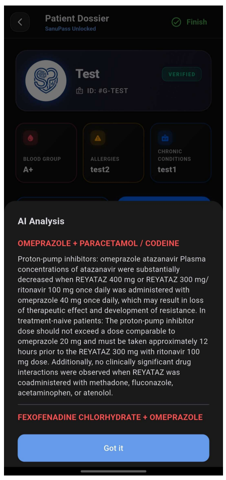

Figure 4.23. Detailed AI drug conflict analysis dialog

To end the consult session, the doctor must explicitly complete the visit, which safety-unlocks the patient's device.

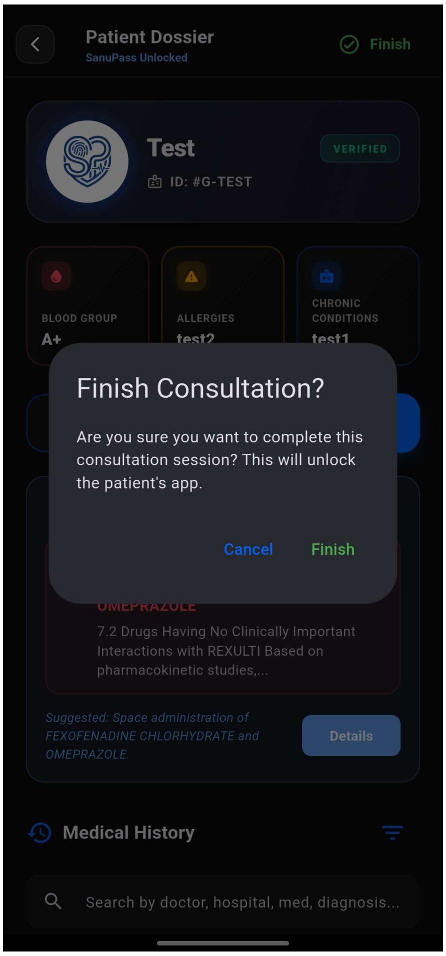

Figure 4.24. Consultation session termination confirmation

4.3.3.3 Adding a Medical Visit

The clinical entry form enables the physician to record:

- The primary **reason for the visit**,
- The definitive or working **diagnosis**,
- Structured **pharmacological prescriptions** (encompassing agent names, dosages, and durations),
- Supplementary **clinical notes**,
- **Diagnostic orders** (such as laboratory workups or imaging diagnostics).

The system automatically appends temporal metadata and attributes each record entry to the corresponding doctor ID, producing an auditable and continuous chronological patient profile.

Upon saving the consultation, the doctor and patient can review the diagnostic summary and geo-proximity verification coordinates, or export a certified digital report of the medical visit.

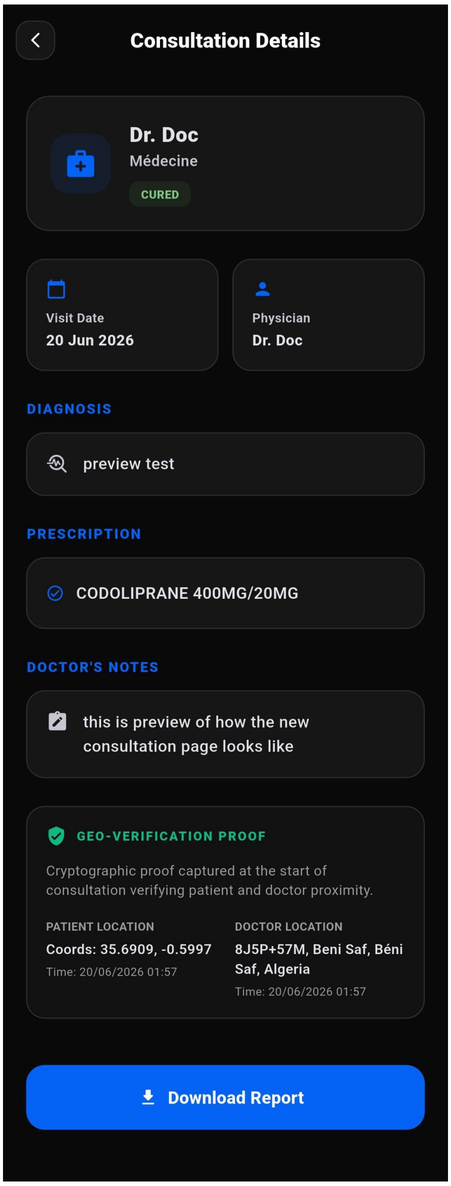

Figure 4.25. Recorded consultation details with proximity proof

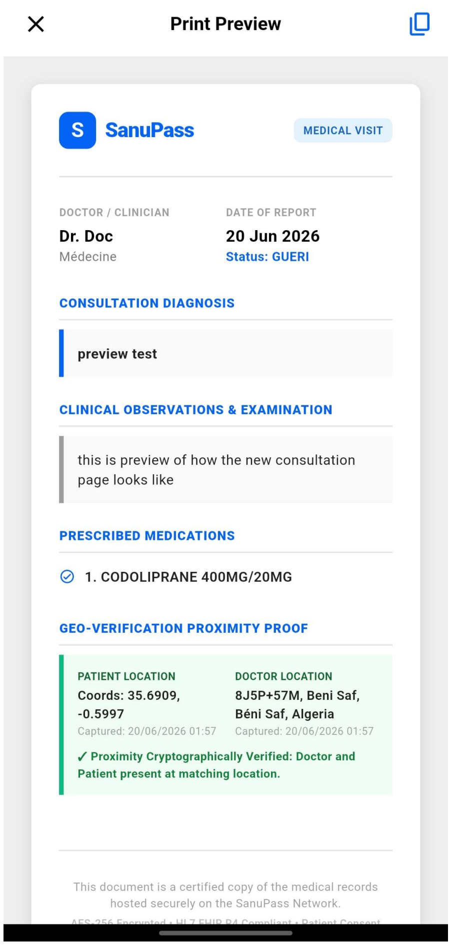

Figure 4.26. Print preview of generated medical visit report

4.3.3.4 Doctor Profile & Settings

The practitioner settings interface serves as the primary system configuration terminal for doctors:

- **Identity and Affiliation**: review of practitioner names, license keys, and hospital assignments,
- **App Preferences**: dark and light appearance modes, notification toggles, and multi-language selections.

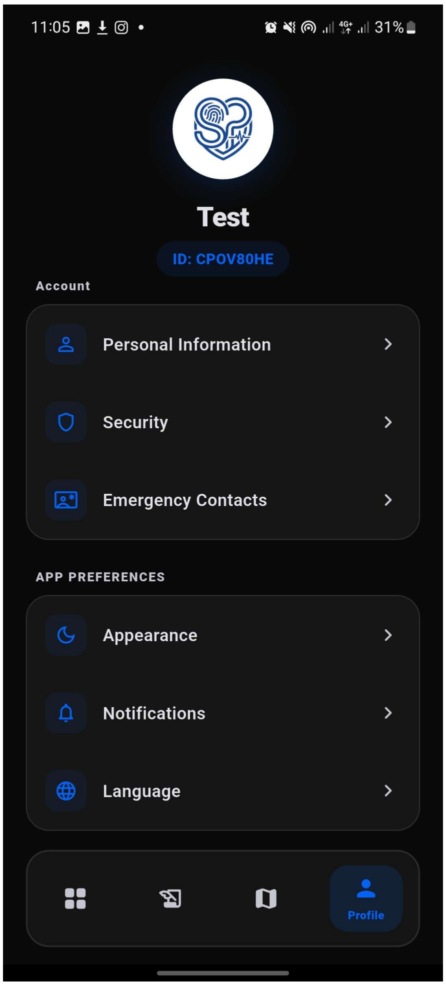

Figure 4.27. Doctor settings and profile interface

CHAPTER V

BUSINESS MODEL CANVAS

Socio-economic evaluation and deployment strategy of the SanuPass platform

5.1 Value Proposition

5.1.1 What Problems Do We Solve for Our Customers?

The SanuPass architecture resolves three critical friction points in contemporary healthcare:

- **Data Fragmentation**: clinical histories, allergenic records, and active pharmacotherapies are historically dispersed across physical documents and isolated databases. SanuPass aggregates and unifies these datasets into a consolidated digital passport.
- **Information Blackouts in Emergencies**: when an unresponsive patient enters an emergency care unit, attending clinicians lack immediate access to critical physiological metrics. The SanuPass QR system facilitates near-instantaneous file decryption and display.
- **Lack of Spatial Intelligence**: finding localized health resources matching a patient's immediate clinical needs is historically manual. SanuPass automates this lookup using GIS mapping integration.

5.1.2 What Customer Needs Are We Satisfying?

The platform addresses vital requirements for data privacy, operational efficiency, and rapid utility:

- Patients obtain absolute sovereignty and custody over their clinical history, granting access selectively on an on-demand basis.
- Medical practitioners receive structured, verified medical profiles that reduce the risks of prescribing errors, speed up diagnostic processes, and identify adverse interactions.
- The public gains access to a localized tool to instantly query and navigate to adjacent pharmacies, clinics, and emergency hospitals.

5.1.3 How Is Our Offering Different from Our Competitors?

SanuPass differentiates itself through:

- A **unifying integration** combining a digital medical passport, GIS mapping, and AI diagnostics into a single interface, a combination absent in existing regional options,
- **Absolute patient autonomy** over personal health details, enforced through temporary tokens and an instant kill-switch utility,
- A **localized trilingual framework** (French, Arabic, and English) specifically optimized for the Maghreb demographic,
- An active **artificial intelligence** system scanning for potential drug interactions.

5.1.4 What Is Our Unique Value Proposition?

> *"SanuPass is the first intelligent digital medical passport that allows every citizen to carry their vital health data, share it securely with a temporary token, and instantly locate the nearest health facilities — all from a single mobile application."*

5.2 CustomerSegments

5.2.1 Who Are Our Main Customers?

The primary customer base comprises individuals requiring regular medical follow-up or traveling frequently, and healthcare professionals who need access to patient records:

- **Patients managing chronic conditions**: individuals diagnosed with diabetes, hypertension, chronic asthma, or severe drug and food allergies.
- **Frequent Travelers**: individuals moving across provinces (wilayas) or crossing borders, necessitating a portable record of their clinical baseline.

- **The Geriatric Demographic**: an aging population segment requiring ongoing therapeutic supervision.
- **Medical Professionals**: certified clinicians needing rapid retrieval of accurate patient profiles.

5.2.2 What Different Customer Segments Are We Targeting?

The target market is structured around three primary pillars:

0. **Individual Patients**: The primary users who carry their medical records, set reminders, and seek health services.
0. **Medical Professionals**: Doctors, nurses, and pharmacists who scan QR codes and enter clinical records.
0. **Healthcare Facilities**: Clinics, hospitals, and diagnostic centers requiring B2B system integrations.

5.2.3 What Are the Specific Needs of Each Customer Segment?

Each target demographic presents specialized operational requirements:

- **Patients** seek reliable portability, simplified user flows, and automated assistance like pharmacological alerts.
- **Travelers** require cross-border and regional accessibility to health files in emergency settings.
- **Elderly populations** demand clear notification schedules for drug compliance coupled with simplified interface designs.
- **Medical professionals** demand instantaneous, secure, and structured diagnostic data rendered in an easy-to-read layout.

5.2.4 How Can We Categorize Our Customers into Distinct Groups?

Users are grouped based on authorization permissions and interaction patterns:

- **Unauthenticated Visitors**: Users who browse public healthcare maps and general health updates.
- **Registered Patients**: Users with personal access to their digital passports, reminders, and access logs.
- **Registered Doctors**: Validated healthcare providers authorized to request access and record visits.
- **Institutional Partners**: Private clinics and hospitals adopting our B2B workflow solutions.

Table 5.1. Target market estimation for SanuPass in Algeria

Segment	Estimated Population	Core Need
Chronic patients	≈ 6 million	Data portability
Inter-wilaya travelers	≈ 3 million/year	Emergency access
Elderly (65+)	≈ 4 million	Medical reminders
Doctors	≈ 80,000	Rapid record access
Total Addressable Market	**≈ 13 million**	

5.3 Customer Relationships

5.3.1 What Type of Relationship Does Each Customer Segment Expect?

Customer cohorts demand relationship dynamics defined by high security, systemic trust, and user autonomy:

- Patients require complete privacy guarantees, encrypted records storage, and frictionless automated self-service,
- Physicians expect consistent system uptime, functional reliability, and stringent onboarding protocols for credentials verification,
- Clinical organizations demand Service Level Agreements (SLAs) with dedicated technical support structures.

5.3.2 How Do We Currently Maintain Relationships with Our Customers?

Interaction models are managed through the following mechanisms:

- **Automated Self-Service**: user interfaces designed to allow independent profile setup without training,
- **Integrated Feedback Channels**: in-app user support terminals and frequently asked question (FAQ) repositories,
- **Security Audits**: publishing transparent assessments regarding data security rules and backend system logs.

5.3.3 How Can We Improve or Personalize Our Customer Interactions?

Future relationship management strategies will integrate:

- **Contextual Messaging**: personalized notification rules handling drug regimens and vaccine schedules,
- **Verification Workflows**: strict KYC processes to manually validate medical credentials for practicing doctors,

- **Interactive Forums**: moderated peer-to-peer discussion portals helping patients and medical staff share general health insights.

5.4 Channels

5.4.1 Through Which Channels Do Our Customers Want to Be Reached?

Marketing and operational channels bifurcate along target audience lines:

- Consumer segments (B2C) interact primarily via app stores, web portals, and local push notifications,
- Enterprise clients (B2B) require direct business proposals, industry conferences, and hands-on clinical training sessions.

5.4.2 Which Channels Are the Most Effective for Reaching Each Segment?

Primary customer acquisition vectors rely on:

- **Application Stores**: Google Play and the Apple App Store serve as the primary distribution channels for consumers.
- **Clinical Referrals**: Direct recommendations from physicians to chronic patients.
- **Enterprise Sales**: B2B engagements securing institutional integrations within private clinics.

5.4.3 How Can We Integrate Different Channels to Improve Customer Experience?

Channel orchestration ensures user journey consistency:

- A centralized web portal functions as the primary reference point for downloads and user guides.
- In-app warnings synchronize dynamically with email notifications to ensure real-time user updates.
- Social platforms (Facebook, Instagram, LinkedIn) raise public awareness and gather feedback.

5.5 Key Partners

5.5.1 Who Are Our Key Partners?

The ecosystem relies on several critical partnerships:

- **Algerian Ministry of Health**: functions as the regulatory and institutional partner validating legal compliance,
- **Medical Facilities**: clinics and hospitals adopting the platform within their daily clinical workflows,
- **Firebase and Google Cloud**: partners offering technical database structures and cloud hosting,
- **OpenStreetMap and the Overpass API**: providers of open-source cartographic datasets,
- **The National Library of Medicine**: providing reference datasets for drug-drug interaction scanning.

5.5.2 Which Partnerships Help Us Reduce Costs or Acquire Resources?

Operational costs are kept low through strategic resource partnerships:

- Leveraging OpenStreetMap bypasses commercial geolocation licensing costs,
- Accessing the National Library of Medicine databases removes data acquisition fees for pharmacology profiles,
- Utilizing Google Cloud and Firebase serverless solutions aligns infrastructure pricing with active application queries.

5.5.3 How Can We Align Our Interests with Those of Our Partners?

Mutual value creation guides our partnerships:

- Aligning with national security regulations validates the Ministry of Health's digitization goals,
- Streamlining patient check-in processes increases clinical throughput for private medical centers,
- Delivering aggregated, anonymous health statistics aids public institutions in tracking epidemiology dynamics.

5.6 Key Activities

5.6.1 What Main Activities Do We Need to Undertake to Deliver Our Value Proposition?

Delivering the core value proposition requires focused operational actions:

- Iterative updates and engineering maintenance of the Flutter codebase,
- Frequent synchronization of pharmaceutical catalogs and interaction libraries,
- Monitoring and patching the Firebase security configuration.

5.6.2 What Are the Essential Operations for Our Business?

Daily operations focus on maintenance and quality assurance:

- Performing manual credentials verification for medical practitioners,
- Checking server responsiveness and conducting recurring database encryption audits,
- Running user support workflows handling account access issues.

5.6.3 Which Activities Create the Most Value for Our Customers?

Key value drivers for the end user include:

- Processing real-time drug interaction logic when updating patient prescription records,
- Brokerage of secure sharing transactions using temporary 6-digit CSPRNG tokens,
- Real-time distance calculations and map routing toward active care centers.

5.7 Key Resources

5.7.1 What Are Our Essential Physical, Intellectual, and Human Assets?

The platform's operational foundation rests on four asset categories:

- **Technological Assets**: Firebase cloud servers, local mapping databases, and pharmacological datasets.
- **Intellectual Property**: The proprietary token exchange protocol, security configuration models, and biometric BMI formulas.
- **Human Resources**: Flutter application developers, system security engineers, and clinical advisors.
- **Network Capital**: A vetted registry of medical practitioners and clinical partner organizations.

5.7.2 Which Tools, Technologies, or Partnerships Are Essential to Succeed?

Our underlying software stack represents our most vital resource:

- The Flutter framework and Dart language to compile the code across Android and iOS platforms.
- The Firestore database engine to support cloud storage and real-time updates.
- The Overpass API and Leaflet/flutter_map integration to serve vector map layers.

5.7.3 What Are the Main Competitive Advantages of Our Resources?

Strategic advantages derived from our resource selection include:

- A vector-based mapping implementation that bypasses high Google Maps API commercial licensing costs.
- A serverless data structure designed to scale with user growth, minimizing idle-capacity expenses.
- An optimized, local offline database comprising Algerian drug profiles to ensure rapid, connection-independent searching.

5.8 Cost Structure

5.8.1 What Fixed and Variable Costs Are Associated with Our Business Model?

The financial structure is divided between predictable fixed commitments and scaling variables:

- **Fixed Costs**: Core server maintenance, data storage allocations, engineering salaries, and regulatory audit fees.
- **Variable Costs**: Geographic query volume, promotional campaigns, and customer support resources.

Table 5.2. Cost structure of SanuPass (in Algerian Dinars)

Category	Description	Estimation/year
Cloud infrastructure	Firebase (Firestore, Auth, Storage, Hosting)	≈ 70,000 – 280,000 DA/year
Third-party APIs	NLM, Google Maps, Overpass (free)	≈ 0 – 28,000 DA/year
Development	Team salaries (2 Flutter devs, 1 backend)	Variable
Marketing	User acquisition, SEO, social media	≈ 70,000 – 210,000 DA/year
Certification	Data security and compliance in Algeria	Variable

5.8.2 What Are the Most Significant Costs for Our Business?

The primary financial drivers for the business consist of:

- Ongoing software development and deployment maintenance to guarantee optimal cross-platform user experience,

- Firestore operations usage that scales dynamically with expanding user query volume,
- Formal certification fees to satisfy local healthcare data protection laws.

5.8.3 How Can We Reduce Costs or Improve Our Operational Efficiency?

We improve our fiscal efficiency through several strategies:

- Embedding OpenStreetMap coordinates to eliminate expensive commercial mapping dependencies,
- Utilizing offline data synchronization via Firestore caching to minimize cloud-side read transactions,
- Structuring automated self-onboarding pipelines to minimize customer relations staffing overhead.

5.9 Revenue Streams

5.9.1 Which Products or Services Are Our Customers Willing to Pay For?

Both patient cohorts and clinical entities exhibit willingness to purchase specialized tools that optimize their healthcare experience:

- Individual patients display willingness to pay for premium safety enhancements, including real-time AI drug interaction analysis and complete medical history records.
- Private clinical operations demonstrate demand for B2B portal integrations, allowing immediate, structured record retrieval during patient check-in.

5.9.2 What Are the Different Ways We Can Generate Revenue?

The business monetizes the platform through two key structures:

- **Freemium Subscriptions (B2C)**: patients download the core application for free, opting to unlock premium utilities via a monthly subscription estimated between 300 and 500 DA,
- **B2B Enterprise Licenses**: selling annual software access plans to private clinics to enable structured medical record queries.

5.9.3 What Is Our Pricing Model?

The consumer-facing pricing model uses a freemium architecture:

- **Standard Tier (Free)**: contains the baseline medical passport, geographical clinic finder, and basic reminders,
- **Premium Tier** (monthly subscription $\approx$ 400 DA):
  - Advanced, real-time AI parsing for potential drug interactions,
  - Unlimited archives for patient visit histories,
  - Export utilities generating standardized PDF health profiles,
  - Priority support channels.

Under an assumed 5% premium conversion rate among an initial active cohort of 100,000 users, the projected monthly revenue is modeled as follows:

$$\boxed{\text{Monthly Revenue} = 100,0000.05400\,\mathrm{DA} = 2,000,000\,\mathrm{DA}/\mathrm{month}} \tag{5.1}$$

5.10 Business Model Canvas Grid

To summarize our socioeconomic strategy, Figure 5.1 displays the structured Business Model Canvas for the SanuPass platform.

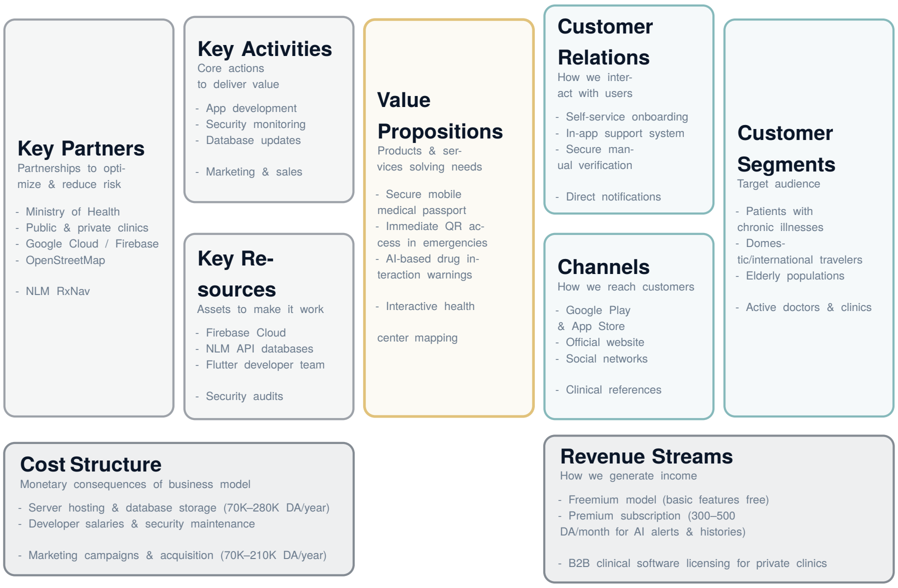

Figure 5.1. Business Model Canvas for the SanuPass platform

GENERAL CONCLUSION

THE SanuPass project was designed to address a concrete and urgent need in the healthcare ecosystem: **secure medical data portability** combined with **real-time geo-spatial intelligence**. By centralizing the patient's vital information in a digital passport accessible via a temporary QR Code, SanuPass bridges the critical gap between fragmented health data and the need for immediate accessibility in emergency situations.

Summary of Contributions

Throughout this thesis, we presented the entire development cycle of the platform:

- **Analysis of existing systems** (Chapter I) identified a lack of localized digital medical passport solutions optimized for the Algerian clinical context, establishing the project's foundational necessity.
- **System design** (Chapter II) mapped operational requirements for patient and clinician cohorts, structured interaction behaviors via UML, and defined the token-based security handshake protocol.
- **Development and execution** (Chapter III) detailed the hybrid software stack (Flutter, Firebase, and geospatial APIs) and configured the multi-layered safety mechanisms.
- **System implementation** (Chapter IV) introduced the user interfaces featuring glass-morphic designs, the interactive GIS mapping features, the automated AI safety alerts, and the QR scanner utility.
- **The Business Model Canvas** (Chapter V) analyzed the socioeconomic viability of the platform, highlighting a total addressable market exceeding 13 million potential users in Algeria.

The primary engineering contributions of this work encompass:

- A **secure data exchange protocol** using time-bounded CSPRNG tokens that establish a real-time verification handshake between doctors and patients,
- An **atomic kill-switch utility** enabling immediate and complete revocation of active profile access rights,
- A **geospatial parsing engine** using the Haversine formula and Overpass API query strings to map and locate regional medical installations,

- An **automated safety module** analyzing potential drug-drug conflicts and patient allergenic profiles.

Future Perspectives

Future development objectives target:

- Conforming to the **HL7 FHIR** schema to allow interoperability with enterprise hospital networks,
- Incorporating **on-device machine learning models** to deliver personalized health analytics,
- Distributing the final builds to public marketplaces (Google Play and the App Store),
- Scaling deployment workflows to neighboring Maghreb and North African markets.

Ultimately, SanuPass introduces a transformative framework for digital health systems in Algeria. By establishing patient-centered custody over clinical histories while providing practitioners with secure access, the platform offers a viable path toward updating public health infrastructure and raising the standard of care.

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Abstract

Résumé :

SanuPass est un écosystème mobile multiplateforme conçu comme un passeport médical numérique intelligent avec suivi géo-médical en temps réel. Développée avec Flutter et Firebase, la plateforme permet aux patients de centraliser leurs données de santé vitales (groupe sanguin, allergies, maladies chroniques, traitements actifs) et de les partager de manière sécurisée avec les professionnels de santé via un QR Code à jeton temporaire. Le système intègre une carte géo-médicale interactive pour la localisation des centres de santé les plus proches (formule de Haversine), un module d'alertes intelligentes basé sur l'IA pour la détection des interactions médicamenteuses, et un support trilingue (FR/AR/EN). SanuPass répond à un besoin critique de portabilité sécurisée des données médicales dans le contexte algérien et constitue une contribution innovante au domaine de la santé numérique mobile.

Abstract:

SanuPass is a cross-platform mobile ecosystem designed as an intelligent digital medical passport with real-time geo-medical tracking. Built with Flutter and Firebase, the platform enables patients to centralize their vital health data (blood type, allergies, chronic diseases, active treatments) and securely share them with healthcare professionals via a temporary token QR Code. The system integrates an interactive geo-medical map for locating the nearest health facilities (Haversine formula), an AI-powered smart alert module for detecting drug interactions, and trilingual support (FR/AR/EN). SanuPass addresses a critical need for secure medical data portability in the Algerian context and represents an innovative contribution to the field of mobile digital health.

ملخص:

سانوباس هو نظام بيئي للهواتف المحمولة متعدد المنصات مصمم كجواز سفر طبي رقمي ذكي مع تتبع جغرافي طبي في الوقت الفعلي. تم تطويره باستخدام فلوتر وفايربيس، وهو يتيح للمرضى تجميع بياناتهم الصحية الحيوية (فصيلة الدم، الحساسية، الأمراض المزمنة، العلاجات النشطة) ومشاركتها بشكل آمن مع المهنيين الصحيين عبر رمز الاستجابة السريعة المؤقت. يدمج النظام خريطة جغرافية طبية تفاعلية لتحديد أقرب المراكز الصحية (صيغة هافرسين)، ووحدة تنبيهات ذكية قائمة على الذكاء الاصطناعي للكشف عن التداخلات الدوائية، ودعم ثلاثي اللغات (الفرنسية والعربية والإنجليزية). يستجيب سانوباس لحاجة ماسة لنقل البيانات الطبية بشكل آمن في السياق الجزائري ويمثل مساهمة مبتكرة في مجال الصحة الرقمية عبر الهاتف المحمول.

Mots clés : passeport médical numérique, mHealth, Flutter, Firebase, QR Code, géolocalisation, interactions médicamenteuses, IA santé

Keywords: digital medical passport, mHealth, Flutter, Firebase, QR Code, geolocation, drug interactions, health AI

الكلمات المفتاحية: جواز سفر طبي رقمي، الصحة المحمولة، فلوتر، فايربيس، رمز الاستجابة السريعة، تحديد الموقع الجغرافي، التداخلات الدوائية، الذكاء الاصطناعي في الصحة