

PetCare Hub



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Abstract

PetCare Hub is created as an all-inclusive AI-driven pet care service platform, which is linked to trusted providers of services. Existing platforms are generally restricted to simple service listing and do not offer the smart monitoring, professional verification, and infrastructure needed in the current pet care.

PetCare Hub uses complete Role-Based Access Control (RBAC) access to overcome these shortcomings, having Pet Owners, Verified Service Providers, and Administrators. The AI-assisted device consists of two primary support applications: a Pet Care Chatbot (driven by Google Gemini API), which may be used to answer any general questions, and Disease Prediction Service, the health recommendation engine that is a machine learning-powered application.

It is a platform on which qualified professionals are allowed to give services by a Service Provider Verification Workflow. The integrated service management facilitates pictures upload, service description, pricing and booking, Stripe payment, and email notification. The Real-time Geofencing Technology will enable pet owners to create safe areas and get immediate alerts whenever pets leave these areas.

Quality assurance is ensured by the system of 5 stars ratings and reviews of the providers. Other features are profile management and medical history of pets, real time location and instant notifications using Socket.io.

PetCare Hub is built on React.js, Node.js, and Firebase that provides a secure, trusted environment with JWT authentication, Firebase security rules, and role-based access control that makes pet care services more available, reliable and smart.

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Finally, we are grateful to our friends who made the process of studying and overcoming challenges more manageable. May Allah (SWT) guide us all on the right path.

UZAIR YAMEEN AND MESHEZABEL ROPHIS
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“Be the change you want to see in the world.”

Michael Scofield

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Acronyms and Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
CSS	Cascading Style Sheets
CRUD	Create, Read, Update, Delete
GPS	Global Positioning System
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	HTTP Secure
IoT	Internet of Things
JSON	JavaScript Object Notation
JWT	JSON Web Token
ML	Machine Learning
NoSQL	Not Only SQL
npm	Node Package Manager
PCI-DSS	Payment Card Industry Data Security Standard
RBAC	Role-Based Access Control
REST	Representational State Transfer
SDK	Software Development Kit
SMTP	Simple Mail Transfer Protocol
UI	User Interface
UML	Unified Modeling Language
URL	Uniform Resource Locator
UX	User Experience

Chapter 1

Introduction

In today's fast digitizing world, pet owners and pet care service providers have a unique set of challenges. Managing appointments, working with real-time location tracking related to pet services, integrating secure payment systems, and allowing for seamless communication between pet owners, veterinary clinics, and pet sitters can become a complex and time-consuming task [1]. Traditional solutions tend to be fragmented tools, manual coordination, and lack of accessibility that result in missed appointments, inefficient service delivery, poor user experience, etc. to solve these problems, we introduce PetCare Hub, a complete cloud-based web platform for streamlining every aspect of pet care management [2]. PetCare Hub is a cohesive solution for pet owners to be able to book services and track pets and caregivers in real-time, access veterinary records, and communicate directly with service providers all from their one easy-to-use interface. Service providers, on the other hand, have the advantages of an automated booking management system, integrated GPS/geofencing for service area controls, and efficient management of client communications and payments [3].

By automating and centralizing scheduling, communication, and record-keeping, PetCare Hub saves on administrative overhead, eliminates redundant workloads, and provides a smarter and more responsive pet care experience. Both pet owners and service providers benefit from the transparency, reliability and intelligence of a next generation, cloud-powered platform. PetCare Hub is not only set up to make the delivery of pet services more efficient, but it also provides the technological platform that will enable more intelligent and connected pet communities [4].

1.1 Project Overview

Despite the rise of digital solutions for pet owners and animal service providers, the availability of credible, specialized and trustworthy care platforms remains a great challenge. Finding accurate health advice, reliable service listings, appointment management and real-time care information in one place is not always easy for pet owners, veterinary professionals and service providers [5]. This brings about fragmented user experiences and leaves people to consult multiple and often unverified sources to meet their pet care needs.

The lack of domain-specific digital pet care solutions is particularly pronounced in many regions, where the use of general listing sites or messaging platforms is leading to inconsistent quality of service, concerns about security and limited access to expert advice. Although general marketplaces and forum-like applications are not entirely useless, they usually lack such important features as an integrated medical records management tool, professionally reviewed health information, smart booking processes, and AI-assisted disease evaluation solutions [6].

The ineffectiveness of such generic solutions is made more pronounced as the need to have safe, efficient, and accessible methods of pet care increases. They do not have such standards as rigorous professional verification, medical triage, transparent rating and review systems, which is prerequisite of good pet and veterinary services. This is not only dangerous to the owners of pets, but it also remains a challenge to the service providers aiming at attracting new customers and developing trust towards them [7].

The creation of PetCare Hub was aimed at bridging these gaps. The platform is built on a combination of bookings, veterinary records, service listings, and live communication in a secure and professional setting which is strengthened by professional verification where available and augmented with an AI-powered disease prediction tool. Centralizing access and automating some aspects of care will allow PetCare Hub to avoid requiring users to control all the services, letting both owners and providers concentrate on what is most important to them taking care of animals [8].

Simply, PetCare Hub is the gap between the sophistication of quality pet care and the digital solutions, which were disjointed before. It helps to alleviate the stress of looking for credible, reliable, and secure care which is becoming increasingly important as pet ownership and the need for modern digital services continue to rise [9].

1.2 Problem Description

The pet care services are normally inefficient and frustrating to both the service providers and the pet owners. The problems encountered in the pet care industry are:

1. **Disjointed Service Discovery:** Pet owners often have to go through numerous sites to identify trusted pet sitters, veterinarians, or groomers, which leads to the loss of opportunity on both sides, users and service providers [10].
2. **Manual Scheduling and Coordination:** A number of solutions currently in use are highly dependent on phone calls, text, and manual record-keeping, which causes scheduling conflicts, missed appointments, and poor communication clarity [11].
3. **Absence of Real-Time Tracking:** Face-to-face or outdoor services, including dog walking, or home veterinary visits, do not always have clear methods through which owners can monitor the status of the service or the location of their pets in real-time, which can be stressful and result in safety issues [12].
4. **Fragmented Tools:** The major features such as booking, payment monitoring, notifications, and health records are divided between various applications and systems, which are ineffective and prone to errors among the owners and providers of the features and tools themselves [13].
5. **Unclear Communication and Status:** Often pet owners are left wondering about the status of their appointment, progress of their service, or what is coming up next, which can lead to frustration and lack of trust [14].
6. **Data Security and Accessibility:** Data security and access is not sufficient in paper-based or legacy digital solutions, which can cause data loss and may have limited platform scalability due to insufficient data backup and data security [15].

1.3 Project Objectives

The main objectives of PetcareHub are:

1. To offer a user-friendly cloud-based platform for pet owners to schedule a range of pet care services easily, manage their pet's profile, track their appointments and communicate with the service providers – all from a central dashboard [16].
2. To allow service providers (pet sitters, veterinarians, groomers) to list their services, manage their services, manage communication with clients and update the service availability efficiently using an integrated dashboard.

3. To integrate real time GPS and geofencing capabilities for tracking pets and service personnel in an effort to improve the safety and transparency of outdoor or at-home services [17].
4. To support secure and seamless payment solutions within the platform, facilitating invoicing, tracking of payments and supporting multiple means of transaction [18].
5. To take advantage of cloud technology to ensure reliable data storage, authentication, scalable backend services and real-time data, providing data security along with high platform availability [19].
6. To provide analytics and reporting tools for both pet owners and service providers to gain insights such as history of booking, pet health and service popularity [20].

1.4 Project Scope

Some of the functionalities and features implemented by PetCare Hub include:

1.4.1 Inclusions

User Management

- **Account Creation & Login:** Registration, secure authentication with the help of Firebase authentication, password reset, and social login support [15].
- **Role-Based Access:** Two main roles of user namely Pet Owner and Service Provider with specific access controls and separate user dashboards.

Service Management

- **Service Listings:** Pet service providers can create, update and remove various service offerings (such as pet sitting, dog walking, grooming or veterinary consultation) [11].
- **Category Organization:** Services can be categorized by type (i.e., veterinary, walking, grooming) and filtered out by availability, location and reviews.

Processing of Booking and Appointments

- **Service Booking:** Owners are able to book available services, choose time slots and make special requests.
- **Automated Conflict Management:** The system ensures against double booking and handles the overlapping appointment issues.

- **Booking Status Tracking:** Both providers and owners will be able to see the status of the appointment (pending, confirmed, canceled, completed) from their individual dashboards [10].

Monitoring and Geofencing of Session

- **Real Time Location Tracking:** Track the location of pets and service providers during live appointments with the help of integrated GPS [12].
- **Geofencing:** Establish and protect safe zones for pet activities. Seconds later, notifications are sent in case of pets leaving or re-entering defined zones [21].
- **Route Logging:** Read historical routes and session logs for transparency and accountability.

Payments and Notifications

- **Integrated Payments:** Safe payment and invoicing of in-app payments for completed services [18].
- **Automated Reminders:** Reminders and push notifications when a booking is due, it is time for a vaccination or for an important pet milestone.

Communication and Evaluative

- **In-App Chat/Alerts:** In-process messaging and alert system for instant communication between the owners and the service providers [14].
- **Service Feedback & Ratings:** Owners can provide feedback and give ratings to service providers after completed appointments.

Dashboards

- **Owner Dashboard:** Owner central hub to manage their pets, bookings, payments, health records and communicate with owners.
- **Provider Dashboard:** Track listings, appointments, revenues, reviews, as well as track live session activity [22].

1.4.2 Exclusions

Native Video Conferencing

- **No Built-in Video Calls:** PetCare Hub is not a platform that comes with native video or audio calling. Any live video features (pet monitoring or consultation, etc.) must be done via third-party video conferencing tools (Zoom, Google Meet, WhatsApp, etc.).

- **No Real Time Video Analysis:** Any safety or session monitoring analysis is based on logs, GPS/geolocation data or post-session uploads, not live-streamed analysis.

Device Compatibility

- **No Dedicated Mobile App:** PetCare Hub is designed as a web-based, responsive application; there is no dedicated mobile application for either iOS or Android. Users have access to all functionality through supported web browsers.

Advanced AI Features

- **No AI Based Pet Emotion Recognition:** Real-time AI-based emotion or health analytics based on live video or sound is excluded; only core session monitoring using geofencing and routing is included.
- **No Automated Veterinary Diagnostics:** The system does not offer medical diagnosis and treatment recommendations; it is just a platform for information and service facilitation.

1.5 Methodology

PetCare Hub uses a modular approach where each core feature is handled independently for maximum scalability, maintainability and clear separation of responsibilities. The principal modules of the platform are as follows:

User Management Module

Handles user registration, authentication, and profile management with the help of the Firebase Authentication and custom role-based access control (RBAC). This enables secure onboarding, session control and permission assignment for the Pet Owner, Service Providers and Admins [15].

Service Management Module

Empowers service providers to list, edit, and categorize their offerings (e.g., pet sitting, vet care, grooming). It handles detailed service attributes, media uploads, availability organisation and provides filtering for the pet owners.

Booking & Appointment Module

Facilitates booking of services by pet owners such as real-time availability check, conflict-free scheduling, and integrated calendar management. Automatic notifications with support for external video meeting links (Zoom, Google Meet - remote consultation flows) inform users and providers of booking status (confirmed, canceled, completed) [10].

Management of AI Disease Prediction & Recommendation Module

Integrates Custom Trained Random Forest AI model for animal disease prediction. This module takes clinical and symptom information submitted by users, anticipates potential

diseases and recommends urgency and steps for care [23]. It also provides individual recommendations for both pet owners and providers with intelligent triage logic [24].

Conversational AI Chatbot Module

Contextual Chatbot: Returns provider- and service-aware support (answers around business hours, choice of service, clarification of type of animal), using cache augmented prompts to return more relevant answers.

Global Pet Health Assistant: Using Google’s Gemini API to provide general pet care information, tips for prevention and natural language assistance for navigating the platform [8].

Geolocation & Safety Module

Handles live tracking of pets and service providers using leaflet/opensource stack, updates of location in real time (using Firebase Realtime DB) and geofencing algorithms [25]. Gives historical route logging and safe zone notifications to the owners [17].

Payment Processing Module

Integrates Stripe for secure payment of bookings of service, payouts to providers and transaction history. Payment state, refunds, commission splits and Web hook verification are end-to-end (visible to both owners and providers) [18].

Module for Notification & Messaging

Sends real-time notifications of the system and transactions (via the use of the Firebase Cloud Messaging and Resend for email). Alerts such as booking updates, payment receipts, geofence / tracking events and service reminders [14].

Data Management Module

Ensures the data of all the users, bookings, payments, and reviews are centralized using the Firestore of Firebase. Robust access rules and backup protocols help to protect sensitive information and provide for easy auditing and recovery [26].

This modular structure is the foundation of PetCare Hub’s capacity to provide secure, efficient, user-centric pet care solutions that can be quickly updated to obtain new features and integrated with other modules reliably as the platform requirements evolve [19].

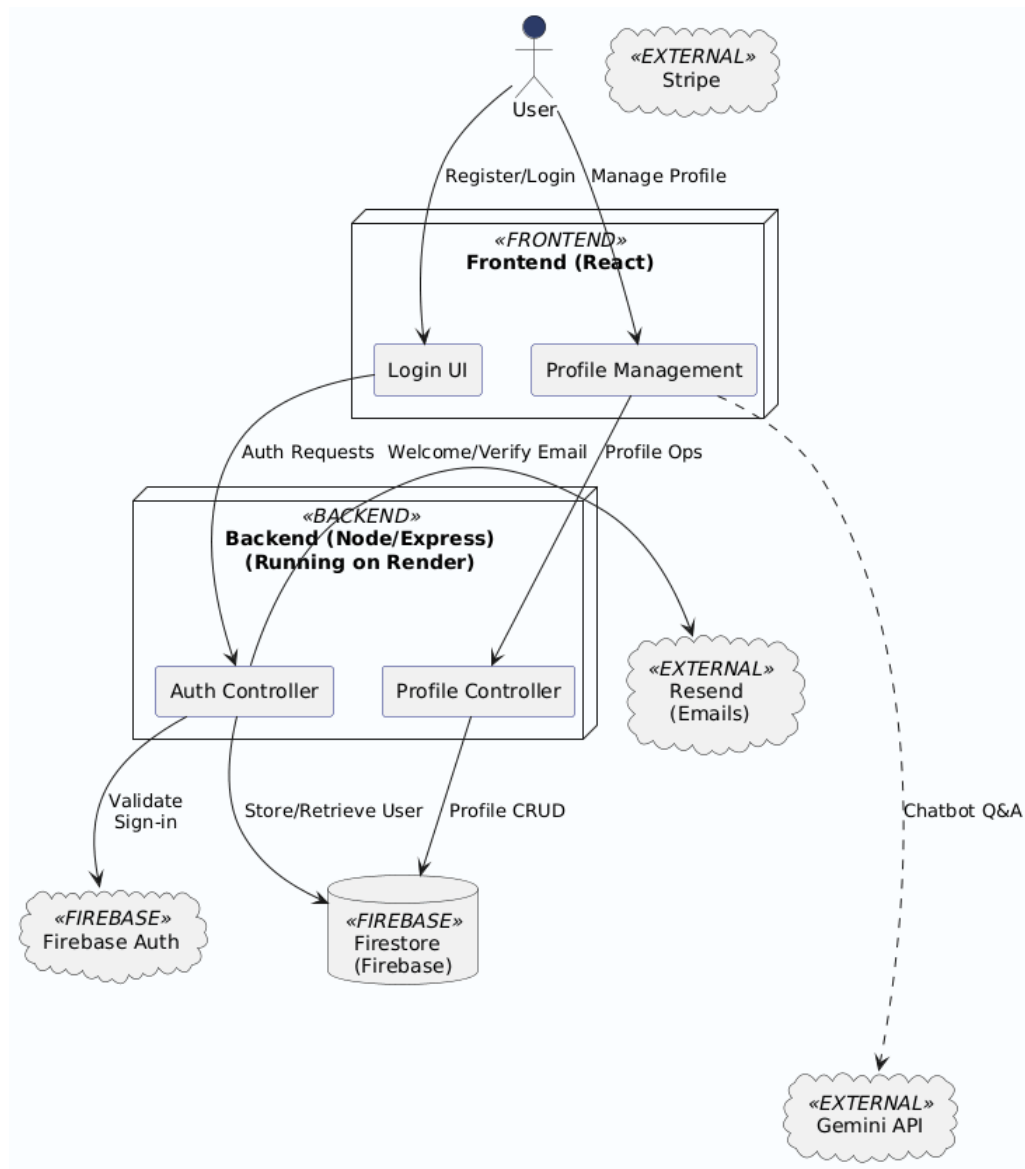


Figure 1.1: PetCare Hub – User Management and Authentication System Architecture.

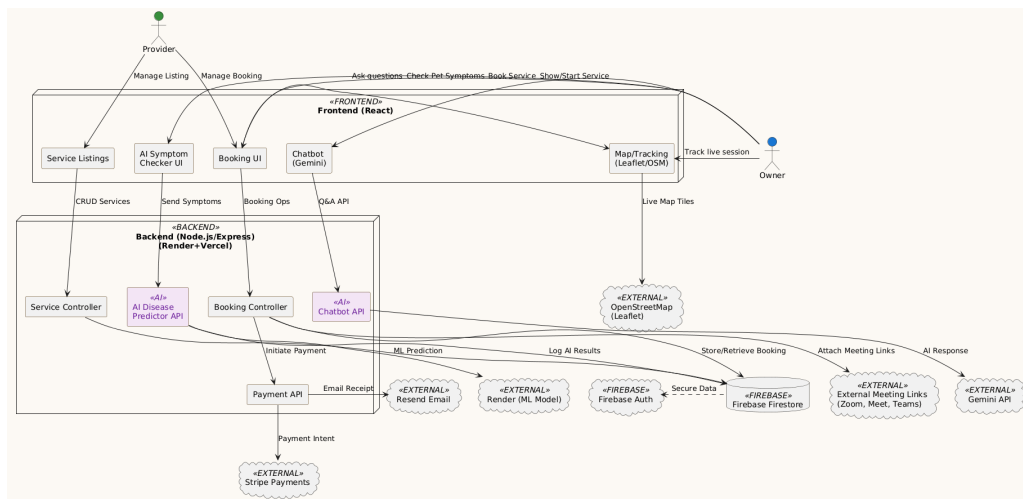


Figure 1.2: PetCare Hub – Core System Architecture for Service Booking, AI Disease Prediction, and Communication.

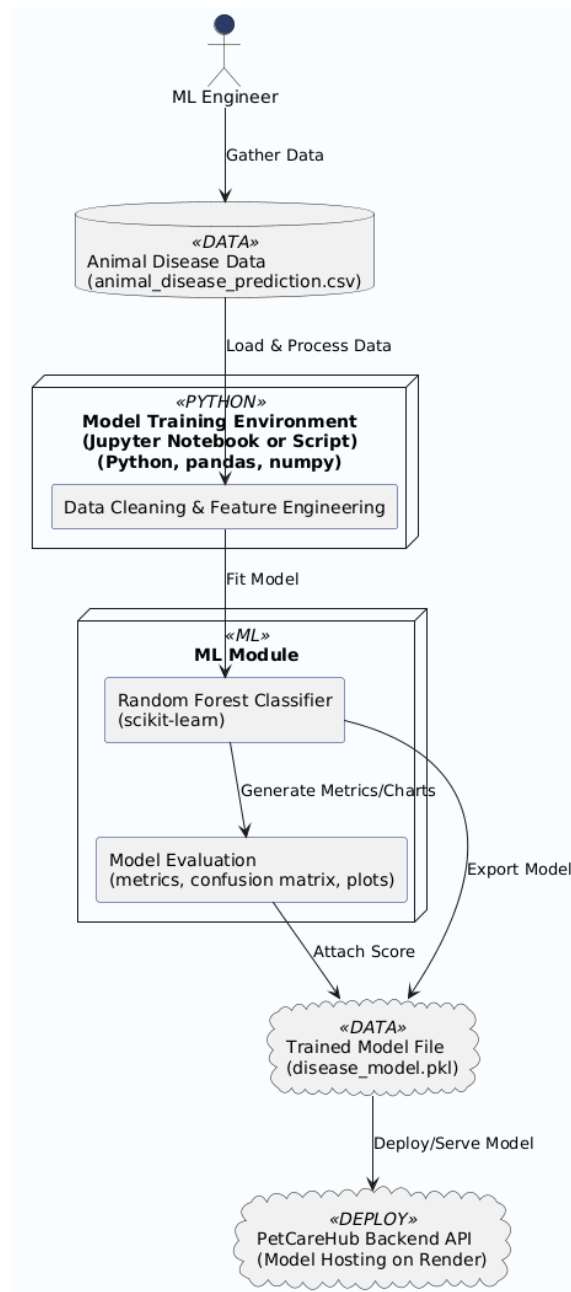


Figure 1.3: PetCare Hub – AI Model Training Process for Disease Prediction.

Chapter 2

Literature Review

Digital transformation in pet care over the past 10 years has transformed the way pet owners receive services, the way suppliers run their businesses and the way clinicians provide care. The classical system of appointments and listings of services has transformed into a high-tech multi-functional platform, where real-time interaction, distant consultation, and health monitoring are accessible by data-driven means [1].

With the recent breakthroughs in Artificial Intelligence (AI), machine learning for diagnostics, cloud computing, and geospatial technology, it became possible to create specific and reliable platforms within the pet care industry within a short time. These technologies enable services such as AI-based symptom checkers, automated appointment booking, real-time location tracking, and seamless digital payments [3]. Despite the overall expansion of general marketplaces, there is still a vacuum for domain-specific, professionally-validated, and transparent pet care marketplaces — specifically those offering proactive health monitoring and AI-enabled recommendations [4].

The most important innovations mentioned in the literature are:

- **AI/ML in Disease Prediction & Early Warning Systems:** Early disease prediction in animals through artificial intelligence and machine learning monitoring systems [23, 6].
- **Integration of Open Geospatial Data:** Leveraging platforms such as OpenStreetMap for pet tracking and logistics management [12, 17].
- **Cloud-Based Communication & Serverless APIs:** Ensuring scalable and reliable operations for pet care applications [19, 15].
- **Digital Payment, Real-Time Notification & Conversational AI:** Enhancing user experience and trust using chatbots, notifications, and seamless digital transactions [18, 14].

These technological advances are being utilized by modern pet care platforms like PetCare Hub to bridge the gap between accessibility, professional reliability, and user-centric design, supporting improved animal health and efficiency in service.

2.1 Digital Pet Care Platforms of Specialty

Specialized digital platforms have been launched to meet the shortfalls of general-purpose solutions by the pet care industry. These platforms are centered on the unique needs of pet owners and service providers and ensure accuracy, dependability, and a higher level of service [2].

In the case of pet care, the need to trust the information and professionally validated services is particularly important, since the quality of the advice, the reliability of the appointments and the health recommendations has a direct impact on both the well-being of the animal and the trust of the owner [5]. General platforms, such as generic online marketplaces or generic scheduling tools, often lack specific features tailored to healthcare for animals such as integrated health records, artificial intelligence-based symptom checking, or access to credentialed professionals [11].

2.2 Helping Pets Platforms with Artificial Intelligence

Artificial intelligence integrated in pet care platforms brings to life great opportunities for highly individualized and responsive user experiences. AI-powered virtual assistants and chatbots can be used to give real-time support, personalized recommendations, and instant responses to a wide variety of pet health and service-related queries [8].

In PetCare Hub, AI-powered systems can offer users with fast access to the right advice depending on the particular situation, be it checking out symptoms, getting a reminder about booking an appointment, or estimating the nearest service provider. The intelligent assistants of the platform use subject-specific knowledge and local information to surpass generic responses and provide custom feedback to the needs of each pet owner based on the specific requirements of the latter, which is called multimodal in reference to their usage at the site of the platform being discussed [7].

It leads to a smarter, more enjoyable platform that enables users to make informed choices, improves the health of pets, and ease the intricacies of keeping pets by being a more engaging platform of interaction experience [9].

2.3 Professional Checking Systems

Professional verification systems are in place to make sure that the qualified and authorized service providers are the ones who operate within such a platform as PetCare Hub. With

the checks and role-based access controls, the system maintains an excellent level of service quality and user confidence so that the pet owners can be assured of all booking and interaction [26].

2.4 Digital Pet Care Platforms: Comparative Overview

2.4.1 General Marketplaces

General classifieds or even service marketplaces do provide the opportunity to advertise to pet service providers, although they usually do not offer trusted credentials, animal health tools or built-in care management. They typically lack features like AI disease prediction, real-time tracking, in-app appointment management, and health records [10].

2.4.2 Appointment & Directory Apps

Some of the apps are based on the organization of appointments and the presence of clinics or vets, which offers easy entry to the service providers. Although they make it easy to book, it is not always accompanied by professional verification, AI-based symptom verification, and long-term, continuous communication solutions to longitudinal pet health [13].

2.4.3 Specialty Pet Health Solutions

Specialty Pet Health Solutions will have a small number of employees. In some developed platforms, consultations with telemedicine, or finding a professional veterinarian can be a paid service, and in many cases, the provider must be verified and already licensed as a veterinarian. Nevertheless, a majority of them do not have complete integration of AI tools in disease triage, extensive geofencing, real-time mapping, direct payments via Stripe, and smart chatbot assistance as in PetCare Hub [24, 27].

2.5 Compared to Existing Platforms

A list of features and services of existing pet care platforms in comparison with PetCare Hub is provided below, and shows the unique combination of AI capabilities, professional validation, and built-in health management that will make PetCare Hub stand out from the crowd of digital pet care platforms.

Table 2.1: Comparison of Existing Digital Pet Care Platforms with PetCare Hub

Platform / System	Features and Focus	Comparison with PetCare Hub
General Marketplaces	Broad listings for pet services, limited or no professional credential checking, minimal health record integration, basic communication tools.	PetCare Hub provides end-to-end, domain-specific services with verification, AI symptom checker, and integrated booking, unlike general platforms which lack comprehensive features and validation.
Appointment Apps	Offer service provider directories, appointment scheduling, sometimes payment integration; limited professional vetting, rarely any AI or live tracking.	PetCare Hub adds AI-powered health tools, authenticated provider listings, real-time tracking, and in-app chat, exceeding the limited scope of simple appointment or directory apps.
Specialty Pet Health Solutions	Some focus on telemedicine, professional vet search, sometimes payment integration and credential verification, but usually lack integration of AI, mapping, and everyday booking flows.	PetCare Hub uniquely combines verified professional access, AI-driven diagnosis (disease predictor), live chat/chatbot (Gemini), Stripe payments, OpenStreetMap-based tracking, and unified record management in one platform.
PetCare Hub (Our Project)	Specialized pet care platform with provider verification, AI-powered symptom checker, appointment scheduling, real-time geofencing, integrated Stripe payments, chatbot, and unified data management.	Unified, intelligent, and verified pet care ecosystem, with features including: professional validation, AI tools, secure payments, real-time location services, and modern communication in one dedicated platform.

Chapter 3

Requirement Specifications

PetCare Hub was conceived to overcome the significant gap problems of existing digital pet care solution, which suffer from the fragmented nature of services, professional invalidation and lack of intelligent tools, resulting in inefficiency and trust issues for both the pet owners and service providers [1].

The requirements of the system were carefully outlined to ensure that all the basic functions such as user registration and authentication, verifying service providers, booking an appointment, predicting the disease based on AI, tracking the patient in real-time, and making payments securely and intelligently, and chatting with the chatbot, include all the various parts that work together to provide a professional, reliable, and user-centered experience [2].

Requirements were formed through a comprehensive analysis of existing platforms (general marketplaces, appointment apps and specialty pet health solutions) combined with first-hand knowledge of the needs of pet owners, veterinary professionals and service providers. This analysis uncovered great deficiencies in areas such as professional credibility, health triage tools, integrated communications and booking-to-payment flows.

The end specification has functional and non-functional requirements that make PetCare Hub a full-featured, intelligent platform that offers a bridge between generic service listings and the specialized and trustworthy pet care ecosystem that today's user base requires [4].

3.1 Existing System

Before the development of PetCare Hub, a lot of research was done on platforms that offer pet care services, appointment scheduling, health management, and artificial intelligence-based support. This review helped to define the landscape of things at the moment and to inform the specific gaps PetCare Hub was designed to address.

3.1.1 Health Support Systems Based on AI

Recent breakthroughs in artificial intelligence have shown the promise of intelligent health assistants and chatbots in health care and general consumer-based applications. However, these innovations have not been widely or effectively applied to the animal health and pet care services. PetCare Hub specializes these AI capabilities to be more specific to the pet care sector, and their implementation includes things like disease prediction models and conversational AI specific to pet health questions [8].

3.1.2 Professional Verification Systems

Other websites offer simple profiles of providers, but they do not follow a stringent screening of the professionals. The systems in place do not usually demand documented evidence of veterinary licenses, certifications, and ongoing professional verification leaving users unsure of what a specific provider is and how trustworthy they are in general [15].

3.1.3 First Choice Pet Service Platforms

Some of the most popularly used platforms analyzed include:

General Marketplaces: These marketplaces do not provide oversight of the service providers offering. They do not have any special features for pets health management, professional verification, or any integrated artificial intelligence tools which is essential for any credible pet care [10].

Appointment and Directory Apps: These provide users with convenient ways to schedule appointments and find contact information for clinics and providers. However, they generally do not offer real-time communication, AI symptom checking, payment integration or even live-tracking - limiting them for full-fledged care [16].

Specialty Veterinary Solutions: There are some platforms which focus on telemedicine or professional vet finding and have more stringent requirements for providers. Yet, they often do not have full integration of booking, payment, AI diagnostics, geofencing and ongoing health records management that PetCare Hub delivers in a unified system [3].

3.2 Gap Identified

Existing platforms are not comprehensive, intelligent and professionally validated solutions for pet care. Key identified gaps include:

- **Absence of specialized focus on pet care:** Present platforms focus on general listings and/or basic scheduling and do not place an emphasis on holistic solutions for pet health management, such as diagnostics, tracking, and integrated records [5].
- **Lack of rigorous professional verification processes:** Most systems do not have rigorous processes in place to guarantee that only licensed veterinarians, certified groomers, or qualified trainers can provide services, which makes it difficult for users to know the credibility of the providers [11].
- **No dedicated AI-based health assistance:** Current platforms do not have AI-powered symptom checkers, the ability to predict diseases and intelligent chatbots specific to pet health queries and triage [6].
- **Poor integration between booking and consultation:** Most of them do not have seamless, end-to-end workflows that link service discovery, booking, payment and real-time communication in one place [19].
- **Limited or no real-time tracking and safety features:** Platforms generally do not offer live GPS tracking, geofencing, or route history tracking for pet services, making it less transparent and less confidence-inspiring for owners [12].
- **Weak quality assurance mechanisms:** Lacking are comprehensive rating, review validation and feedback mechanisms that are geared specifically towards pet care services and provider accountability.
- **Lack of inbuilt payment and monetization solutions:** No seamless and secured payment processing integrated with booking workflows and transactions are fragmented or made external [18].

PetCare Hub bridges all these gaps by bringing together professional verification, AI-powered health tools, real-time tracking capabilities, unified booking and payment system, smart chatbot support and quality assurance - all in one secure and easy to use platform for both pet owners and service providers.

3.3 Proposed System

To overcome the shortcomings in the field of digital pet care services, we propose PetCare Hub, which is a comprehensive, safe and intelligent web platform, based on cutting-edge artificial intelligence, real-time communication and strict professional verification.

The main idea behind the system is to create a trusted environment where verified pet service providers (veterinarians, groomers, trainers, sitters) will be able to provide their professional services and pet owners will have access to artificial intelligence-based health tools, easy booking, real-time tracking, and direct consultation. The platform guarantees credibility by professional verification and individual support by AI-powered disease prediction and conversational chatbots [7].

3.3.1 Important Characteristics of Proposed System

- **Focus on Specialized Pet Care Management:** Custom-built for full-service pet health, safety, and services coordination with high professional and security standards.
- **Extensive Professional Verification System:** Multi-step administrative or credential-based approval for listing services and interacting with users is enforced to ensure only licensed veterinarians, certified trainers, and qualified service providers are able to provide services to users.
- **Dual AI-Powered Assistance:**
 - **AI Disease Predictor:** Custom trained machine learning model (Random forest, scikit learn) for triaging disease through symptoms, urgency and care [23].
 - **Conversational AI Chatbot (Google Gemini API):** Answers questions about pets care, service information, provider business hours and pet health advice in real-time [9].
- **Role-Based Access Control (RBAC):** Multi-tier user system (Pet Owner, Service Provider, Admin) to ensure security, integrity of data and appropriate access to features [15].
- **Integrated Service & Booking Management:** Providers can create, update and manage listings (with description, price, availability) of their services. Owners can search, filter and book services seamlessly.
- **Real-Time GPS Tracking & Geofencing:** Live location monitoring with Leaflet & OpenStreetMap, safe zone alerts, route history for transparency during pet services [17].
- **Secure Payment Processing:** The Stripe integration takes care of end-to-end transactions, automated invoicing and payment status updates for both owners and providers.
- **Appointment & Consultation Services:** Users can check the availability of the providers, make an appointment and add external meeting links (Zoom, Google Meet, Teams) for virtual consultations.

- **Quality Assurance and Rating System:** Complete 5-star rating and review system allows pet owners to provide feedback to completed services driving accountability and quality improvement.
- **Automated Notification System:** Integration of Firebase Cloud Messaging & Re-send email for real time notifications for bookings, payment, reminders, geofence alerts and verification updates [14].
- **Advanced Analytics & Dashboards:**
 - **Owner Dashboard:** Control pets, bookings, payments, health records & communication.
 - **Provider Dashboard:** Service, appointment, earnings, review and live session tracking manage.
 - **Admin Dashboard:** Control of users, verification queue, analytics of the platform, content moderation.
- **Modern Full Stack Architecture:** Based on React, Node.JS/Express (using Render & Vercel), Firebase (Firestore, Realtime Database, Authentication, Storage), Python (ML Inferencing) and creating a responsive, secure & scalable platform [22].
- **Python-Based ML Inference Service:** Dedicated Python backend (deployed on Render) to provide the AI disease prediction service through the RESTful API to analyze the symptoms in real time and provide healthcare recommendations [24].

PetCare Hub is a groundbreaking combination of cutting-edge AI, professional vetting, real-time communication, and in-depth service management - building a trustworthy, intelligent platform to manage modern pet care and uphold the highest standards of trust, safety, and user experience.

3.4 Requirement Specification

To ensure that PetCare Hub will meet its targets a comprehensive set of requirements are used to guide development and testing to ensure it is a high quality, credible, secure and user-focused platform.

3.4.1 User Requirements

Users expect:

Pet Owners:

- Access to verified and credible service providers that specialize in the care of pets (veterinary, grooming, training, sitting).

- Ability to peruse of services, view profiles of providers, book appointments and make secure payments by integrated payment systems.
- AI for symptom checker for initial pet health evaluation and conversational chat-bot for on the spot guide.
- Real-time GPS tracking & geofencing active service sessions: Transparency & safety.
- Unified dashboard to run a pet, bookings, health records, payment & communication.

Service Providers:

- Ability to create, update and manage the listing of services including pricing, descriptions and availabilities.
- Professional verification system to develop credibility and trust with clients.
- Dashboard to control the bookings, check the earnings, monitor the payments and respond to reviews.
- Tools to plan consultation time, leave a link to meetings and receive automatic notifications.

Administrators:

- Access to queues of verification by users, content moderation, platform and revenue tracking analytics.
- Circulation tool to manage the disputes and monitor the health of the system and make sure to abide by professional standard.

All Users:

- Cross-Device (desktop, tablets and mobile) secure, responsive and intuitive interface.

3.4.2 Functional Requirements

The system needs to do the following:

- **User Registration and Authentication** Role based registration (Pet Owner, Service Provider, Admin) Secured login Using Firebase Authentication [15].
- **Professional Verification Process:** Multi-step verification process requiring that verification of credentials (licenses, certifications) be submitted and administrative review be conducted before service listing by providers.

- **Service Management System:** Verified providers need to be able to create, post, update and manage service offerings with media uploads (stored securely via Firebase Storage).
- **Service Browsing and Booking System:** Pet owners need to be able to search, filter, have access to detailed information about the service and be able to book an appointment seamlessly [19].
- **Dual AI System:**
 - **AI Disease Predictor:** Takes symptoms submitted by users and give them the disease prediction, disease severity and care recommendations [28].
 - **Conversational Chatbot (Gemini API):** Answer real time pet care questions, service requests and provider information.
- **Appointment Booking & Scheduling System:** Users should be able to check the available slot of the providers, schedule time and attach or access external meeting links (zoom, google meet, teams) for virtual appointment.
- **Real-Time Tracking & Geofencing:** Real-time GPS tracking & safe zone alerts on in-session of service & route history logging [25].
- **Payment Processing and Monetization:** Integration with Stripe payment processors for secure transactions, automatic invoicing of payments, payment status update, payment tracking and payment payouts to providers [18].
- **Quality Assurance and Rating System** to permit pet owners to give 5 star ratings and written reviews on completed services with provider response capability.
- **Notification System:** Automated Email (Resend) and In-app notification (Firebase Cloud Messaging) for booking confirmation, reminders, payment receipt and geofence alerts.
- **Admin Dashboard and Platform Management:** Ultimate tools for user management, verification queue, dispute resolution with analytics and revenue tracking.
- **Progress Tracking and Analytics:** In depth records of booking history, payment transactions, services usage and user activity.

3.4.3 Non-Functional Requirements

The system must uphold:

- **Security and Privacy** Strong security using firebase authentication and firestore security rules, JWT tokens, safe use of sensitive pet healthcare and user data [15].

- **Professional Credibility:** Maintenance of integrity of the platform with the strict verification of the providers and the continuous quality monitoring.
- **Scalability and Performance:** Need to be able to support concurrent users with reasonable performance, page load times of less than 2 seconds and API responses of less than 500 milliseconds [19].
- **User Experience:** Clean, responsive, intuitive interface with optimized (desktop, tablet and mobile) user experience [16].
- **Availability and Reliability:** 99.9% uptime goal with stable integration of all external services (AI, payment, email, mapping, communication).
- **Data Integrity and Backup:** Safeguarding user data, service data, bookings data, payment data, health data and taking regular backups in the case of FireBase [26].
- **Documentation and Maintainability:** Good documentation and maintainability of codes and architecture for future scaling and feature addition, as well as team onboarding.
- **Compliance and Standards:** Compliance with Data Protection Regulations, Professional Standards of Pet Care & Transparency with Guidelines for using AI (Disclaimers for AI-based Health advice).

3.5 Limitations of the Project

While innovative and comprehensive, the current version of PetCare Hub has a number of limitations representing areas of future improvement:

- **AI Prediction Accuracy and Context Sensitivity:** The AI disease predictor might need some refinement and bigger data sets for training in order to deal with rare diseases, breed-specific or very nuanced clinical situations with higher accuracy [29].
- **Manual Professional Verification Dependency:** Credibility on the platform is through manual review of credentials by administrators who may have some automated processes in the future for consistency of review and speed.
- **Limited Real-Time Video Consultation:** Currently, the platform only allows external meeting links (Zoom, Google Meet, Teams) and not in-app video calling, which may not be a seamless experience for the user.
- **AI Chatbot and Predictor Boundary Limitations:** The AI tools cannot give definite diagnosis and cannot take the place of professional veterinary consultation, which restricts its use in case of emergency or critical health situations. There need to be some disclaimers.

- **Geographic and Regulatory Constraints:** Professional verification presently targets general credentials and does not consider geographical veterinary licensing requirements, which could potentially hamper global scalability.
- **Basic Analytics and Reporting:** The platform does not have advanced analytics (predictive health trends, one-of-a-kind care recommendations, or advanced analytics based on usage patterns for owners and providers).
- **Depending on External Service Integrations:** The system requires a reliable internet connection and access to 3rd-party APIs (Gemini, Stripe, Firebase, OpenStreetMap, Resend), which puts the system at risk of collapse.
- **Single-Language Support:** The platform, and AI services are currently only in English, which restricts the accessibility of non-English speakers to them and reduces the global coverage.
- **Scalability of Manual Verification:** When the platform expands, manual provider verification can become a bottleneck and it needs automated provider validation systems or can be connected with professional registries.
- **Minimal Interconnection with the External Systems:** PetCare Hub is not directly connected to any veterinary practice management software, pet insurance, or existing clinic databases.
- **Issues of Content and Service Moderation:** Continuous quality control, review validation and dispute resolution are critical aspects that need to be taken care of as content usage and volume of service grows.
- **No Offline Support:** The site does not support any offline features, and thus does not work well in poorly connected areas.

3.6 Use Cases

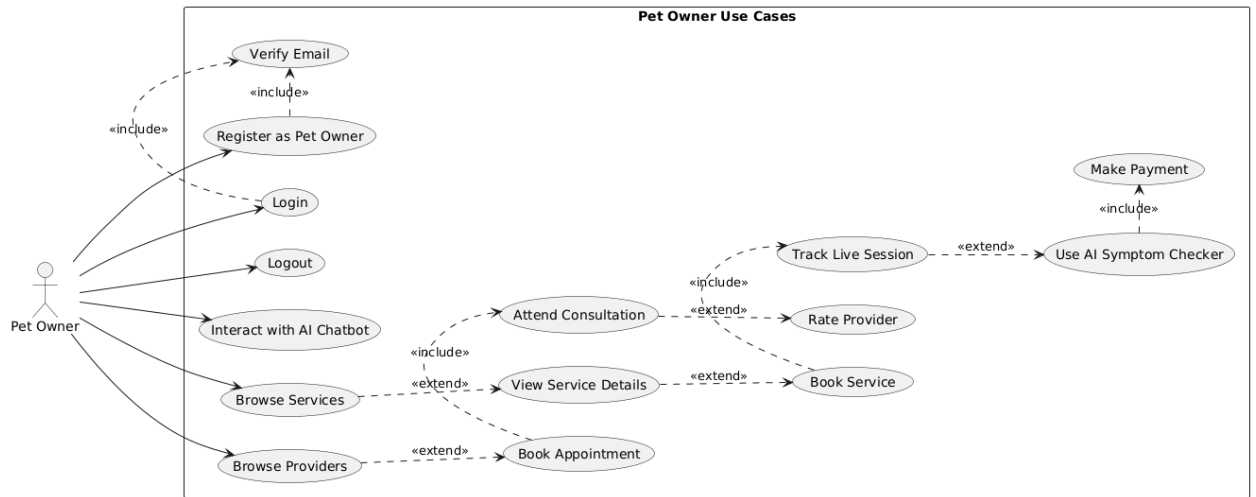


Figure 3.1: PetCare Hub – Pet Owner Use Case Diagram

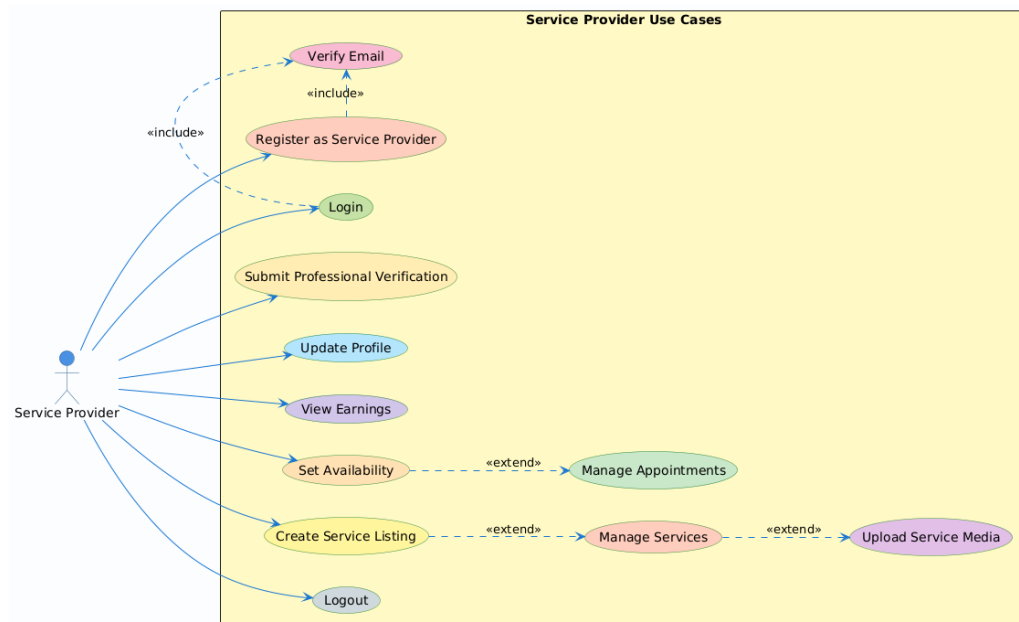


Figure 3.2: PetCare Hub – Service Provider Use Case Diagram

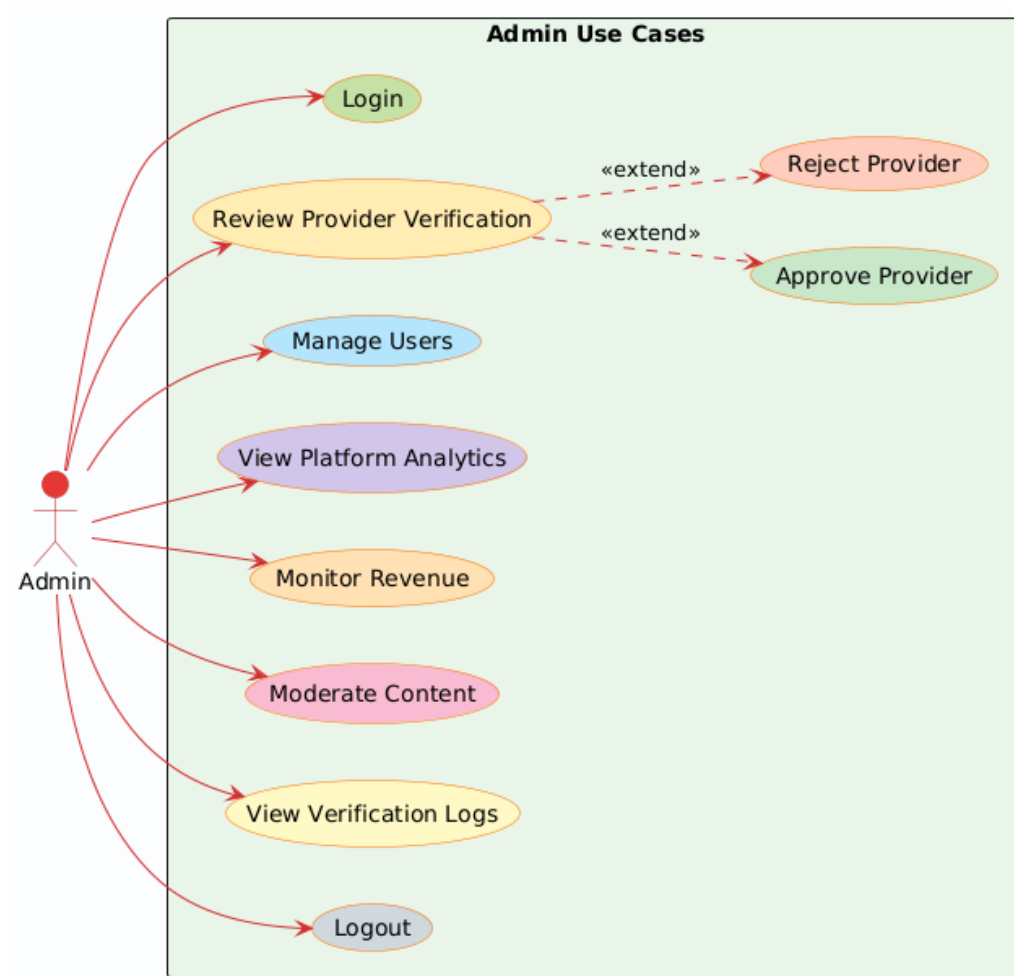


Figure 3.3: PetCare Hub – Admin Use Case Diagram

Table 3.1: Use Case Specification: UC1 - User Registration

Use Case ID	UC1
Use Case Name	User Registration
Actor(s)	User (Pet Owner, Service Provider)
Precondition	User is on registration page
Priority	High
Basic Flow	User registers an account by providing email, password, role selection (Pet Owner or Service Provider), and additional professional information if registering as a service provider
Detailed Flow	
Actor Actions	System Response
User fills registration form with email, password, role (Pet Owner/Service Provider)	System validates input format and requirements
User submits registration	System stores user data in Firebase Firestore and sends verification email via Resend
Alternative Flow (if any)	
Actor Actions	System Response
User provides existing email	System displays "Email already registered"
Invalid input (weak password, invalid email format)	System displays "Invalid data. Please check fields"
Service Provider selects role but doesn't provide required professional information	System displays "Please complete professional information"

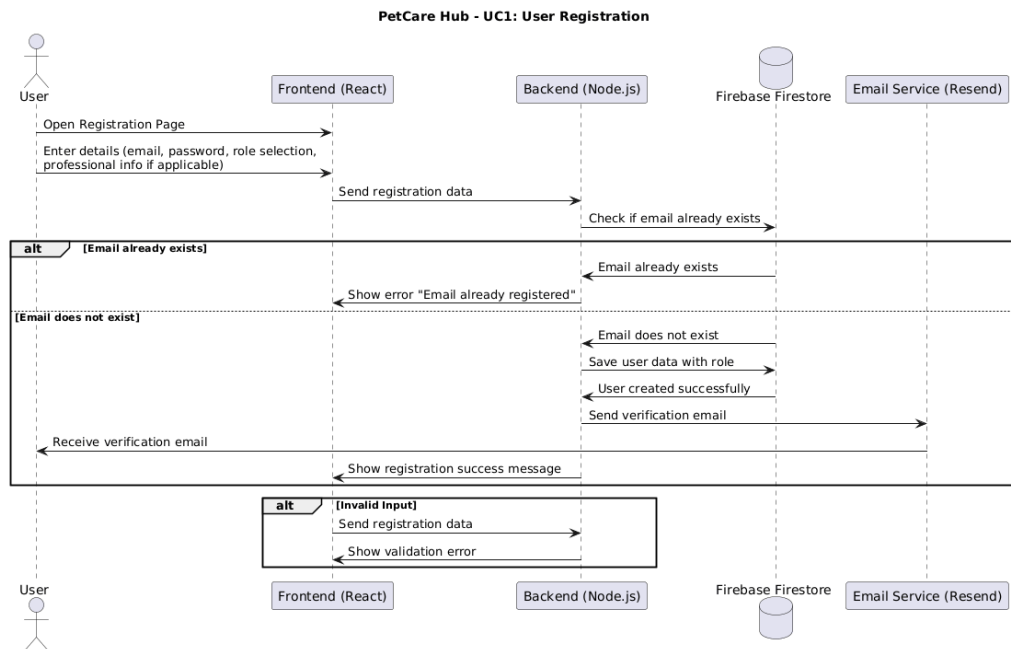


Figure 3.4: PetCare Hub – User Registration Sequence Diagram

Table 3.2: Use Case Specification: UC2 - User Login and Email Verification

Use Case ID	UC2
Use Case Name	User Login and Email Verification
Actor(s)	User (Pet Owner, Service Provider, Administrator)
Precondition	User has registered and verified email
Priority	High
Basic Flow	User logs in using email and password, system verifies credentials and email verification status, then redirects to appropriate dashboard based on user role
Detailed Flow	
Actor Actions	System Response
User enters email/password	System checks credentials and verifies email status
Valid credentials and verified email	User redirected to role-specific dashboard (Pet Owner/Service Provider/Admin)
Alternative Flow (if any)	
Actor Actions	System Response
Invalid credentials	System shows "Invalid email or password"
Email not verified	System shows "Please verify your email first"
Service Provider account not verified by admin	System shows "Account pending verification"

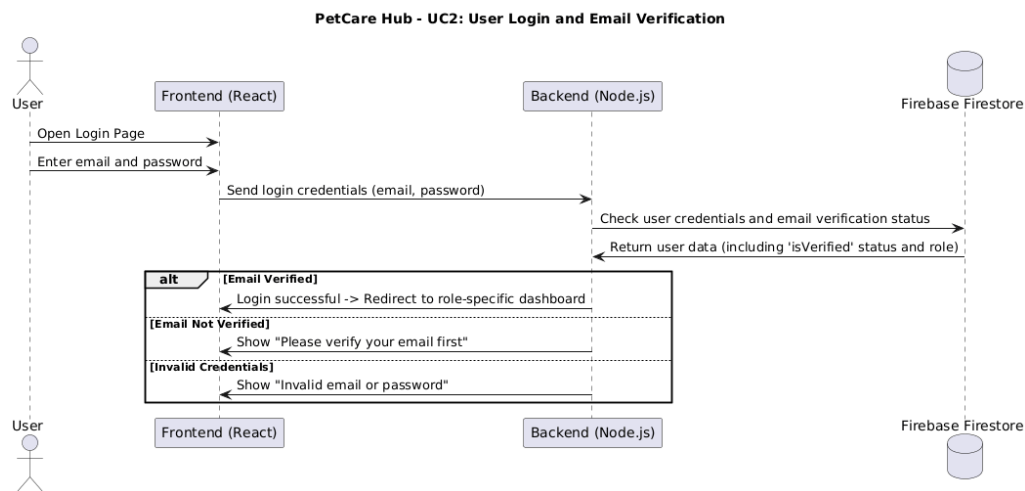


Figure 3.5: PetCare Hub – User Login and Email Verification Sequence Diagram

Table 3.3: Use Case Specification: UC3 - Service Provider Submit Verification Documents

Use Case ID	UC3
Use Case Name	Service Provider Submit Verification Documents
Actor(s)	Service Provider
Precondition	Service Provider is logged in and has not been verified yet
Priority	High
Basic Flow	Service Provider submits certification documents and professional information for admin verification
Detailed Flow	
Actor Actions	System Response
Service Provider uploads certification documents and fills professional details	System uploads documents to Firebase Storage and saves verification request
Alternative Flow (if any)	
Actor Actions	System Response
Invalid document format	System shows "Only PDF/JPG/PNG files allowed for certificates"
Incomplete professional information	System shows "Please complete all required fields"
Document upload fails	System shows "Document upload failed, please try again"

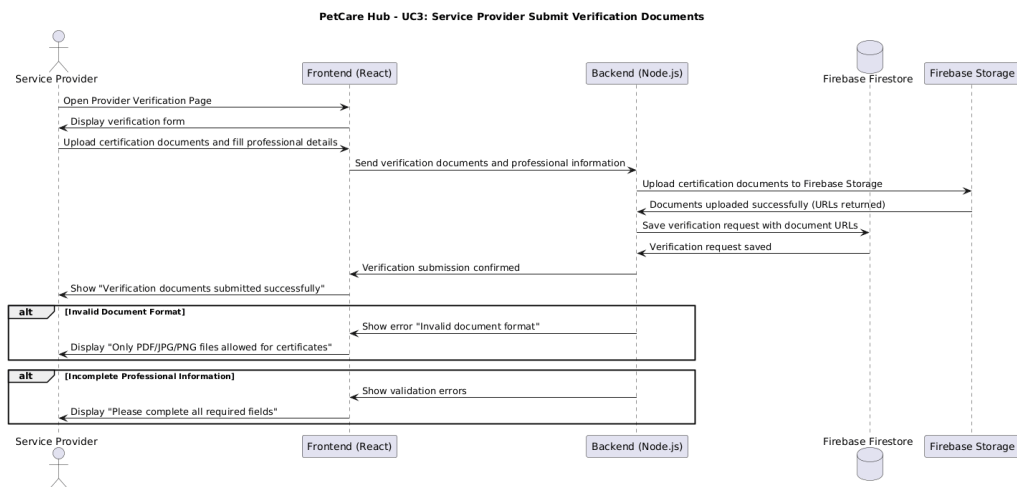


Figure 3.6: PetCare Hub – Service Provider Submit Verification Documents Sequence Diagram

Table 3.4: Use Case Specification: UC4 - Pet Owner Browse Services

Use Case ID	UC4
Use Case Name	Pet Owner Browse Services
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in
Priority	Medium
Basic Flow	Pet Owner browses available pet care services created by verified service providers
Detailed Flow	
Actor Actions	System Response
Pet Owner opens services page	System displays list of available pet care services with provider details
Alternative Flow (if any)	
Actor Actions	System Response
Pet Owner filters services by category	System shows filtered results (Veterinary, Grooming, Training, Pet Sitting, etc.)
Pet Owner searches for specific services	System displays matching services based on search criteria
No services available	System shows "No services available at the moment"

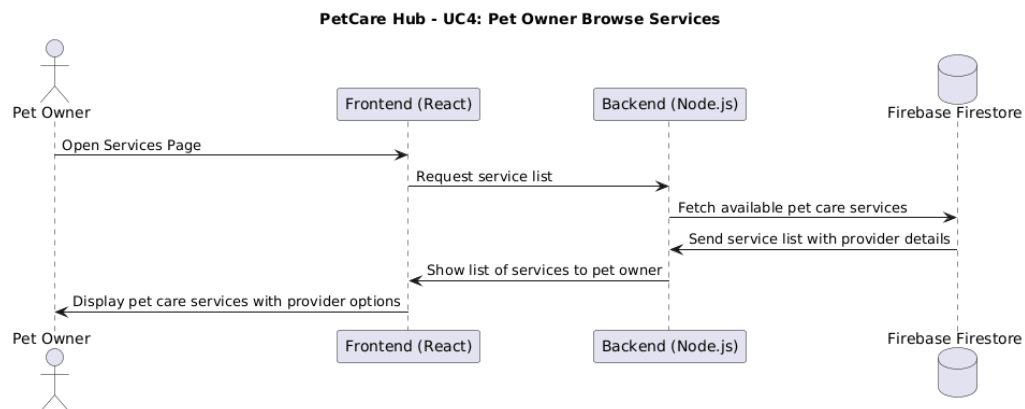


Figure 3.7: PetCare Hub – Pet Owner Browse Services Sequence Diagram

Table 3.5: Use Case Specification: UC5 - Pet Owner Book Service

Use Case ID	UC5
Use Case Name	Pet Owner Book Service
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in and viewing service details
Priority	High
Basic Flow	Pet Owner books a pet care service using Stripe payment processing
Detailed Flow	
Actor Actions	System Response
Pet Owner clicks "Book Service" button	System initiates Stripe payment process
Pet Owner completes payment details	System processes payment and confirms booking
Alternative Flow (if any)	
Actor Actions	System Response
Payment fails or is declined	System shows "Payment failed, please try again"
Pet Owner already booked the service	System shows "You already have an active booking for this service"
Service is no longer available	System shows "Service no longer available"

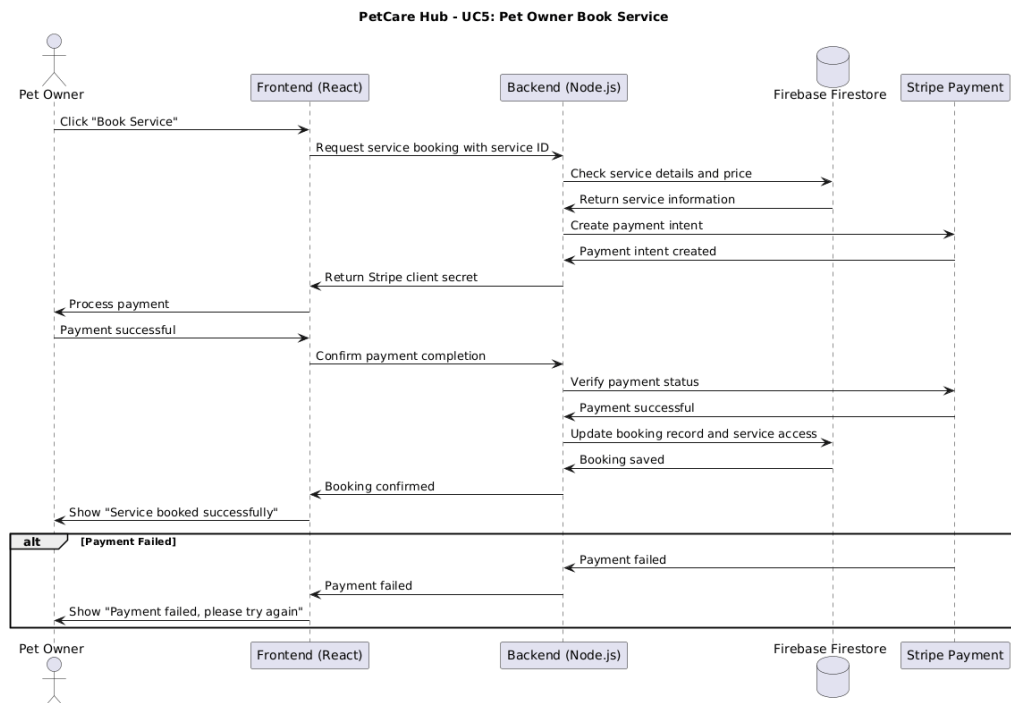


Figure 3.8: PetCare Hub – Pet Owner Book Service Sequence Diagram

Table 3.6: Use Case Specification: UC6 - Service Provider Create Service

Use Case ID	UC6
Use Case Name	Service Provider Create Service
Actor(s)	Verified Service Provider
Precondition	Service Provider is logged in and verified by admin
Priority	High
Basic Flow	Verified service provider creates a new pet care service with details and pricing
Detailed Flow	
Actor Actions	System Response
Service Provider fills service creation form	System validates provider verification status
Service Provider submits service details	System saves service and makes it available for pet owners
Alternative Flow (if any)	
Actor Actions	System Response
Service Provider not verified by admin	System shows "Account verification required"
Incomplete service information	System shows "Please complete all required fields"
Invalid pricing information	System shows "Please enter valid price"

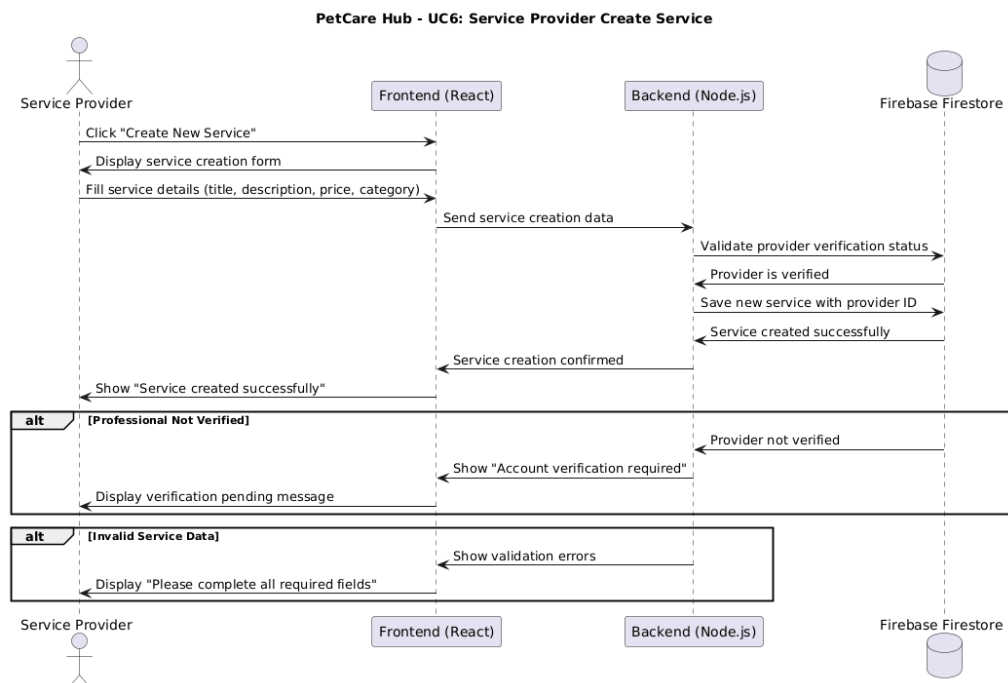


Figure 3.9: PetCare Hub – Service Provider Create Service Sequence Diagram

Table 3.7: Use Case Specification: UC7 - Pet Owner Upload Pet Profile Media

Use Case ID	UC7
Use Case Name	Pet Owner Upload Pet Profile Media
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in and has created a pet profile
Priority	Medium
Basic Flow	Pet Owner uploads pet photos and health documents to their pet's profile, system stores files securely
Detailed Flow	
Actor Actions	System Response
Pet Owner selects pet profile and uploads image/document file	System saves file to Firebase Storage and stores metadata in Firestore
Alternative Flow (if any)	
Actor Actions	System Response
Invalid file format	System shows "Only JPG, PNG, and PDF files allowed"
File size exceeds limit	System shows "File too large. Maximum size exceeded"
Upload fails	System shows "File upload failed, please try again"
Storage limit reached	System shows "Storage limit reached. Please delete old files"

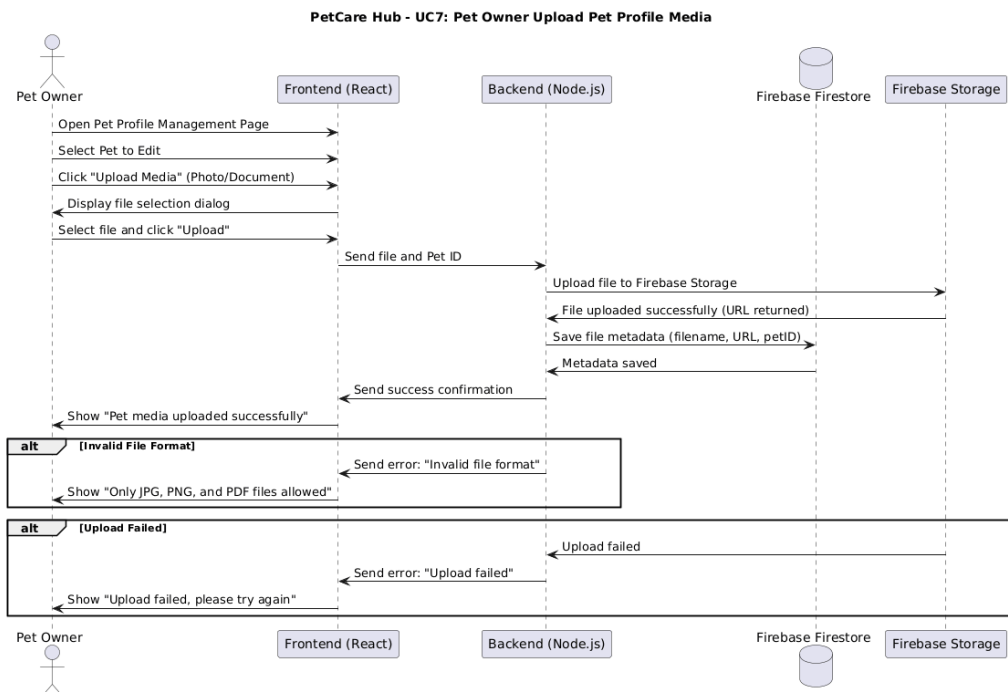


Figure 3.10: PetCare Hub – Pet Owner Upload Pet Profile Media Sequence Diagram

Table 3.8: Use Case Specification: UC8 - Pet Owner Use AI Symptom Checker

Use Case ID	UC8
Use Case Name	Pet Owner Use AI Symptom Checker
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in and has a pet profile
Priority	High
Basic Flow	Pet Owner submits pet symptoms to AI disease predictor, receives predicted disease with severity and urgency recommendations
Detailed Flow	
Actor Actions	System Response
Pet Owner selects pet and fills symptom form	System validates input data
Pet Owner submits symptoms	System sends data to ML API (Render), receives disease prediction with severity, urgency, and recommendations
Alternative Flow (if any)	
Actor Actions	System Response
Incomplete symptom data	System shows "Please complete all required fields"
ML API unavailable	System shows "Service temporarily unavailable, please try again"
No prediction available	System shows "Unable to predict. Please consult a veterinarian"

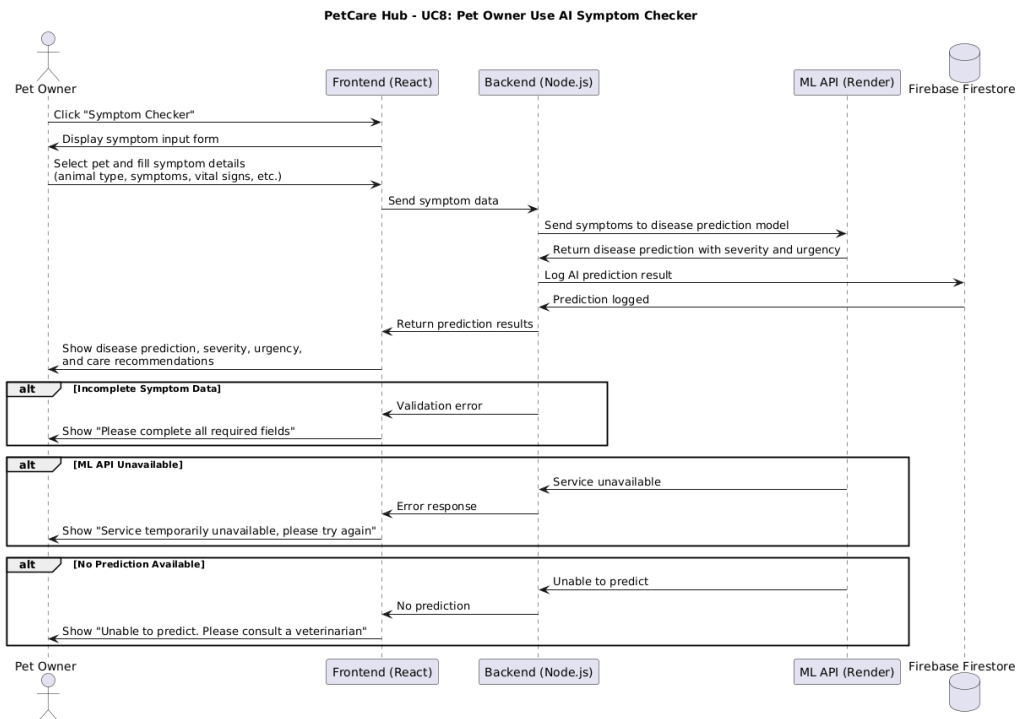


Figure 3.11: PetCare Hub – Pet Owner Use AI Symptom Checker Sequence Diagram

Table 3.9: Use Case Specification: UC9 - Pet Owner Track Live Service Session (GPS)

Use Case ID	UC9
Use Case Name	Pet Owner Track Live Service Session (GPS)
Actor(s)	Pet Owner
Precondition	Pet Owner has an active booking with live tracking enabled
Priority	Medium
Basic Flow	Pet Owner views real-time GPS location of service provider and pet during active service session on interactive map
Detailed Flow	
Actor Actions	System Response
Pet Owner opens active booking	System displays live map with current location using Open-StreetMap/Leaflet
Pet Owner views real-time movement	System updates location in real-time via Firebase Realtime Database
Alternative Flow (if any)	
Actor Actions	System Response
Service not yet started	System shows "Service has not started yet"
GPS tracking unavailable	System shows "Location tracking temporarily unavailable"
Geofence violation detected	System shows alert "Pet has left safe zone"
Service session ended	System shows "Service completed. View route history"

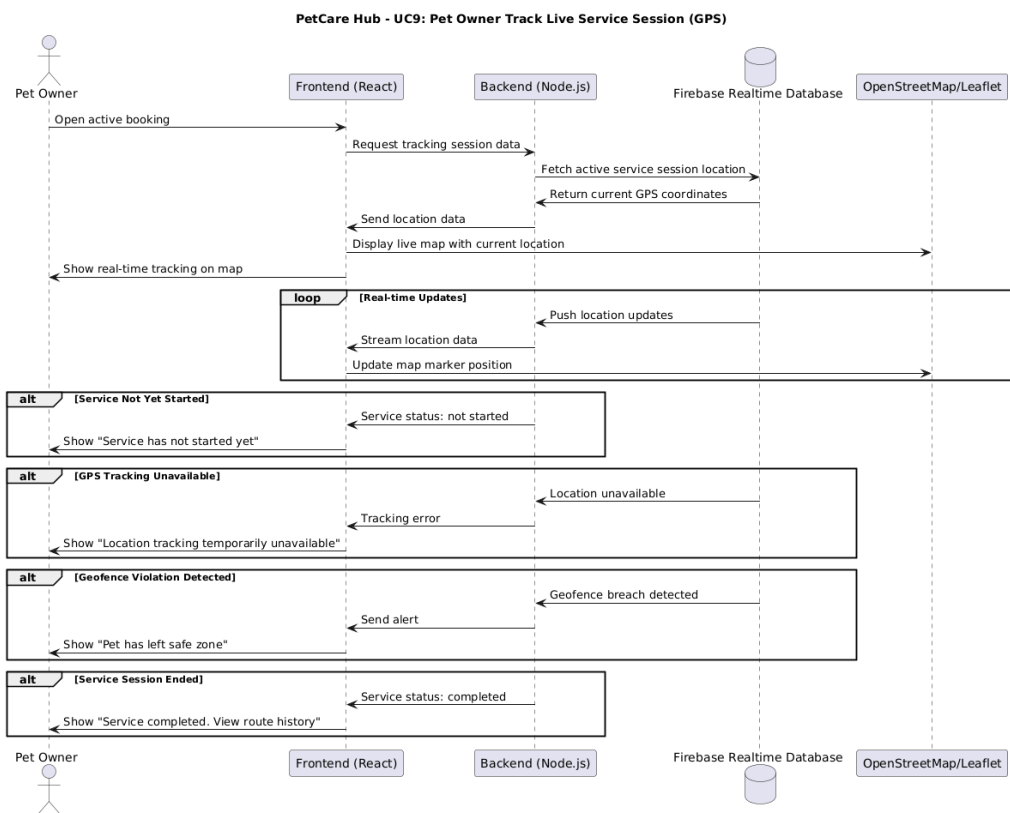


Figure 3.12: PetCare Hub – Pet Owner Track Live Service Session (GPS) Sequence Diagram

Table 3.10: Use Case Specification: UC10 - Pet Owner Interact with AI Chatbot

Use Case ID	UC10
Use Case Name	Pet Owner Interact with AI Chatbot
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in
Priority	High
Basic Flow	Pet Owner interacts with AI chatbot for pet care advice, service information, and platform assistance
Detailed Flow	
Actor Actions	System Response
Pet Owner asks question about pet care or services	System processes question using Gemini API and returns AI response
Alternative Flow (if any)	
Actor Actions	System Response
Chatbot API unavailable	System shows "Chatbot temporarily unavailable"
Invalid or inappropriate question	System shows "Please ask pet care-related questions"

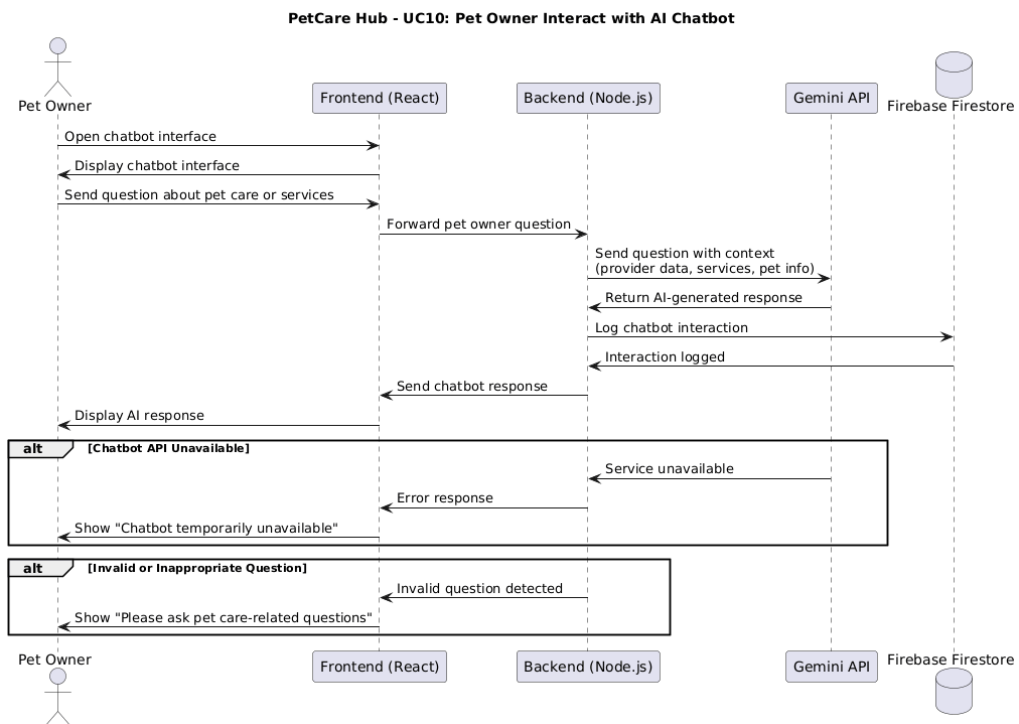


Figure 3.13: PetCare Hub – Pet Owner Interact with AI Chatbot Sequence Diagram

Table 3.11: Use Case Specification: UC11 - Pet Owner Manage Pet Profile

Use Case ID	UC11
Use Case Name	Pet Owner Manage Pet Profile
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in
Priority	Medium
Basic Flow	Pet Owner creates, updates, or deletes pet profiles including details like name, breed, age, medical history, and photos
Detailed Flow	
Actor Actions	System Response
Pet Owner opens pet management page	System displays list of existing pets
Pet Owner creates/updates pet profile with details	System validates input and saves pet data to Firebase Firestore
Alternative Flow (if any)	
Actor Actions	System Response
Incomplete pet information	System shows "Please complete all required fields"
Invalid data format	System shows "Please check input format"
Pet Owner deletes pet profile	System shows confirmation dialog and removes pet data

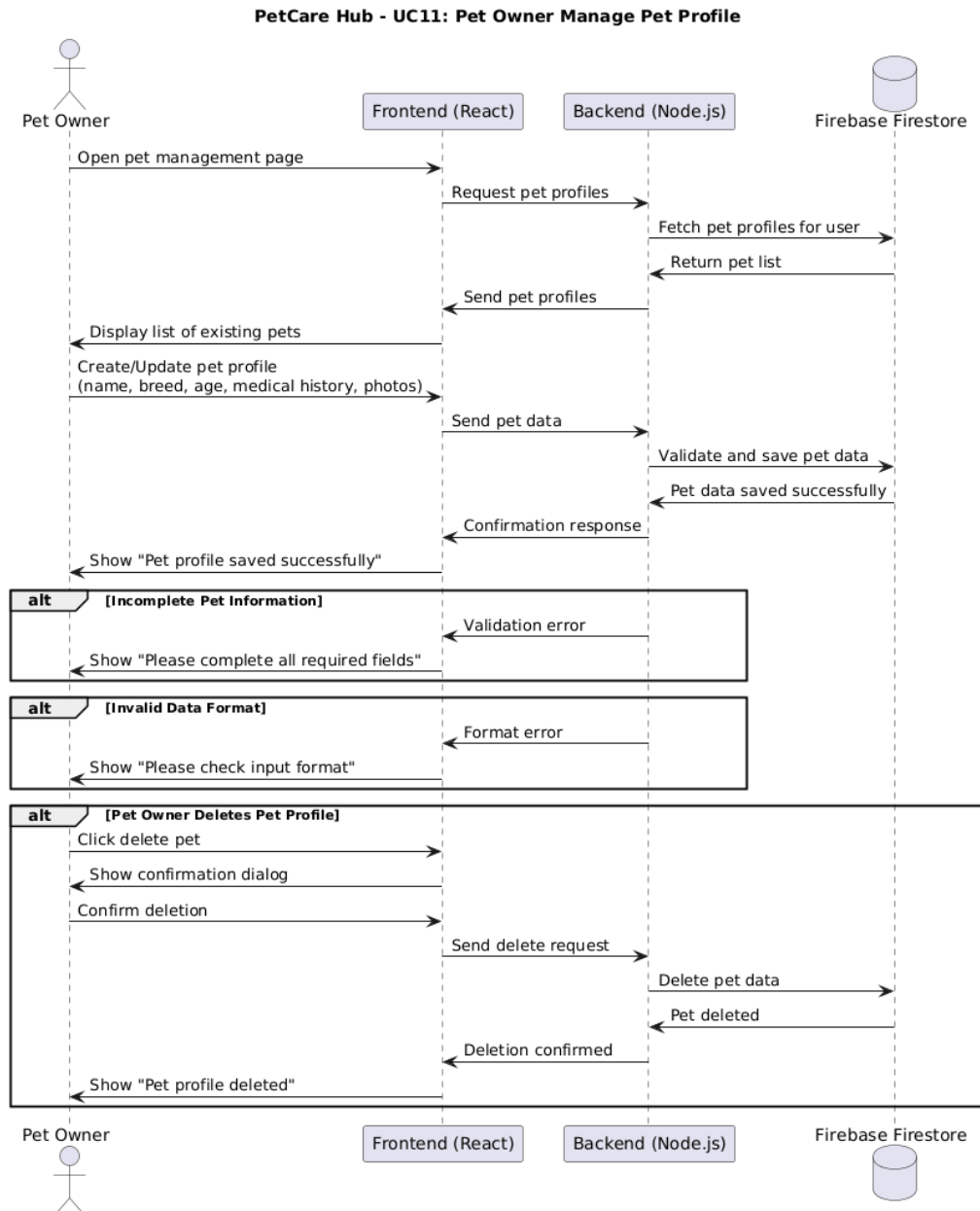


Figure 3.14: PetCare Hub – Pet Owner Manage Pet Profile Sequence Diagram

Table 3.12: Use Case Specification: UC12 - Service Provider View Earnings

Use Case ID	UC12
Use Case Name	Service Provider View Earnings
Actor(s)	Service Provider
Precondition	Service Provider is logged in and verified
Priority	Medium
Basic Flow	Service Provider views earnings dashboard showing total revenue, completed bookings, and payment history
Detailed Flow	
Actor Actions	System Response
Service Provider opens earnings/analytics page	System displays earnings summary with total revenue and booking statistics
Service Provider views payment history	System shows list of completed payments with amounts and dates
Alternative Flow (if any)	
Actor Actions	System Response
No completed bookings yet	System shows "No earnings data available yet"
Payment data unavailable	System shows "Unable to load earnings data. Please try again"

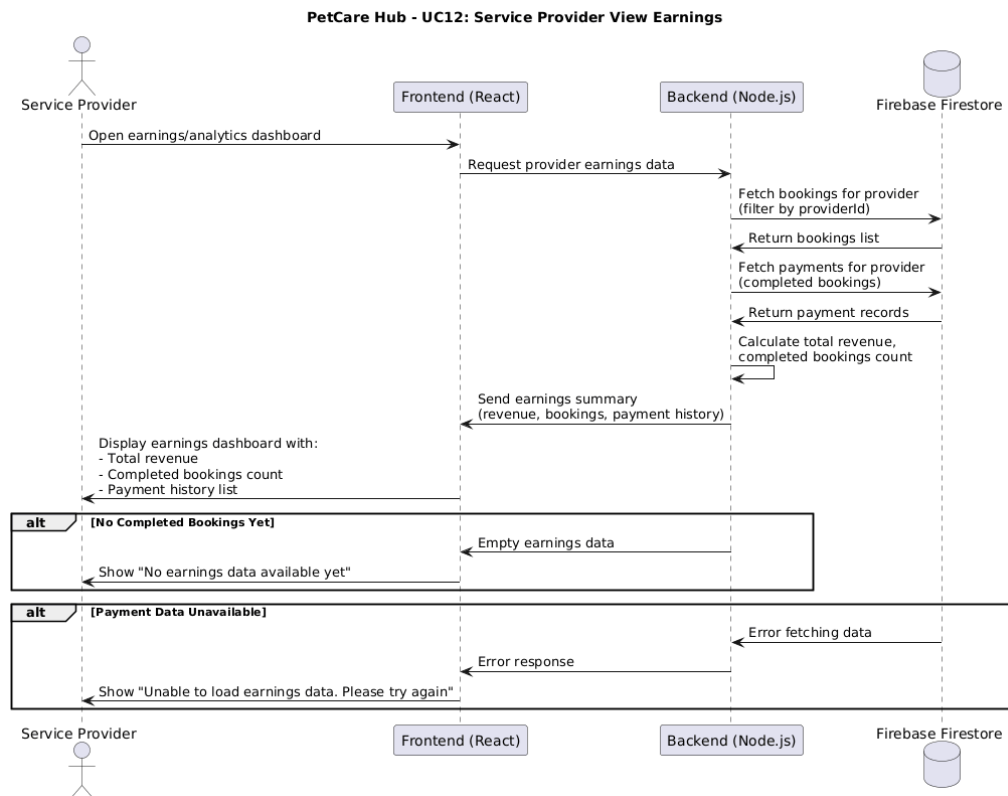


Figure 3.15: PetCare Hub – Service Provider View Earnings Sequence Diagram

Table 3.13: Use Case Specification: UC12 - Pet Owner Leave Review/Rating

Use Case ID	UC12
Use Case Name	Pet Owner Leave Review/Rating
Actor(s)	Pet Owner
Precondition	Pet Owner is logged in and has completed a service booking
Priority	Medium
Basic Flow	Pet Owner submits a rating (1-5 stars) and written review for a completed service
Detailed Flow	
Actor Actions	System Response
Pet Owner selects completed booking	System displays review form
Pet Owner submits rating and review text	System saves review to Firestore and triggers automatic rating recalculation for service
Alternative Flow (if any)	
Actor Actions	System Response
Pet Owner already reviewed this service	System shows "You have already reviewed this service"
Invalid rating (not 1-5 stars)	System shows "Please select a valid rating (1-5 stars)"
Review text too short or empty	System shows "Please provide review feedback"

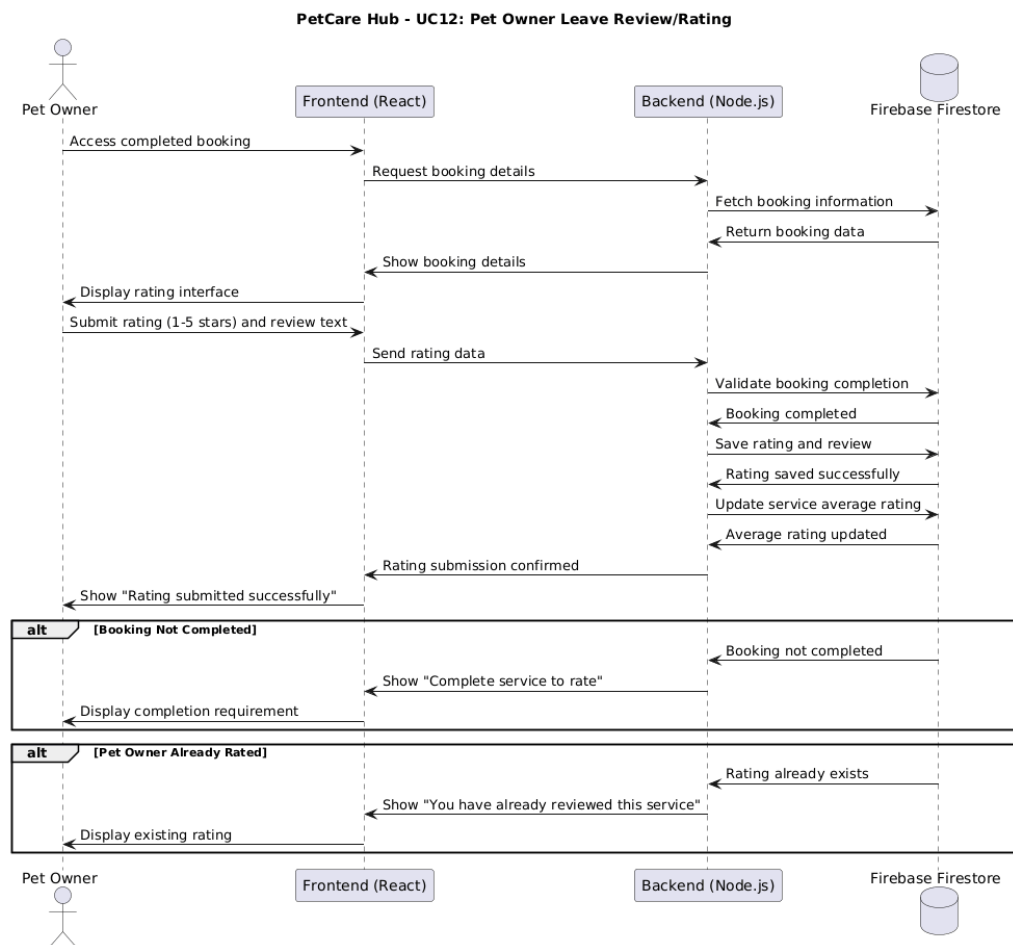


Figure 3.16: PetCare Hub – Pet Owner Leave Review/Rating Sequence Diagram

Chapter 4

Design

PetCare Hub is built with a modular cloud native architecture that ensures seamless interaction between pet owners and service providers. The main objective is to provide a smooth, safe experience of integrating service discovery, AI-enabled health tools, real-time GPS tracking, booking management and payment processing - all together and within a unified and responsive platform that focuses on reliability, scalability and user trust [1].

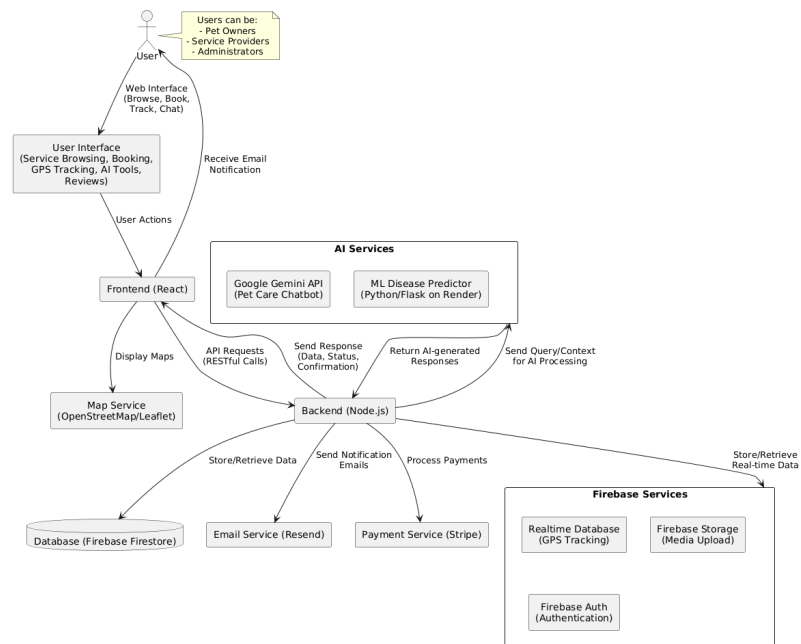


Figure 4.1: PetCare Hub - System Architecture Diagram

4.1 Overview

The system is based on cloud native client-server architecture with five major parts to provide seamless user experience for booking of services, AI powered health tools, real time tracking and secure payments [2].

4.1.1 Frontend (React)

The user interface is web-based which is responsible for registration, login, service browsing/booking, pet profile management, gps tracking visualization, interaction with AI chatbot and review submission. It communicates with the backend using secure calls to the backend using the RESTFul API calls [19].

4.1.2 Backend (Node.js)

The backend is used for running the core business logic of the application managing the user authentication, verification of the providers, service or booking management, Stripe payment, real-time locations and AI coordination. Deployed via Render and Vercel, it is a primary gateway to all the external services [22].

4.1.3 Database (Firebase Firestone)

This NoSQL database is responsible for persistent storage of user accounts (role based access), profile of pets, service listing, bookings, payment history, reviews and AI interaction logs. firebase realtime database used for the live gps tracking data [26].

4.1.4 AI Services (Google Gemini API/ML Disease Predictor)

These intelligent services assist the users:

Google Gemini API: Serves as the global pet care assistant that provides general advice and answers to queries in the platform [8].

ML Disease Predictor (Python/Flask on Render): Analyzes symptoms for a pet using a model that has been trained (Random Forest) and the results are disease predictions with severity recommendations [23].

4.1.5 Email Service (Resend)

The backend is used for automated, event-triggered emails sent using Resend: registration, booking confirmations, payment receipts and provider verification updates [14].

4.2 Component Interaction Flow

Components of PetCare Hub work together by well-defined interfaces, to provide a seamless user experience.

4.2.1 User Interaction

Users use the frontend developed in ReactJS to register, browse services, book appointments, track their pets using GPS, use AI tools, profile management, and submit reviews [16].

4.2.2 Frontend-Backend Communication

The frontend makes secure requests using Restful API to the Node.js backend as authentication, service bookings, payments, GPS updates, AI interactions, and provider verification [15].

4.2.3 Backend Processing

The backend is responsible for authentication, role-based access control, payment processing through Stripe, managing real-time information from GPS through the use of the Firebase Realtime Database, and routing AI queries to the appropriate services.

4.2.4 AI Service Interaction

Google Gemini API is used for the general pet care queries. The ML Disease Predictor takes the symptoms and returns predictions, with severity recommendations. Both services return the response using the backend [7].

4.2.5 Backend to DB Communication

Fire base Firestore for User Accounts, pet profiles, services, bookings, payments, reviews, and AI logs Firebase Realtime Database is used to manage the data of live GPS tracking.

4.2.6 Email Notification

The backend is set up so that Resend will be used to send out automated emails for registration, bookings, payments, and verification updates.

4.2.7 Displaying Data to User

The backend is sending role-specific information to the frontend which presents services, bookings, live GPS maps, AI responses, and dashboards in a pet care-centric interface [10].

4.3 Design Constraints

Several design constraints were taken into consideration at the time of developing the PetCare Hub, in order to establish practicality, security and efficiency.

4.3.1 Web-Based Interface Only

The platform is a react web application and does not have any native mobile or desktop applications hence requires modern web browsers and internet connection.

4.3.2 AI Service Limitations

Google Gemini API and ML Disease Predictor has rate limits which may effect the response times due to heavy traffic. The ml model has some data formats and computational power requirement [6].

4.3.3 Email Delivery Limitations

Email notifications through Resend are dependent on external services of sending emails, and may experience delays or filtering by spam blockers: Time critical communications such as booking confirmations will be affected.

4.3.4 File Format Restrictions

For security and processing efficiency, pet media uploads only allow for JPG, PNG and PDF file formats. Other formats are still not supported.

4.3.5 Provider Verification Process

There is a bottleneck in case of high registration periods with manual administrative approval. Automated authentication of credentials and integration with professional licensing databases is not applied yet [11].

4.3.6 Payment Processing Dependency

Payments is all done using Stripe only. Stripe API failures or changes could impact on bookings and transactions. Alternative ways of paying are not currently supported [18].

4.3.7 Session Management and Authentication

Firestore Authentication using JWT token for single session authentication. Multi factor authentication and OAuth social login is not implemented [15].

4.3.8 Constraints of Database Design

NoSQL document based structure of the database is taken care by the Firestore. While, there is the ability to scale up the system, complex relational queries can be optimized and there are some limitations to the reporting capabilities [26].

4.3.9 AI Content Boundaries

AI tools are a good source of guidance but can't replace veterinary diagnosis and deal with emergency situations. Users of this service that need urgent care should contact veterinary professionals directly [9].

4.3.10 Scalability Considerations

Manual verification of providers and real-time tracking via GPS can present architecture optimization difficulties in handling enormous concurrent user volumes and data throughput [17].

4.4 Design Methodology

PetCare Hub's architecture is object-oriented which allow to develop it modular fashion with well defined responsibilities. This strategy makes maintenance an easy process, help in making the system more scalable, helps in supporting the variety of users (Pet Owners, Service Providers, Administrators) and integration with third-party services (AI Tools, Payments, GPS Tracking, Email Notifications) without affecting the security and verifying process [25].

4.4.1 Development Method

Agile (Iterative and Incremental) approaches to development was used. The project was broken down into doable modules - user management, role based access control, provider verification workflows management, service and booking management, integration of AI (Gemini chatbot, machine learning based disease predictor), real-time GPS tracking, payment processing, review systems and email notifications. Each module was developed separately, test and integrated separately.

There were important advantages of this approach:

- Continuous testing was used to make sure that important aspects such as provider verification, AI health tools and GPS tracking works correctly before integrating.
- Early bug finding - In particular for components of security-critical components such as payment processing and real-time location data.

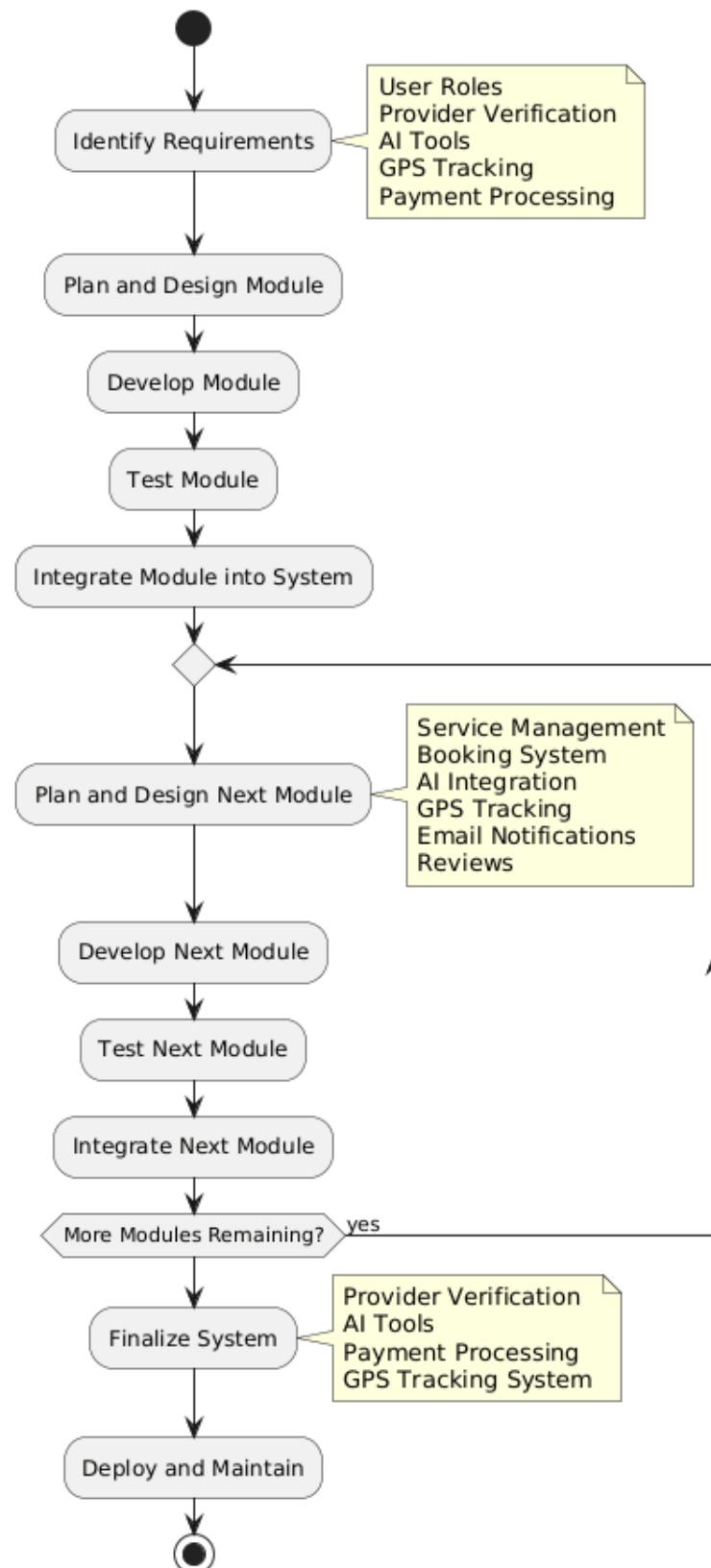


Figure 4.2: PetCare Hub Development Model Diagram

4.4.2 Object-Oriented Design

Every component of PetCare Hub - user management, service provider verification, booking system, AI chatbot, payment processing, geofencing & notifications are considered to be an independent module with encapsulated data and behaviour. This modular approach means that teams can work on different parts of the platform and have the consistency across the platform.

4.4.3 Use of UML

Design diagrams are done using Unified Modeling Language (UML):

- Use Cases Diagrams: Illustrated showing the communication between the users (Pet Owners, Service Provider, Admins) and the system functionality.
- Sequence Diagrams: Component Interactions of Showtime Booking, Payments, Geofencing and Ai Chatbot Processes.
- Component Diagrams: Show architecture of system and external integrations (stripe, firebase, google maps, socket.io).

4.4.4 Design Process

- Identify system requirements - major user flows
- Breaking down system to modules (authentication / providers verification / booking / payments /geofencing/ ai chatbot)
- Construct sequence diagrams of complicated flowcharts
- Define User Roles & User Use Cases
- Design architecture using external integrated services
- Refine based on feedback & need of pet care industry

4.4.5 Conventions and Guidelines

- Design of a Restful API- with proper authentication
- Uniform naming of Code (camelCase in JavaScript/TypeScript)
- Standard Symbols of Diagrams UML
- Loosely coupled & tightly cohesive modules
- Secure process of verification of service provider

- Contextual responses of AI chatbot in Pet Care
- Payment Handling Compliant to PCI
- Professional communication E-Mail/Push notifications
- Geofencing Protocols - with an Eye for Safety [12]

4.5 Workflow Diagram

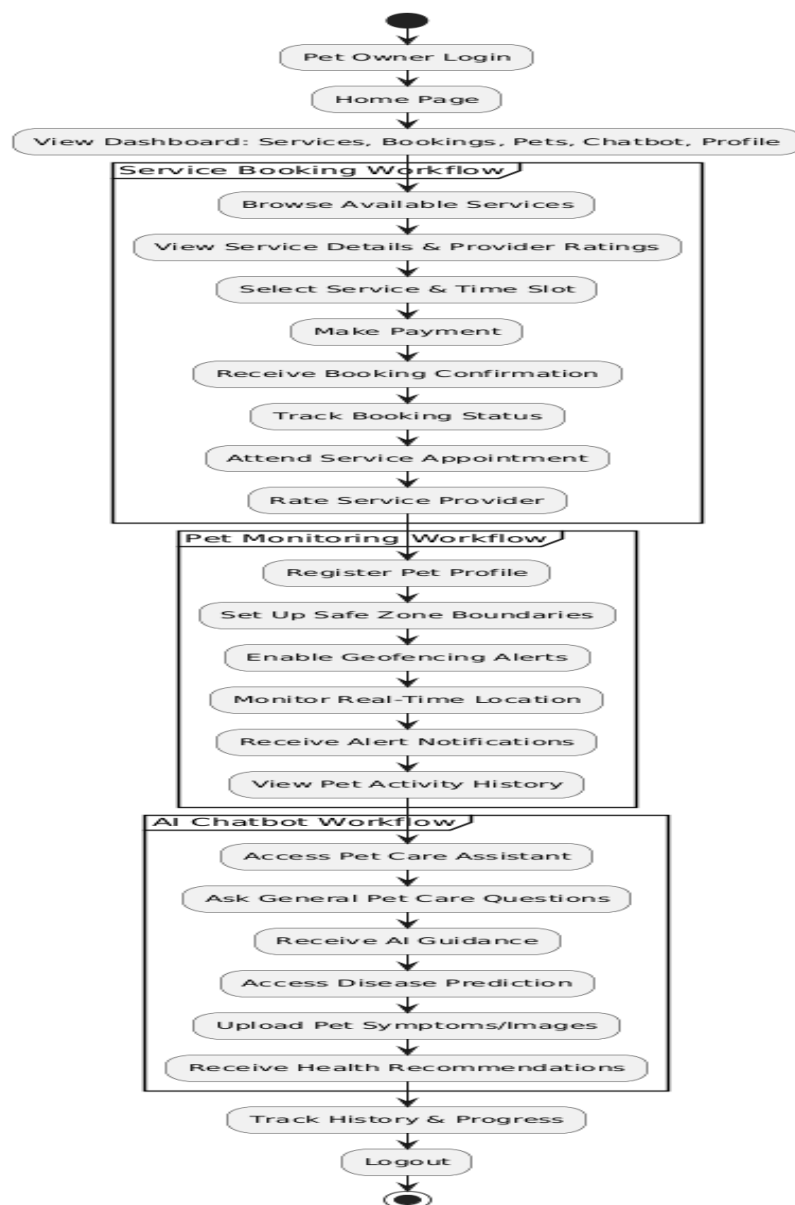


Figure 4.3: Pet Owner Workflow Diagram - PetCare Hub

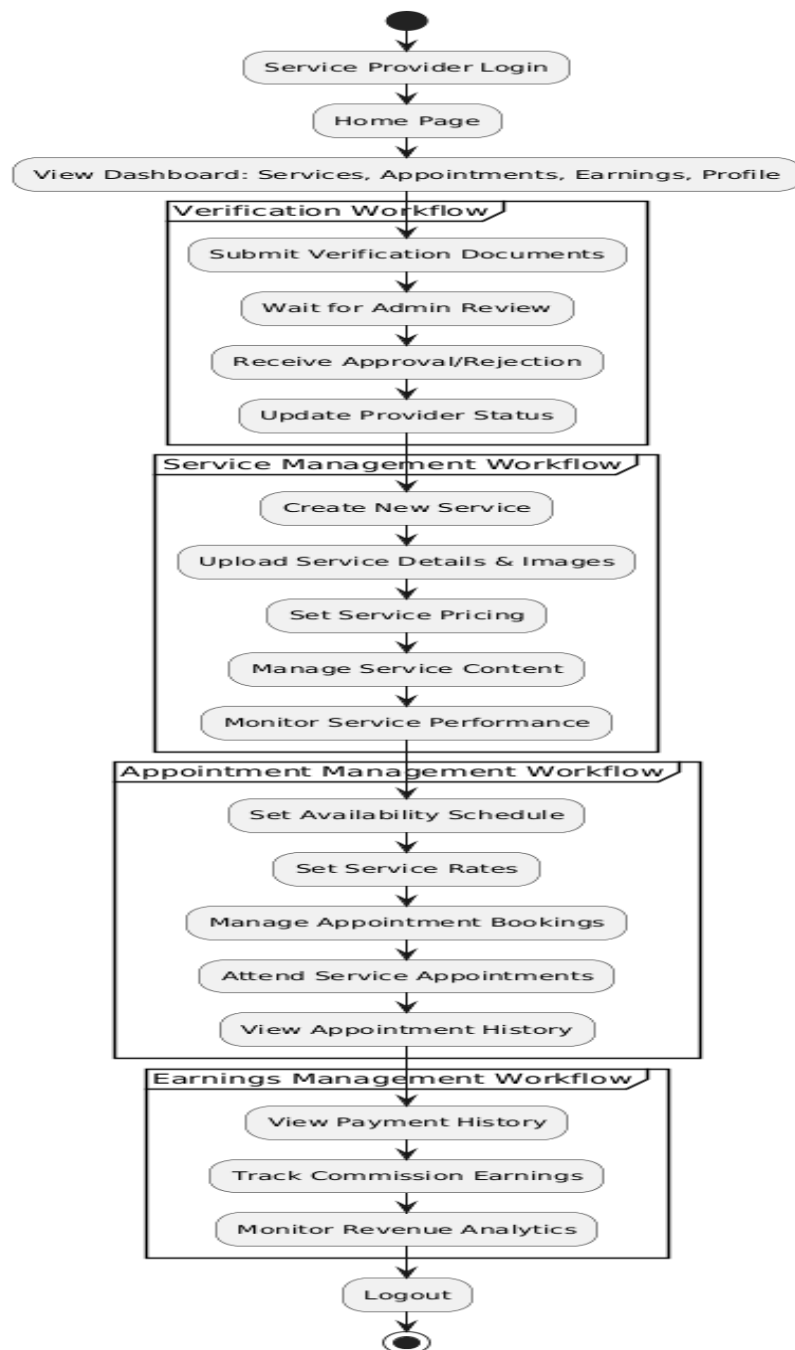


Figure 4.4: Service Provider Workflow Diagram - PetCare Hub

4.6 Sequence Diagram

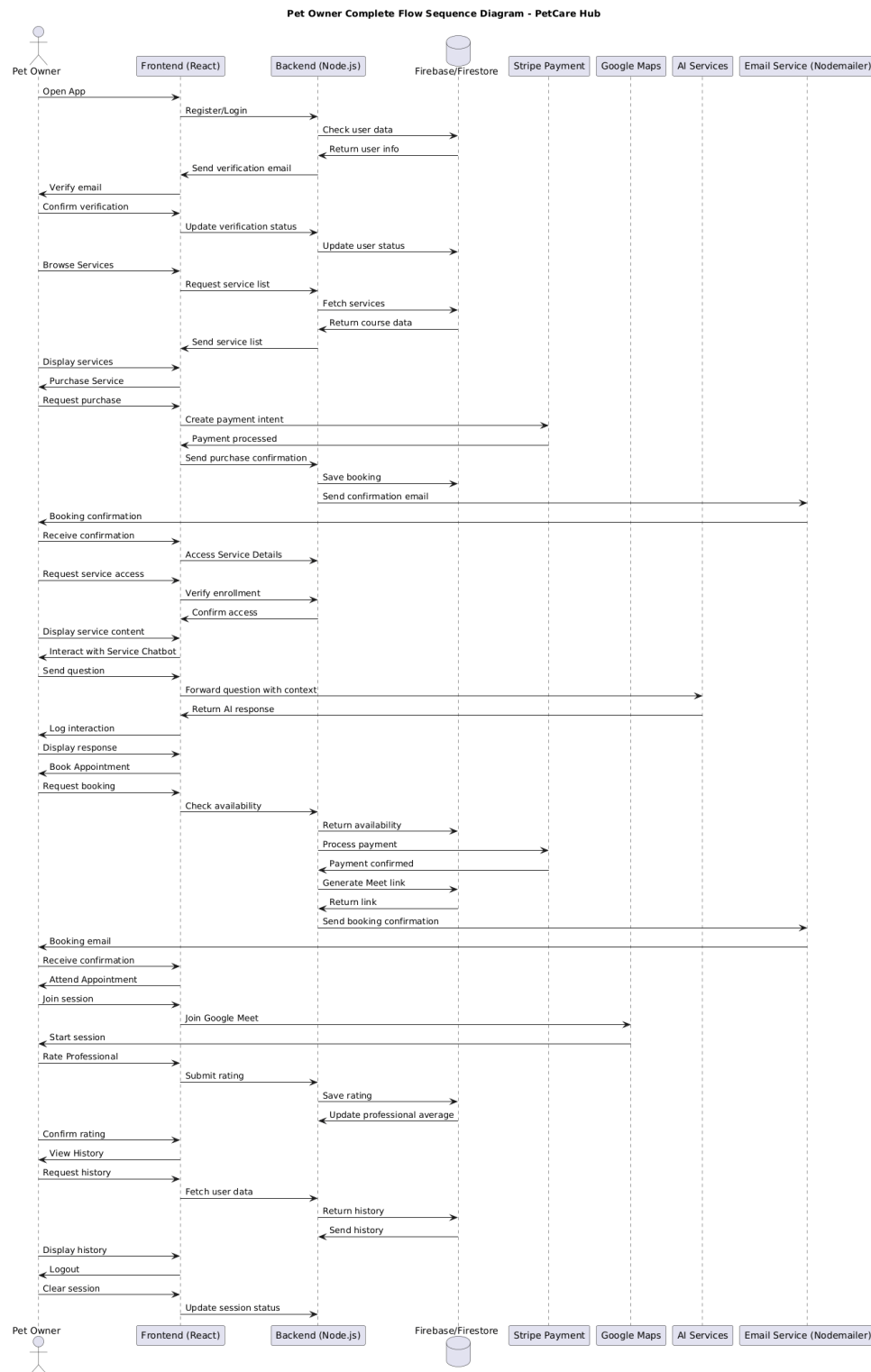


Figure 4.5: Pet Owner Complete Flow Sequence Diagram - PetCare Hub

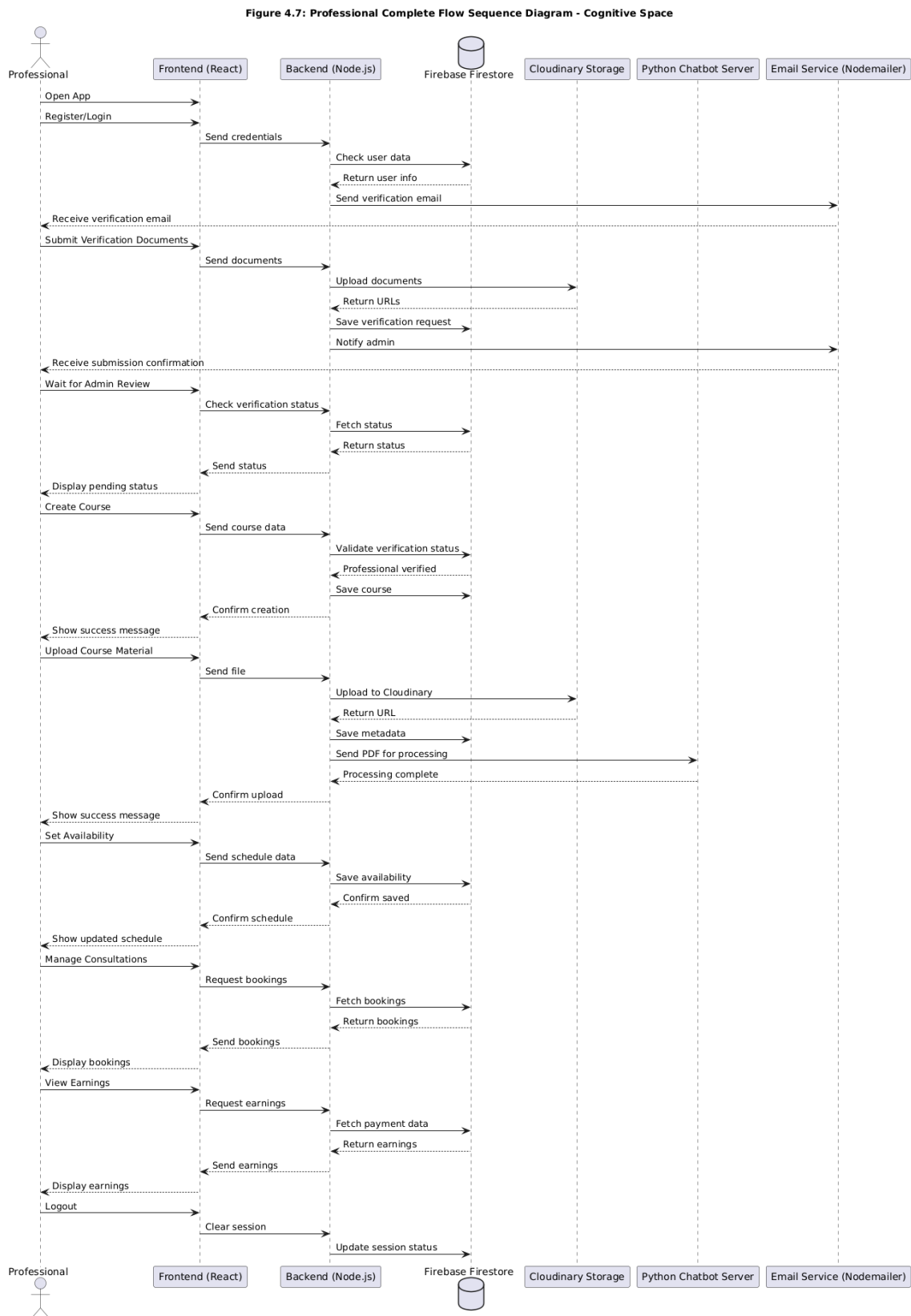


Figure 4.6: Service Provider Complete Flow Sequence Diagram - PetCare Hub

4.7 High Level Architecture

High level architecture refers to diagrams that illustrate the operation of various parts of the system combined together by abstracting away complex logic. This way only shows user and system interaction. This is useful in order to describe the system to non-developers such as stakeholders. Below are the following high-level architecture diagrams:

4.7.1 Activity Diagram

The following activity diagram illustrates the workflow of PetCare Hub starting from browsing pet care services all the way till final service completion and rating.

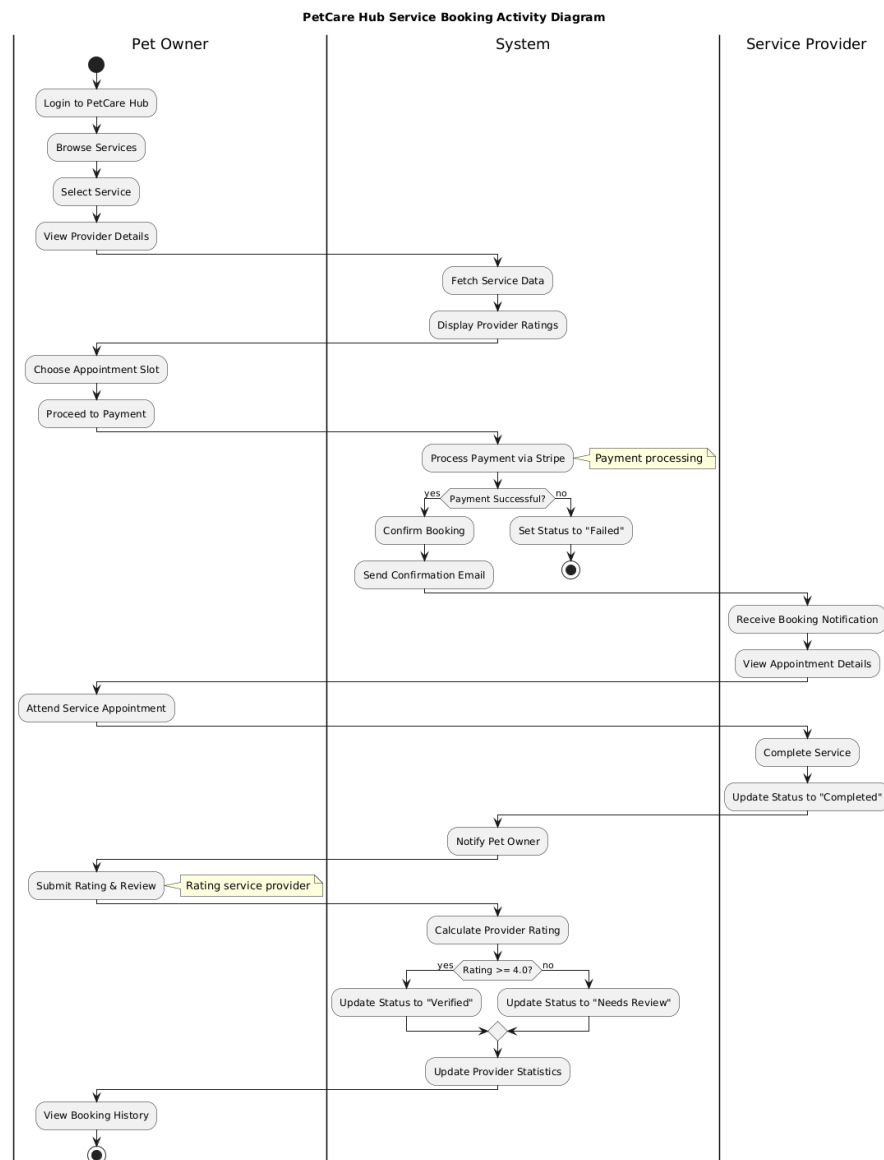


Figure 4.7: Service Provider Complete Flow Sequence Diagram - PetCare Hub

4.8 Low Level Architecture

Low-level architecture explains the detailed interaction between each of the system components. Here are the following low level diagrams.

4.8.1 ER Diagram

The following ER Diagram highlights the entities in PetCare Hub and their attributes and the relationship between each entity.

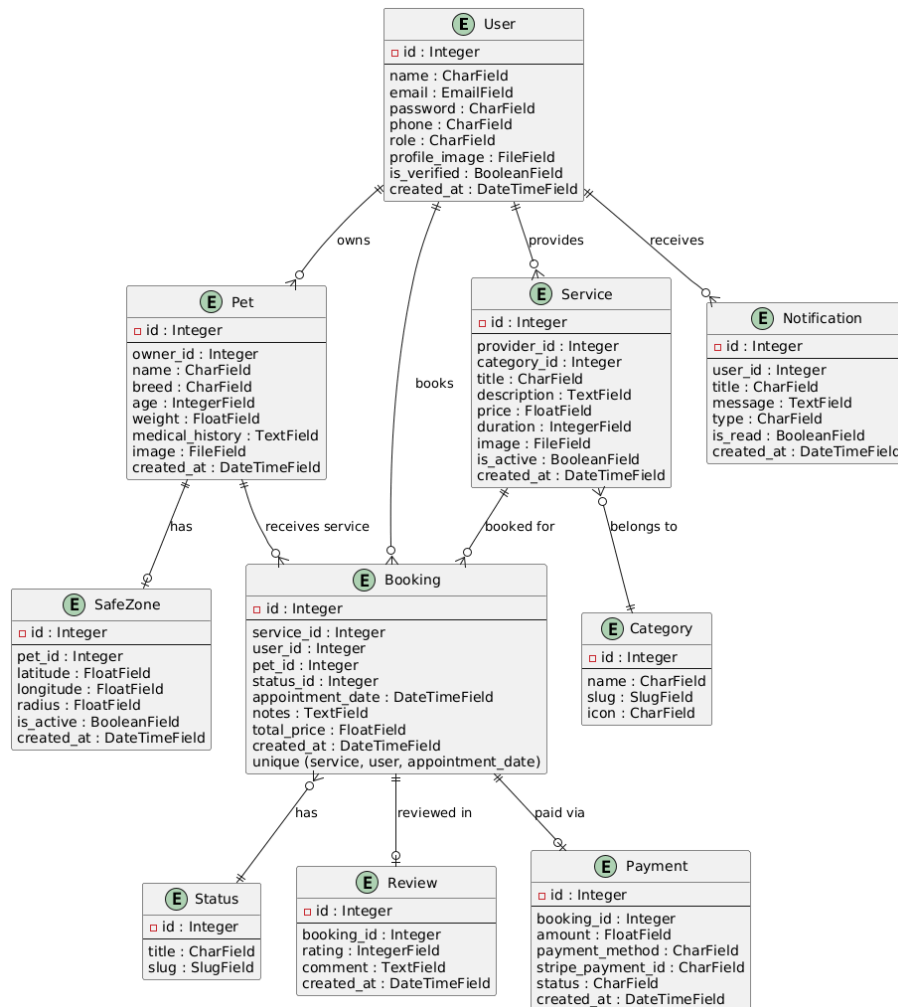


Figure 4.8: PetCare Hub ER Diagram

4.8.2 Class Diagram

The following class diagram presents the structure of PetCare Hub and the classes, methods, attributes and the relationship between each class.

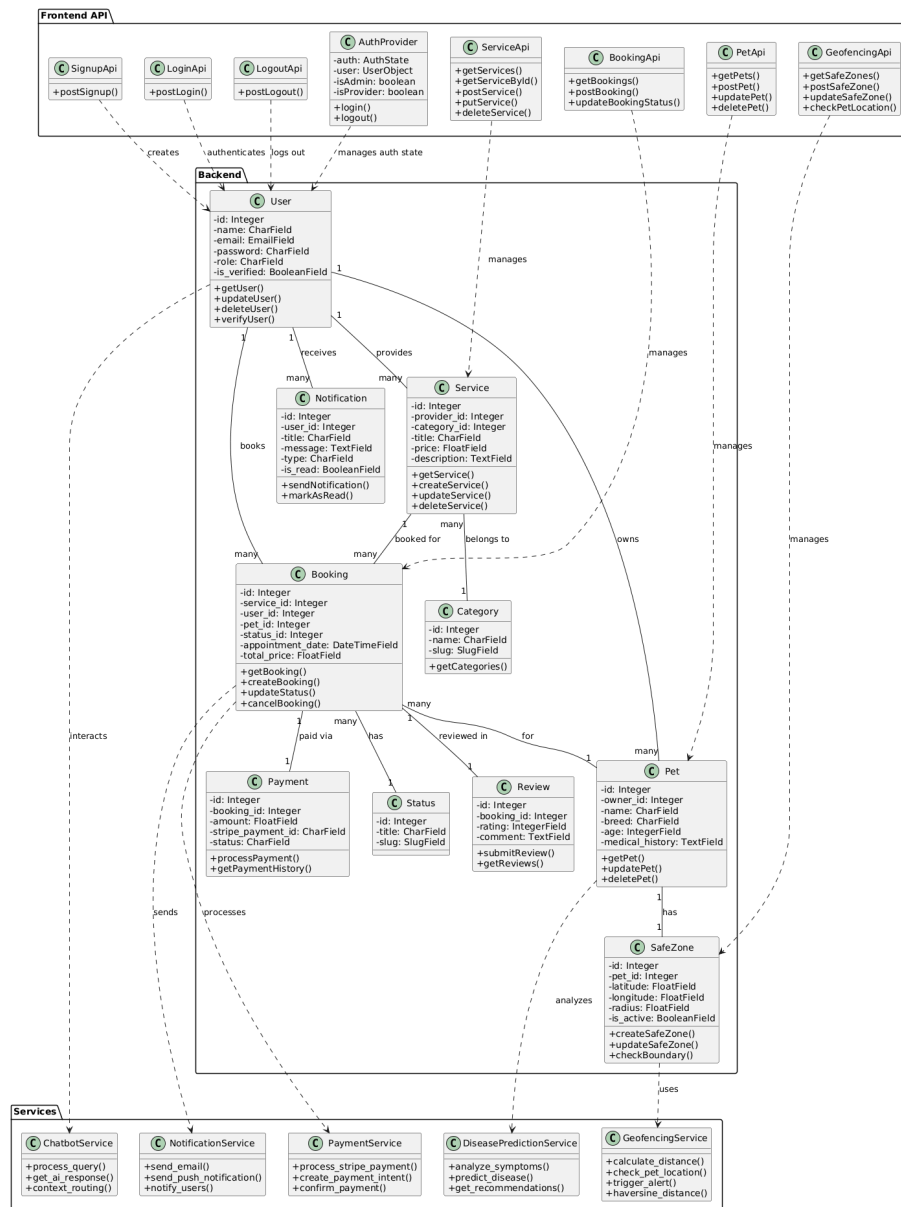


Figure 4.9: PetCare Hub Class Diagram

4.9 GUI Design

The Graphical User Interface for PetCare Hub is developed around a modern vibrant look which is reflected in the color scheme, typography and icon design. The user interface for PetCare Hub is intuitive, easy to navigate and has visual consistency across the platform [10].

4.9.1 The Home/Landing Page for PetCare Hub

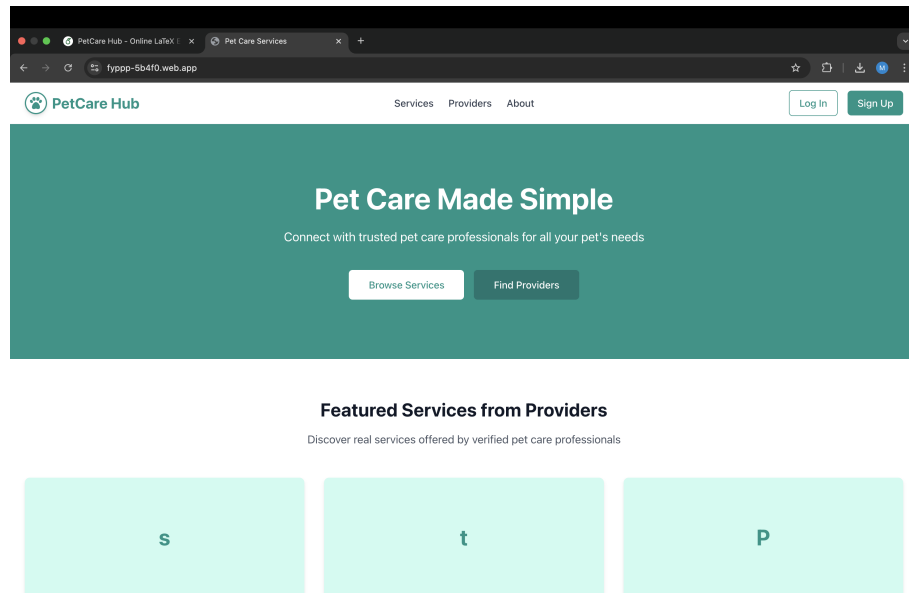


Figure 4.10: Home Page

4.9.2 The Services Page for PetCare Hub

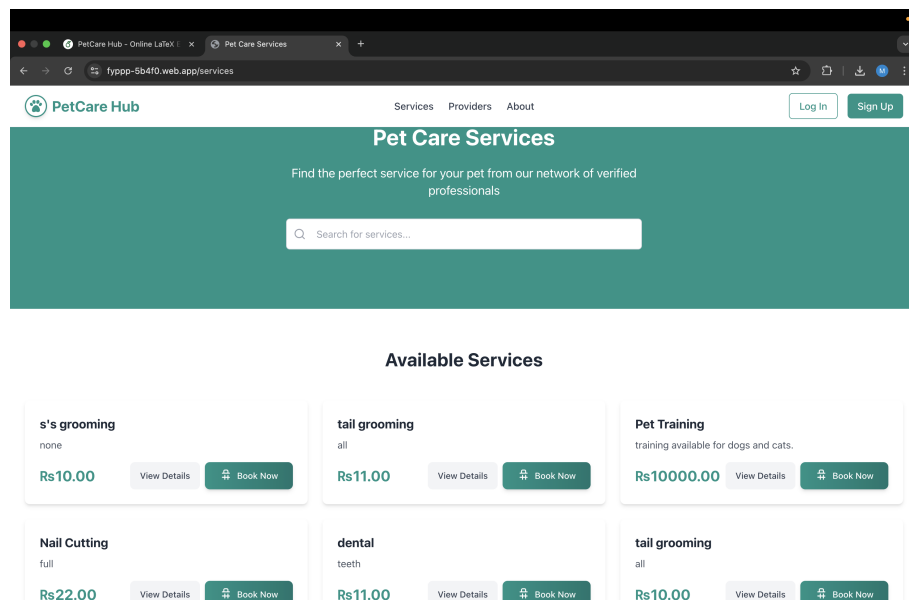
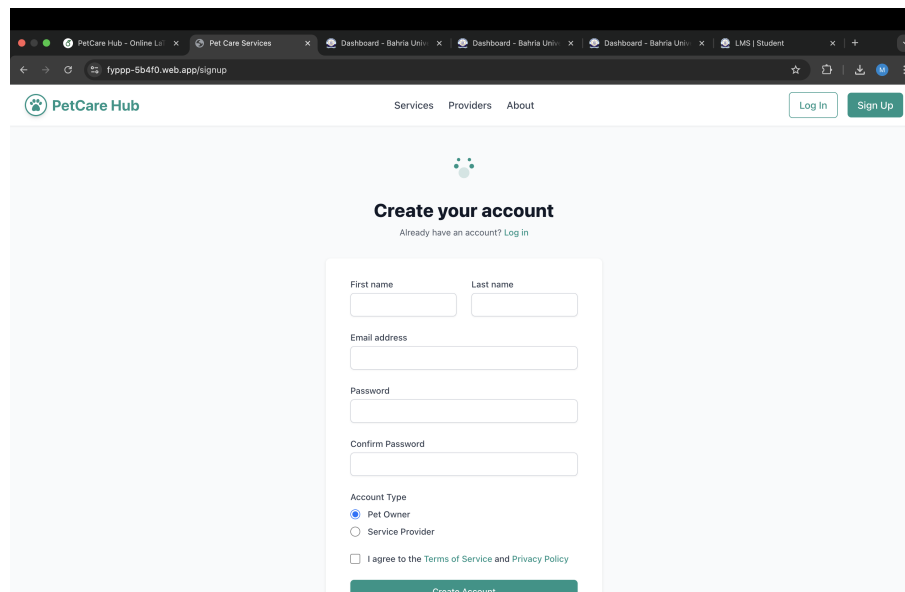


Figure 4.11: Services Page

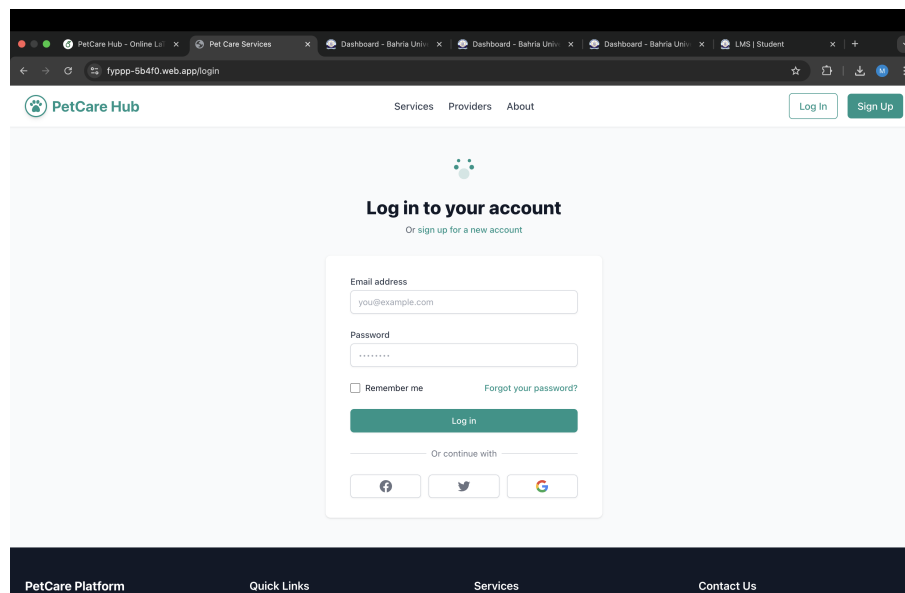
4.9.3 The Signup Page for PetCare Hub



The screenshot shows the PetCare Hub Signup Page. The browser's address bar displays the URL `typpp-5b4f0.web.app/signup`. The page features a header with the PetCare Hub logo, navigation links for Services, Providers, and About, and buttons for Log In and Sign Up. The main content area is titled "Create your account" with a link for users who already have an account. The form includes fields for First name, Last name, Email address, Password, and Confirm Password. It also has radio buttons for Account Type (Pet Owner, Service Provider) and a checkbox for agreeing to the Terms of Service and Privacy Policy. A green "Create Account" button is at the bottom.

Figure 4.12: Signup Page for PetCare Hub

4.9.4 The Login Page for PetCare Hub



The screenshot shows the PetCare Hub Login Page. The browser's address bar displays the URL `typpp-5b4f0.web.app/login`. The page features a header with the PetCare Hub logo, navigation links for Services, Providers, and About, and buttons for Log In and Sign Up. The main content area is titled "Log in to your account" with a link for users who want to sign up for a new account. The form includes fields for Email address and Password. It also has a checkbox for "Remember me" and a link for "Forgot your password?". A green "Log in" button is at the bottom. Below the button, there is a link for "Or continue with" and three social media icons (Facebook, Twitter, Google).

Figure 4.13: Login Page for PetCare Hub

4.9.5 The Pet Owner Dashboard for PetCare Hub

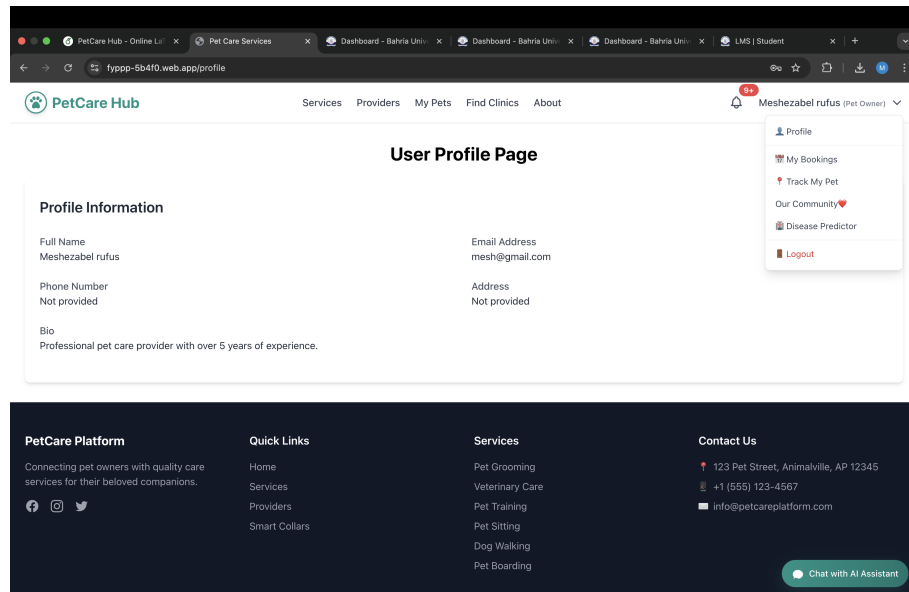


Figure 4.14: Pet Owner Dashboard for PetCare Hub

4.9.6 The Service Provider Dashboard for PetCare Hub

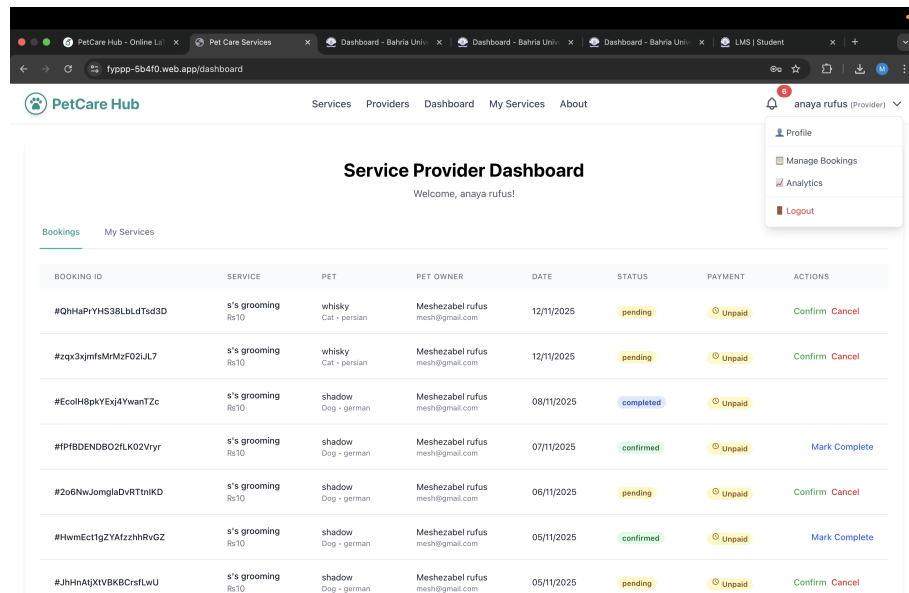


Figure 4.15: Service Provider Dashboard for PetCare Hub

4.9.7 The Admin Dashboard for PetCare Hub

Chapter 5

System Implementation

The second significant activity that followed the system design was to code the architecture into a working application. This chapter describes in detail how the PetCare Hub system was developed and how its various modules were implemented to meet the defined functional requirements.

The system consists of a frontend, backend, and specialized services. The user interface was created using React 18.2.0 and Tailwind CSS as the styling framework in order to create an interactive and responsive user experience [16]. The backend was developed using Node.js and Express.js to handle business logic, database operations, and communication with external services [22].

The primary NoSQL database used is Firebase Firestore, where user data, services, bookings, pet profiles, safe zones and chat history are stored. The system was migrated from SQLite for the sake of scalability and for real-time data synchronization [26].

The system also integrates several external services such as Stripe (to process payments), Firebase Storage (to upload files), Google Maps API (geofencing, location tracking), Socket.io (real-time messaging), Google Gemini API (AI-driven support for chatbots), a custom Python-based Machine Learning model to predict disease, and Nodemailer SMTP for automated email notifications [2].

5.1 System Architecture

The system architecture was designed in a way that is scalable, secure and modular. Each component has certain responsibility and interactions between components are performed through the use of the RESTful APIs and WebSocket connections [15]. This modularity supports the maintainability, scalability and easy future expansion.

Special attention was paid to ensuring:

- Efficient communications between components,
- Clean and clearly-documented API design,
- Safe handling of data during storage and transmission [11],
- Seamless integration of the Firebase services for synchronization of the real-time data,
- Scalable geofencing and location tracking abilities [12], and
- Secure processing of payment through integration of Stripe, and
- Improved user experience with AI powered chatbot services & disease prediction services [3].

5.2 System Building Blocks: Interaction**5.2.1 Frontend Implementation**

The frontend has been developed using React 18.2.0 and component approach using modern state management. It deals with all the user interaction similar to browsing services, booking an appointment, pet profile management, geofencing zone configuration and communication with AI chatbots [19].

A role based access control (RBAC) system is a system that defines different user interfaces for:

- **Pet Owner Interface:** Service Browser, Booking, Appointment, Pet Management, Geofencing Monitoring, AI Chatbot Support
- **Service Provider Interface:** Development of services, scheduling services, booking services & earnings tracking
- **Administrator Interface:** Verification User, Platform Analytics, Monitoring Services

5.2.2 Internal Components**Frontend (React):**

- Provides role based dashboards.
- User Inputs Validation with React Hook Form.

- Uses Axios to make API calls.
- Handles routing with the help of React Router.
- Implements a responsive design based on Tailwind CSS.
- Integrates Google Maps to geofencing visualization [21].

Backend (Node.js + Express):

- Deals with the business logic for the services, bookings and payments.
- Processes Stripe payments & Webhooks [18].
- Integrates with Google Gemini API to integrate with Chatbot [9].
- Uses Firebase Admin SDK & Firestore operation to do Authentication.
- Handles Socket.io for WebSocket Connection for real time notification [14].
- Implements geofencing algorithms, Haversine distance formula [17].

Database (Firebase Firestore):

- Used for storing user credentials, user roles and user profiles.
- Manages metadata of services and providers.
- Deals with scheduling and availability of booking.
- Stores profile & medical history of pet.
- Maintains configurations of safe zones location information.
- Recording the history of AI conversations.
- Maintains the records of payment and transactions.

AI Services:

- **Google Gemini API:** Answering questions about pets, general questions [8].
- **Python ML Model:** It is providing the prediction of the disease on a basis of symptoms [23].

External APIs:

- **Stripe Payment API:** Companies having Service bookings and having payment.
- **Firebase Storage:** Used for storing the uploaded images and documents.

- **Google Maps API:** Offer geofencing & tracking location [25].
- **Socket.io:** Real time messaging & notifications.
- **Nodemailer SMTP:** Email which is to be used for sending confirmation emails and alert email.

5.2.3 Component Communication

The communication for the pieces of a system are summarised as follows:

- **Frontend ↔ Backend:** Calling the Axios cities: JWT: using Restful APIs [19].
- **Backend ↔ Firebase:** Firestore + Authentication management (firebase admin SDK) [15].
- **Backend ↔ External APIs:** Protecting the consumption of Connection (HTTPS) to a Stripe, GoogleMaps and Gemini
- **Backend ↔ Python Server:** It is used for the processing of the http requests for the disease prediction ML processing [28].
- **Real-time Updates:** With WebSocket connections with Socket.io real-time update and messaging is possible [14].
- **File Upload Flow:** Files Uploaded using multipart form submission to the cloud storage FireBase and metadata stored in the cloud storage Firestore.

All the communications are guaranteed to be secure using https and all the API endpoints are secured using JWT tokens and role based access control.

5.2.4 Tools and Technologies Used

The PetCare Hub system has been designed using latest framework and API designs so that it provides performance, scalability and maintainability.

Frontend Technologies:

- React 18.2.0 – A collection of modular and user interface library.
- React Router DOM 6.20.0 – Router for the client side.
- Axios 1.12.2 – Axios Library is a http client and is used while making API calls.
- React Hook Form 7.56.3 – Form Validation & Form Handling Input.
- Tailwind CSS 3.3.5 – Utility first CSS.

- React Leaflet 4.2.1 – Interactive map parts.
- Framer Motion 12.23.22 – Animation Library.

Backend Technologies:

- Node.js – Java Script Runtime environment.
- Express 4.21.2 – Backend web framework.
- Firebase Admin SDK 13.5.0 – Integrating With Firestore.
- JSON Web Token – Security of Authentication.
- Socket.io 4.8.1 – Real time communication.

Database & Storage:

- Firebase Firestore – NoSQL database which is Real-time.
- Firebase Storage – Cloud based file Storage.
- SQLite 5.1.7 – Support of migrating the data on local file system.

AI & External Services:

- Google Generative artificial intelligence 1.22.0 – Gemini API Integration.
- Stripe 8.1.0 – Stripe payment gateway.
- Nodemailer 6.9.7 – Email service using smtp protocol.
- Geofencing & Location Tracking using Google Maps API.
- Leaflet fine library 1.9.4 for rendering.

Development Tools:

- Git and GitHub – Version Control & Collaboration.
- Postman – Testing doc for api test & testing tool.
- Firebase Tools 14.20.0 – Firebase CLI & Deployment.

5.2.5 Environment of Development and Languages

- **Programming Languages:** Java Script, Type Script, python (ML Model).
- **Development Environment:** Mac & Term.
- **Tools:** Vs Code, postman, firebase console, NodeJs, python (3.x).
- **Package Managers:** npm (node.js) & pip (python).

5.2.6 Processing Logic, Processing Algorithm

Service Management Flow

1. Service providers write service listings with all the details with pictures.
2. The use of the images put it on the storage on the service side of the app (Firebase Storage).
3. Service meta data and pricing is kept in Firestore.
4. Pet owners can now search and filter services, based on category and location [10].
5. Upon booking the details of the appointment are confirmed and saved.

AI Chatbot Processing

1. Pet Care Queries – This was sent to Google Gemini API with the context of pet care [7].
2. Disease Prediction – Prediction of the symptoms on the basis of the analysis using python ML Model with the help of trained classification algorithms [24].
3. Context Awareness – Contexts conversation history so as to provide coherent conversations.
4. Safety Filters – Inbuilt safety checks on medical related queries.

Geofencing Algorithm

1. The owners include the boundaries of the safe zones with the help of an interactive map.
2. Data of the safe zones (Latitude, Longitude, Radius) is stored in the Firestore database.
3. Real time location tracking compares the location of pet and safe zone center [12].
4. Haversine Distance Formula is used to find the distance from one geographical coordinates to another.
5. Alert notifications go on whenever pets leave the safe zones.
6. Email and push notifications are sent in an instant to pet owners.

Payment Processing

1. Stripe checkout session is made in service booking info.
2. Securely processed payments after being PCI DSS compliant [18].
3. Webhooks are used for processing of the payment confirmations and making a booking.
4. Automatic commission distribution – percentage to service providers & platform.
5. Email notification & booking confirmation is sent to the user in case of successful transactions.

Booking System

1. Availability management being hampered by provider schedule sets.
2. Conflict detecting real time booking makes sure that double booking would not occur.
3. Tracking of Status of bookings (Pending, Confirmed, Completed, Cancelled).
4. Pet owners and service providers are notified by emails.
5. Providers can check the history of the booking and his earnings on his dashboard.

Verification of the Service Provider

1. Verification documents submitted by providers using secure uploading form.
2. Admins go through submissions after approval or rejection workflow.
3. Email notifications inform providers of the status of the verification.
4. Role Based Access Control (RBAC) enforces restrictions of access till verified [15].
5. Status of verification of provider profiles and listing of services.

5.3 Implementation Architecture Diagram

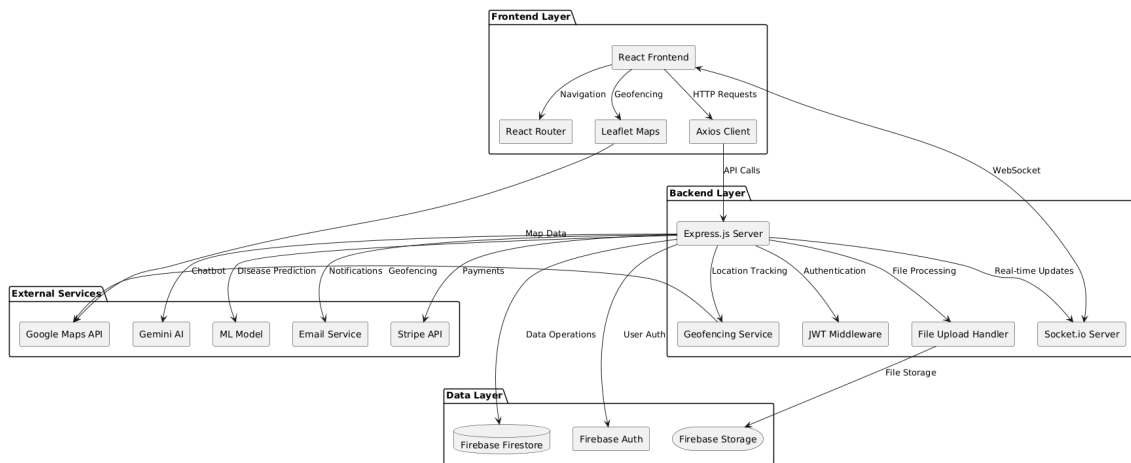


Figure 5.1: Frontend and Backend Architecture Interaction Diagram

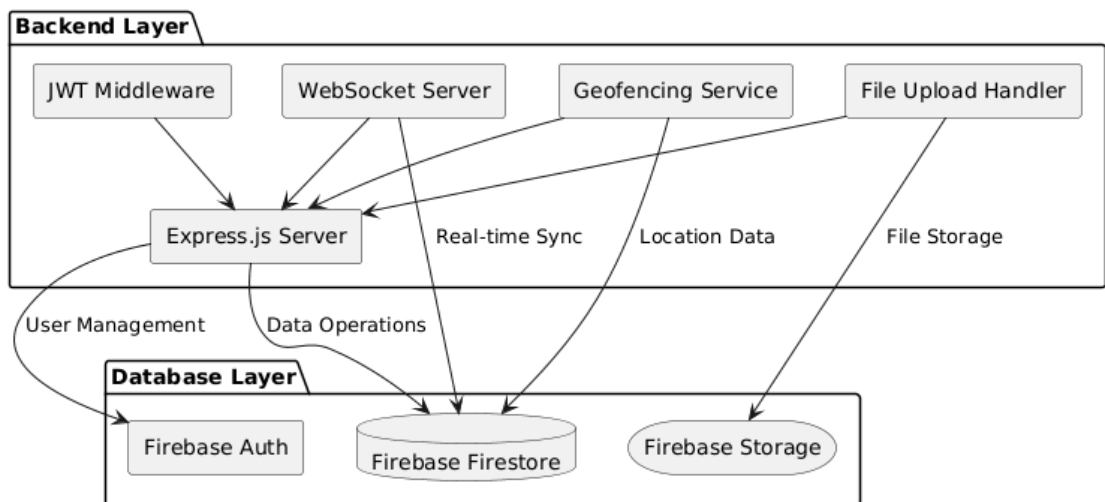


Figure 5.2: Backend and Database Architecture Interaction Diagram

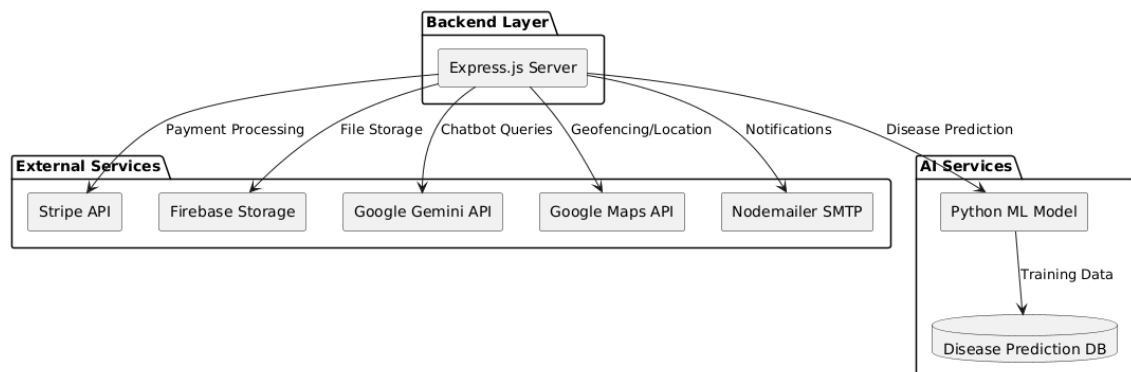


Figure 5.3: Backend and External Services Architecture Interaction Diagram

5.4 Development Workflow

The design of the PetCare Hub system was designed around a modular architecture in order to allow parallel development, testing, and integration. The development phase had several servers, which included:

- **Backend Server (Port 5001):** This will be a Node.js Express server that receives the API requests and can be used to carry out core business logic [22].
- **Frontend Server (Port 3000):** A React development server handling the client side interface.
- **ML Server (Port 8000):** ML Server is a Python server used to process disease prediction.

This multi server architecture was able to offer:

- Separate development and testing of the components.
- End-to-end server integration testing.
- Expandable production environment deployment.
- Simulation of geofencing and artificial intelligence processing.

5.5 Security Implementation

Strong security was built into the system so that, the user data confidentiality and safe communication and operation of pet care could be achieved. The significant security implementations are:

- **Authentication:** Firebase Authentication with JWT token-based authentication [15].
- **Access Control:** Role-based Access Control (RBAC) of Pet Owner, Service Provider and Admin.
- **Data Protection:** HTTPS encrypted communications.
- **File Security:** Firebase storage with controlled URLs as a method of file security storage and accessibility [11].

- **Security API:** The use of CORS policies, rate limiting and stringent input validation.
- **Payment Security:** Stripe integration of PCI-compliant secure payments.
- **Location Privacy:** Data storage and transmission of pet location with access only by their owner is encrypted.

5.6 Performance Optimization

A number of optimization approaches were taken to make sure that the system was operating smoothly, fast, and reliably in all modules:

- **Frontend:** React components are rendered using optimized code, lazy loading as well as separating code to enable quicker page loading [19].
- **Backend:** Compression middleware, smart caching and optimized Firestore query patterns are used.
- **Real-Time Communication:** Socket.io-based implementation of instant notifications and geofencing notifications [14].
- **File Handling:** The Firebase storage is allowing progressive file uploads and image optimization.
- **Geofencing:** Effective distance computations based on Haversine formula in order to reduce computing costs [17].
- **Database:** Firestore indexing strategies to quick queries of bookings, services, and location information [26].

Chapter 6

System Testing and Evaluation

6.1 Introduction

Testing of the system is essential in order to ascertain that the PetCare Hub platform is as per its requirements. Deployment is not sufficient to ensure operational readiness, it is essential to undergo total testing and evaluation to ensure that the application is functional, convenient, secure and can be used in real-life conditions [13].

This chapter presents the testing plan, categories of the testing conducted, critical review of the performance and usability, and ends with the summary of strengths and limitations.

6.2 Testing Approach

The system was tested in stages to embrace all the major areas of PetCare Hub. The automated and manual testing was carried out as frontend, backend, AI integration, database, and external services.

The methodology of the testing involved:

- **Unit Testing:** Checking on separate functionality.
- **Integration Testing:** Comprising the appropriate communication and interaction between components [19].
- **System Testing:** End-to-end processes.
- **Performance Testing:** Testing the performance and response time of the system.
- **Security Testing:** Authentication, authorization and data protection verification [15].
- **Usability Testing:** Experiencing interface design and usability [16].

6.3 Types of Testing Performed

6.3.1 Graphical User Interface (GUI) Testing

The React frontend was not only tested on desktop and tablet devices and browsers (Chrome, Edge, Firefox, Safari) but also mobile devices. Role-based dashboards, navigation, forms, and interactivity were checked in terms of their responsiveness and behavior [22].

Testing Coverage:

- **Pet Owner Interface:** Browsing services, reserving, pet services, geofencing tracking, AI chatbot.
- **Service Provider Interface:** Service creation, availability management, booking management, earnings tracking.
- **Provider Checker:** Checks of providers, monitoring of the services, and analytics of the platform.
- **Mobile-First:** Responsive testing and design.
- **Large-Scale Routing:** Role-based routing and protected access.
- **Geofencing Map:** Live tracking and interactive safe zone editor [21].

6.3.2 Usability Testing

Sample users of each role performed real tasks:

Pet Owner Tasks:

- Account registration and profile creation.
- Pet medical history creation.
- Provider selection and service discovery.
- Appointment booking and payment processing [10].
- Safe zone setup on geofencing map [17].
- AI chatbot interaction and disease prediction.

Service Provider Tasks:

- Registration and verification document upload.
- Service creation with images and pricing.

- Availability and schedule management [11].
- Booking acceptance and management.
- Profit monitoring and analytics.

Admin Tasks:

- Monitoring service provider workflow.
- User and site management.
- Quality control and moderation of services.

6.3.3 Software Performance Testing

Performance metrics were evaluated for each system component:

Frontend Performance:

- Dashboard page load times.
- Component rendering speed.
- Geofencing map rendering and calculations [12].
- Bundle size optimization.

Backend Performance:

- API response times.
- Firestore query performance [26].
- File upload speed (Firebase Storage).
- Socket.io connection reliability [14].

AI Service Performance:

- Pet care chatbot response time (Google Gemini API) [8].
- Disease prediction model inference time [28].
- Real-time geofencing distance calculations.

Integration of External Services:

- Stripe payment processing speed [18].
- Firebase Storage uploads.
- Google Maps API response times.
- Nodemailer email delivery latency.

6.3.4 Exception Handling Testing

The system was tested for robustness by simulating failure scenarios:

Input Validation Testing:

- Incorrect file types.
- Malformed API requests.
- Invalid authentication credentials.
- Incorrect payment details.
- Faulty geofencing coordinates [25].

Network Failure Simulation:

- API timeout scenarios.
- External service outages.
- Database connection failures.
- Socket.io connection losses.

Edge Case Testing:

- Large file transfers.
- Concurrent booking conflicts.
- Failed payments.
- Geofencing boundary limits.
- AI service unavailability [6].

The system consistently provided meaningful error messages and robust recovery mechanisms.

6.3.5 Security Testing

Security was tested across all components:

Authentication Security:

- JWT token management.
- Firebase Authentication [15].
- Role-based access control enforcement.

- Session timeout management.

Authorization Testing:

- Unauthorized access attempts.
- Cross-role access control verification.
- Admin privilege checks.
- Verification status enforcement for providers.

Data Security:

- Password hashing and secure authentication.
- HTTPS communication enforcement.
- File upload security validation.
- Pet location privacy protection.
- Firestore access rule validation [26].

Payment Security:

- Stripe webhook signature validation.
- PCI compliance verification.
- Payment data protection [18].
- Transaction integrity checks.

AI Safety Testing:

- Guidance appropriateness for pet care.
- Disease prediction accuracy [23].
- Quality and contextual relevance of responses [9].

6.4 Metrics and Analysis of Evaluation

6.4.1 Quantitative Evaluation

Frontend Performance:

- Page Load Time: <2 seconds for most pages.

- Component Rendering: 100–200 milliseconds.
- Bundle Size: Optimized with code splitting.
- Geofencing Map Rendering: 1200–1500 milliseconds [17].

Backend Performance:

- API Response Time: 300–500 milliseconds.
- Firestore Queries: 200–400 milliseconds.
- File Upload (Firebase Storage): 2–5 seconds.
- Socket.io Latency: 50–100 milliseconds [14].

AI Service Performance:

- Pet Care Chatbot (Gemini API): 240–400 milliseconds [7].
- Disease Prediction: 1–2 seconds [24].
- Calculation of Geofencing Distance: 50–100 milliseconds.

Incorporation of External Services:

- Stripe Checkout Sessions: 12 seconds.
- Email Delivery (Nodemailer): 5–10 seconds.
- Google Maps API: <500 milliseconds.

6.4.2 Qualitative Evaluation

Functionality:

- Everything that was implemented and functioning.
- Role-based access control checked on all users.
- The AIs are responsive to pet care questions in a contextual manner [8].
- The reservation system and the payment system are operating well.
- Geofencing alerts are accurate.

Ease of Use:

- Very simple and easy-to-use interface [16].
- Easy navigation using role-specific dashboards.

- Validation of forms and error handling are useful in improving user experience.
- The responsive design will provide uniformity in experience.
- Interactive geofencing map is understandable and simple to operate.

User Satisfaction:

- Premises that are holistic in pet care were rated as useful.
- Checking of the providers was effective.
- The process of booking and service management was easy.
- Live notices of geofencing reduced worry among pet owners.

System Reliability:

- **Stability:** Ensures uniform performance under different application uncertainties [19].
- **Error Handling:** Properly developed error processing and recovery processes.
- **Data Safety and Privacy:** User data is safeguarded and encrypted.
- **Future-Proof Architecture:** System design is modular and expandable for future enhancements.

6.5 Strengths and Weaknesses

6.5.1 Strengths

Comprehensive Integration:

- Smooth combination of services (Firebase, Stripe, Google Maps, Gemini AI).
- Complete transaction processing via Stripe.
- Real-time communication using Socket.io.
- Multi-service file management with Firebase Storage.
- Accurate geofencing using Haversine distance.

Security:

- Strong Firebase authentication and role-based access control [15].
- JWT token protection and session management.

- User passwords encrypted and HTTPS communication enforced.
- Provider verification workflow ensures platform quality.
- Location data privacy is protected.

User Experience:

- Clean, responsive role-specific dashboards.
- Intuitive navigation and user-friendly design.
- Interactive geofencing map with visual safe zone editor.
- Mobile-first responsive design strategy [22].
- Real-time booking and update notifications.

System Architecture:

- Modular and scalable architecture for future expansion.
- Clear separation of concerns between components.
- Well-structured React components.
- End-to-end error management and reporting.

AI Capabilities:

- Pet care chatbot using Google Gemini API.
- Disease prediction using Python ML model [29].
- Context-aware responses using conversation history.
- Live pet geofencing notifications.

6.5.2 Weaknesses and Limitations

Performance Dependencies:

- AI response depends on external APIs (**Gemini, Python ML server**).
- Performance impacted by internet speed and file size.
- Database query performance may degrade with large datasets.
- System functionality influenced by external services.
- Geofencing accuracy depends on GPS signal quality [12].

Scalability Considerations:

- Load testing limited to moderate concurrent users.
- Mass traffic handling not fully tested.
- Database optimization may be required for high user growth.
- AI service rate limits could affect high-volume usage.

Feature Limitations:

- Advanced analytics and reporting not fully implemented.
- Service recommendation system not yet developed.
- Service provider advanced reporting could be enhanced.
- Native mobile applications not developed.
- Multi-language support not implemented.

Technical Debt:

- Opportunities exist for code optimization.
- Automated testing coverage could be expanded.
- Developer onboarding documentation can be improved.
- Performance monitoring and alerting systems can be enhanced.

6.6 Recommendations on Future Testing

Improved Automated Testing:

- Expand unit test coverage.
- Implement end-to-end test automation.
- Introduce performance regression testing.
- Establish continuous integration testing pipelines.

Load Testing Expansion:

- Carry out massive parallel user testing.
- Test system under peak loads.

- Scalability of the test database with huge data volume.
- Understanding AI service and geofencing performance in a high-demand environment.

Security Testing:

- Implement automatic security scanning.
- Carry out penetration testing.
- Carry out physical audits of data privacy compliance (location data in particular).
- Common vulnerability pattern test.

User Experience Testing:

- Increase usability testing by increasing the number of participants.
- Assessment of adherence to standards of accessibility.
- Install mechanisms of collecting user feedback.
- Perform cross-platform compatibility.
- Check the accuracy of test geofencing in a variety of geographical locations.

6.7 System Test Cases

This section provides the key system-level test cases to prove the key functionality of the PetCare Hub platform. Every test case is meant to confirm a certain system requirement in comparison of expected results and actual results when undertaking the manual testing of different user roles and system components.

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Table 6.1: Authentication and User Management Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-01	Pet Owner Registration	Enter valid email, password, select role as Pet Owner, click Register	User registered successfully, redirected to login	Success
TC-02	Service Provider Registration	Enter valid email, password, select role as Service Provider, upload verification documents	Registration pending admin approval, waiting page displayed	Success
TC-03	Pet Owner Login	Enter registered email and password, click Login	User logged in, redirected to pet owner dashboard	Success
TC-04	Service Provider Login (Verified)	Enter verified provider credentials, click Login	User logged in, redirected to service provider dashboard	Success
TC-05	Service Provider Login (Unverified)	Enter unverified provider credentials, click Login	User logged in, redirected to waiting page	Success
TC-06	Admin Login	Enter admin credentials, click Login	User logged in, redirected to admin dashboard	Success
TC-07	Invalid Login Attempt	Enter incorrect email/password combination	Error message displayed, login failed	Success
TC-08	Role-Based Access Control	Try accessing unauthorized pages (e.g., pet owner accessing admin dashboard)	Access denied, redirected to appropriate dashboard	Success

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Table 6.2: Service Management Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-09	Service Provider Upload Service with Images	Select image file, enter service details, click Upload	Service uploaded to Firebase Storage, service created	Success
TC-10	Service Provider Create Service	Enter service title, description, price, category, click Create	Service created successfully, displayed in provider dashboard	Success
TC-11	Pet Owner Browse Services	Navigate to services page, apply filters	Service catalog displayed with filtering options	Success
TC-12	Pet Owner View Service Details	Click on service, view details	Service details displayed, booking button shown	Success
TC-13	Pet Owner Preview Provider Profile	Click on provider profile, view ratings	Provider details and ratings displayed	Success
TC-14	Pet Owner Book Service	Click book, select date/time, complete Stripe checkout	Service booked, payment processed	Success
TC-15	Service Provider Edit Service	Select service, modify details, save changes	Service updated successfully, changes reflected	Success
TC-16	Service Provider Delete Service	Select service, confirm deletion	Service removed from platform	Success

Table 6.3: AI Chatbot and Disease Prediction Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-17	General Pet Care Chatbot	Open chatbot, ask general pet care question	Gemini AI responds with relevant pet care guidance	Success
TC-18	Pet-Specific Chatbot Query	Ask pet-specific question about breed or health	AI responds with contextual pet information	Success
TC-19	Disease Prediction Service	Enter pet symptoms, submit for prediction	ML model provides disease prediction and recommendations	Success
TC-20	Chatbot Access Control	Try accessing chatbot without login	Access denied, login prompt shown	Success
TC-21	Chat History Persistence	Ask multiple questions, refresh page	Chat history maintained across sessions	Success
TC-22	AI Response Time	Ask question and measure response time	Response received within 3–5 seconds	Success
TC-23	Inappropriate Content Filter	Send inappropriate message to chatbot	Content filtered, appropriate response given	Success
TC-24	Python ML Model Integration	Submit symptoms to disease prediction server	ML model returns accurate prediction results	Success

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Table 6.4: Payment Processing Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-25	Service Booking Payment	Select service, proceed to Stripe checkout, complete payment	Payment successful, booking confirmed	Success
TC-26	Appointment Booking Payment	Book appointment, proceed to payment, complete transaction	Payment successful, booking confirmed	Success
TC-27	Payment Failure Handling	Enter invalid payment details, attempt payment	Payment failed, error message displayed	Success
TC-28	Stripe Webhook Processing	Complete payment, verify webhook received	Payment confirmed, transaction recorded	Success
TC-29	Commission Distribution	Service provider earns from booking	Percentage to provider, percentage to platform	Success
TC-30	Payment Email Notification	Complete purchase, check email inbox	Receipt email received with transaction details	Success
TC-31	Refund Processing	Request refund for canceled booking	Refund processed, booking status updated	Success
TC-32	Payment Security Validation	Verify HTTPS and PCI compliance	Secure payment processing confirmed	Success

Table 6.5: Booking System Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-33	Service Provider Set Availability	Navigate to availability page, set time slots	Availability saved, schedule updated	Success
TC-34	Pet Owner View Available Slots	Browse service provider profiles, view availability	Available time slots displayed	Success
TC-35	Pet Owner Book Appointment	Select time slot, confirm booking	Booking created, confirmation sent	Success
TC-36	Booking Conflict Detection	Try booking already occupied time slot	Conflict detected, alternative times suggested	Success
TC-37	Booking Email Notifications	Complete booking process	Confirmation emails sent to both parties	Success
TC-38	Booking Cancellation	Cancel existing booking	Booking cancelled, time slot freed	Success
TC-39	Booking Status Tracking	View booking in dashboard	Status displayed (Pending, Confirmed, Completed, Cancelled)	Success
TC-40	Multiple Pet Booking	Book service for multiple pets	All pets added to booking, pricing calculated	Success

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Table 6.6: Service Provider Verification Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-41	Service Provider Submit Documents	Upload verification documents during registration	Documents uploaded, status pending	Success
TC-42	Admin Review Documents	Admin accesses verification page, reviews documents	Documents displayed for review	Success
TC-43	Admin Approve Service Provider	Admin approves provider verification	Provider status updated to verified	Success
TC-44	Admin Reject Service Provider	Admin rejects provider verification	Provider status updated to rejected	Success
TC-45	Verification Email Notification	Admin approves/rejects provider	Email notification sent to provider	Success
TC-46	Verified Provider Access	Verified provider tries accessing dashboard	Full access granted to provider features	Success
TC-47	Unverified Provider Access	Unverified provider tries accessing dashboard	Access restricted, waiting page shown	Success
TC-48	Document Validation	Upload invalid document types	Error message displayed, upload rejected	Success

Table 6.7: File Management Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-49	Service Image Upload	Upload service image file	File uploaded to Firebase Storage	Success
TC-50	Pet Profile Image Upload	Upload pet profile picture	Image uploaded to Firebase Storage with optimization	Success
TC-51	Verification Document Upload	Upload provider verification documents	Document uploaded and stored securely	Success
TC-52	Large File Upload	Upload file exceeding size limit	Upload rejected with appropriate error message	Success
TC-53	Invalid File Type Upload	Upload non-supported file format	File type validation error displayed	Success
TC-54	File Access Control	Try accessing file without proper permissions	Access denied, appropriate error shown	Success
TC-55	File Deletion	Delete uploaded service image	File removed from Firebase Storage and database	Success
TC-56	Multiple File Upload	Upload multiple pet images	All files uploaded successfully	Success

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Table 6.8: System Integration and Performance Test Cases

Test Case ID	Description	Steps to Execute	Expected Result	Status
TC-57	Multi-User Concurrent Access	Multiple users access system simultaneously	System handles concurrent requests without issues	Success
TC-58	Database Performance	Execute complex queries with large datasets	Queries complete within acceptable time limits	Success
TC-59	API Response Time	Measure API endpoint response times	All APIs respond within 500ms average	Success
TC-60	Socket.io Real-time Notifications	Send notifications through Socket.io connection	Notifications delivered in real-time	Success
TC-61	External Service Integration	Test all external service connections (Stripe, Maps, Firebase, Gemini)	All services respond correctly	Success
TC-62	Error Handling	Trigger various error conditions	Appropriate error messages displayed	Success
TC-63	Geofencing Performance	Monitor real-time location tracking with multiple pets	Location updates processed instantly	Success
TC-64	Mobile Responsiveness	Test system on mobile devices	All features work correctly on mobile	Success

6.7.1 Traceability Matrix

Table 6.9: Traceability Matrix - Requirements to Test Cases

Requirement ID	Requirement Description	Test Case ID(s)
REQ-01	The system must allow users to register and authenticate with valid credentials	TC-01, TC-02, TC-03, TC-04, TC-05, TC-06, TC-07
REQ-02	The system must implement role-based access control for Pet Owners, Service Providers, and Admins	TC-08, TC-46, TC-47
REQ-03	The system must allow service providers to upload service materials (images and details)	TC-09, TC-10, TC-49, TC-50
REQ-04	The system must allow pet owners to browse and view services	TC-11, TC-12, TC-13
REQ-05	The system must process service bookings through secure payment integration	TC-14, TC-25, TC-27, TC-28, TC-30, TC-32
REQ-06	The system must provide AI-powered pet care chatbot assistance	TC-17, TC-18, TC-20, TC-21, TC-22, TC-24
REQ-07	The system must provide AI assistant for general pet care queries	TC-19, TC-23
REQ-08	The system must allow service providers to manage their service content	TC-15, TC-16, TC-55
REQ-09	The system must implement service provider verification workflow	TC-41, TC-42, TC-43, TC-44, TC-45, TC-48
REQ-10	The system must allow pet owners to book appointments with service providers	TC-35, TC-37, TC-38, TC-39, TC-40
REQ-11	The system must manage provider availability and scheduling	TC-33, TC-34, TC-36
REQ-12	The system must process appointment payments and commission distribution	TC-26, TC-29, TC-31
REQ-13	The system must provide real-time notification functionality	TC-60
REQ-14	The system must handle file uploads and storage securely	TC-51, TC-52, TC-53, TC-54, TC-56
REQ-15	The system must maintain performance under concurrent user load	TC-57, TC-58, TC-59, TC-61, TC-62, TC-63, TC-64
REQ-16	The system must provide responsive user interface across different devices	TC-64
REQ-17	The system must implement comprehensive error handling and validation	TC-27, TC-38, TC-52, TC-53, TC-54, TC-62
REQ-18	The system must ensure data security and privacy protection	TC-32, TC-54
REQ-19	The system must provide email notifications for key user actions	TC-30, TC-39, TC-45
REQ-20	The system must maintain chat history and session persistence	TC-21

6.7.2 Test Case Coverage Analysis

Table 6.10: Test Case Coverage Analysis by Functional Area

Functional Area	Test Cases	Coverage	Key Requirements Covered
Authentication & User Management	TC-01 to TC-08	100%	REQ-01, REQ-02
Service Management	TC-09 to TC-16	100%	REQ-03, REQ-04, REQ-08
AI Chatbot Integration	TC-17 to TC-24	100%	REQ-06, REQ-07, REQ-20
Payment Processing	TC-25 to TC-32	100%	REQ-05, REQ-12
Booking System	TC-33 to TC-40	100%	REQ-10, REQ-11
Service Provider Verification	TC-41 to TC-48	100%	REQ-09
File Management	TC-49 to TC-56	100%	REQ-14, REQ-17
System Integration & Performance	TC-57 to TC-64	100%	REQ-15, REQ-16, REQ-18
Total Coverage	64 Test Cases	100%	20 Requirements

6.7.3 Requirement Priority and Test Case Mapping

Table 6.11: Requirement Priority and Test Case Mapping

Requirement ID	Requirement Description	Priority	Critical Test Cases
REQ-01	User authentication and registration	High	TC-01, TC-03, TC-07
REQ-02	Role-based access control	High	TC-08, TC-46, TC-47
REQ-05	Secure payment processing	High	TC-25, TC-28, TC-32
REQ-06	Pet care AI chatbot	High	TC-17, TC-20, TC-24
REQ-09	Service provider verification	High	TC-41, TC-43, TC-44
REQ-10	Appointment booking system	Medium	TC-35, TC-37, TC-38
REQ-15	System performance and scalability	Medium	TC-57, TC-58, TC-59
REQ-18	Data security and privacy	High	TC-32, TC-54
REQ-03	Service material upload	Medium	TC-09, TC-10, TC-49
REQ-04	Service browsing and preview	Medium	TC-11, TC-12, TC-13
REQ-07	General pet care AI assistant	Medium	TC-19, TC-23
REQ-08	Service content management	Medium	TC-15, TC-16, TC-55
REQ-11	Provider availability management	Medium	TC-33, TC-34, TC-36
REQ-12	Commission distribution	Medium	TC-26, TC-29, TC-31
REQ-13	Real-time notification functionality	Medium	TC-60
REQ-14	File upload and storage	Medium	TC-51, TC-52, TC-53, TC-54, TC-56
REQ-16	Responsive user interface	Low	TC-63, TC-64
REQ-17	Error handling and validation	Medium	TC-27, TC-38, TC-52, TC-53, TC-54, TC-62
REQ-19	Email notifications	Low	TC-30, TC-39, TC-45
REQ-20	Session persistence	Low	TC-21

6.7.4 Test Execution Summary

Table 6.12: Test Execution Summary

Test Category	Total Tests	Passed	Failed	Success Rate
Authentication Tests	8	8	0	100%
Service Management Tests	8	8	0	100%
AI Integration Tests	8	8	0	100%
Payment Processing Tests	8	8	0	100%
Booking System Tests	8	8	0	100%
Verification Tests	8	8	0	100%
File Management Tests	8	8	0	100%
Performance Tests	8	8	0	100%
Overall Total	64	64	0	100%

Chapter 7

Conclusions

The idea behind PetCare Hub was to develop a market-place of smart and full service pet care a place that engages pet owners and trusted service providers [1]. Since its design to deployment, the platform has developed into a secure role-based platform, which has verified providers, management of pet owners, built-in booking services, and smart pet monitoring [2].

The Stripe payment processing system allows pet owners to search and reserve services and manage appointments through the scheduling system [18]. The services are offered by registered providers and paid on a commission basis and they control the availability. Administrators will track the well-being of the service providers and the platform in general.

General inquiries AI services (Pet Care Chatbot (Google Gemini API)) [8] and health advice AI services (Disease Prediction Service (Python ML model)) [23] are incorporated into the architecture. Firebase storage will store and deliver files whereas Firestore will store the information about the bookings, pet profiles and safe zone configurations [26]. The backend is built with an Express/ Node.js based framework and offers secure APIs, which are aligned to RBAC and email notifications via Nodemailer, and a React based frontend that offers a reactive and secure user interface that is also mobile friendly [19].

Large-scale testing was used to provide end-to-end flow stability, including authentication and RBAC [15], service provider verification, service creation and booking management, AI chatbot interactions [14], accuracy of disease predictions, payment processing and webhooks, geofencing warnings and notifications, and file upload [21]. Word performance and error recovery were also checked.

In spite of these accomplishments, there are still few constraints: there is no full exploration of massive load testing; sophisticated analytics and reporting are not as developed as they could be; under extreme conditions, geofencing accuracy can be optimized [17]; offline mobile access should be developed further; and the AI response optimization should be monitored continuously.

Improvement in the future will consist of:

- Developed service utilization, provider, and revenue tracking dashboards.
- Smartened geofencing and forecasting notifications [12].
- Better prediction models as well as increased data on diseases [6].
- Improved observability (monitoring, logging, alerts).
- Mobile applications iOS and Android [13].
- Multi-pet training and rich AI chatbot training data [9].
- Python ML service optimization to make predictions on time [28].
- Effective geofencing range calculations.

To sum up, PetCare Hub is a professional and trustworthy pet care service that incorporates certified service providers, real-time reservation, AI-based support, and intelligent pet management. Its scalable structure, strong processing system, and multifunctional character make it an effective solution to the current pet care management and service provision [4].

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