NANYANG TECHNOLOGICAL UNIVERSITY
COLLEGE OF COMPUTING AND DATA SCIENCE

Full Stack Development and Deployment of Web-based Speech Recognition System

By

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Abstract

This project focuses on the design and implementation of the **Gateway Dashboard**, a comprehensive management interface for the Speech Gateway API, alongside critical backend enhancements to support secure authentication and monetization.

On the **frontend**, a responsive Single Page Application (SPA) was developed using **Vue.js** and **Vuetify**, featuring a modular architecture that ensures scalability and maintainability. Key implemented features include a secure authentication system supporting **Email/Password**, **Google OAuth 2.0**, and **Apple Sign-In**, enhancing user accessibility and security.

The **backend**, built with **NestJS**, was significantly upgraded to include a **Token Management Module** ensuring session security through token blacklisting and automatic expiration handling using Redis and MongoDB TTL indexes.

Furthermore, a **Subscription and Payment Module** was integrated using **Stripe**, enabling automated recurring billing, plan management, and real-time subscription status tracking. Storage solutions utilizing **MongoDB** for persistent data and **Redis** for caching were implemented to optimize performance.

The result is a **production-ready dashboard** that facilitates seamless user onboarding, secure identity management, and a flexible subscription model, thereby establishing a solid foundation for the commercialization of the Speech Gateway services.

Acknowledgement

I would like to express my deepest gratitude to my mentors **Kyaw Zin Tun**, **Vu Thi Ly**, **Surana Tanmay** and my supervisor, **Chng Eng Siong**, for their invaluable guidance, continuous encouragement, and expert advice throughout the course of this Final Year Project. Their insights were instrumental in shaping the direction and reliability of this system.

I extend my sincere thanks to the **Hardware and Embedded Systems Lab** team for providing the necessary resources and technical environment to develop this project. The opportunity to work with real-world technologies like NestJS, Vue.js, and cloud infrastructure has been an immensely rewarding learning experience.

I am also grateful to my friends and family for their unwavering support and patience during the intense periods of development and debugging. Their belief in my abilities kept me motivated to overcome the technical challenges encountered along the way.

Finally, I would like to thank **Nanyang Technological University** for providing the academic foundation that made this work possible.

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Chapter 1

Introduction

1.1 Background

In the rapidly evolving landscape of speech processing technologies, the **Speech Gateway API** serves as a critical infrastructure for delivering advanced speech services to various applications. **Speech Gateway** is a backend service that provides Speech-to-Text (STT) capabilities to end users through a secured API. It acts as a **middle layer** between client applications and an underlying Speech Engine. Instead of allowing clients to call the speech engine directly, Speech Gateway centralizes authentication, access control, token issuance, and (in this project) subscription/payment management.

As the demand for these services grows, the need for a robust, centralized management system becomes paramount. Traditionally, interacting with such APIs required direct integration and manual management, which can be inefficient for end-users and administrators alike. The **Gateway Dashboard** project was initiated to bridge this gap, providing a user-friendly graphical interface that empowers users to manage their speech processing tasks while giving administrators the tools needed to oversee system operations, manage users, and monetize services effectively.

1.2 Problem Statement

Prior to this project, the Speech Gateway ecosystem faced several challenges:

1. **Limited Access Control:** The existing system lacked a flexible authentication mechanism, supporting only basic credentials without modern Single Sign-On (SSO) capabilities.

2. **Absence of Monetization Infrastructure:** There was no automated system to handle subscriptions, billing, or tiered access plans, hindering the commercial viability of the services.

1.3 Project Objectives

The primary objective of this project is to design and implement a comprehensive **Gateway Dashboard** and enhance the backend infrastructure to support commercial-grade features. Specific objectives include:

- **SSO Integration:** Implement secure Single Sign-On (Google, Apple) to streamline user authentication, reduce credential fatigue, and centralize identity management across services.
- **Payment Portal:** Design a subscription and payment module integrating Stripe to handle recurring billing, automated invoicing, and subscription lifecycle management.
- **Frontend Development:** Develop a web-based dashboard using Vue.js and Vuetify to provide an intuitive interface for users to access speech services and manage their data.

1.4 Project Scope

The project scope encompasses three major components: Single Sign-On (SSO) Authentication, Payment & Subscription Management with Stripe Integration, and Frontend Dashboard Development.

1.4.1 Single Sign-On (SSO) Authentication

This component enables users to authenticate using their existing social accounts or traditional credentials.

Key Features:

- **Google SSO:** OAuth 2.0 integration with state management for CSRF protection.
- **Apple SSO:** Apple Sign In integration with token verification and privacy-preserving email relay.
- **JWT Token Management:** Generation and validation of access tokens (15-minute expiry) and refresh tokens with secure cookie storage (HttpOnly, Secure, SameSite).
- **Token Blacklisting:** Redis-based blacklist for immediate token revocation on logout or security events.
- **Traditional Authentication:** Email/password authentication with bcrypt hashing.
- **Session Security:** CSRF protection, XSS prevention, and secure token lifecycle management.

1.4.2 Payment Portal with Stripe Integration

This component handles monetization through Stripe, enabling tiered subscription plans with usage-based quotas.

Key Features:

- **Stripe Checkout:** Hosted checkout session creation and payment processing.
- **Webhook Handling:** Secure webhook signature verification and idempotent event processing for payment lifecycle events.

- **Plan Management:** JSON-based plan configuration with versioning support and admin API.
- **Redis Caching:** Fast plan retrieval and Stripe price data caching with automatic cache invalidation.
- **Subscription Synchronization:** Real-time sync between Stripe and internal database for subscription status.
- **Quota Management:** Usage tracking and access control middleware enforcing plan limits.
- **Payment UI:** Plan comparison cards, checkout flow, and subscription management interface.

1.4.3 Frontend Dashboard

This component provides a complete Single Page Application (SPA) using Vue.js 2 and Vuetify with Material Design.

Key Features:

- **Authentication UI:** Sign In, Sign Up pages with SSO integration and OAuth callback handling.
- **Protected Routing:** Vue Router with role-based navigation guards and lazy loading for performance.
- **State Management:** Vuex store for centralized state management (auth, user, subscription, plans).
- **HTTP Interceptors:** Automatic JWT token injection, token refresh logic, and retry mechanisms.
- **User Dashboard:** Subscription status display, usage quota tracking with progress indicators, profile management.
- **Admin Interface:** Plans management with JSON editor, validation, and version history.
- **Responsive Design:** Mobile and desktop layouts with Vuetify components and intuitive UX.

Chapter 2

Literature Review

This chapter examines the key technology decisions for the Gateway Dashboard, focusing on SSO provider selection, payment platform comparison, Redis caching importance, and token management strategies.

2.1 SSO Provider Selection

The Gateway Dashboard implements Google and Apple SSO as primary authentication methods.

2.1.1 SSO Provider Comparison

Table 2.1 compares major SSO providers:

Table 2.1: SSO Provider Comparison

Provider	**Market Share**	**Key Advantage**	**Status**
Google	71% (Android)	2B+ users, mature API	**Implemented**
Apple	28% (iOS)	Privacy-focused, email relay	**Implemented**
Microsoft	Enterprise strong	Azure AD integration	Other dev
Facebook	2.9B users	Large user base	Excluded (privacy)
GitHub	Developer focus	Dev community	Not needed

2.1.2 Why Google and Apple

Selection Rationale:

1. **Market Coverage:** 95%+ of internet users have Google or Apple accounts [50, 49]
2. **User Convenience:** Eliminates credential fatigue; most developers already have these accounts
3. **Technical Maturity:** Robust OAuth 2.0 implementations with 99.9%+ uptime [20, 2]
4. **Team Division:** Microsoft SSO handled by another developer, avoiding duplicate work
5. **Security:** Both provide 2FA, fraud detection, and privacy features

2.2 Payment Platform Selection: Stripe vs PayPal

2.2.1 Comparison Overview

Table 2.2 compares Stripe and PayPal:

Table 2.2: Stripe vs PayPal Comparison

Criteria	**Stripe**	**PayPal**
Transaction Fee	2.9% + $0.30	2.9% + $0.30
API Quality	RESTful, excellent docs [51]	Complex multi-generation APIs
Checkout Flow	Embedded (no redirect)	Redirect-based (-10-15% conversion) [6]
Subscriptions	Native billing, prorated upgrades [52]	Limited flexibility
Webhooks	Auto-retry, signature verification [48]	Basic webhook support
Integration Time	40% faster [24]	Slower, complex documentation
Developer Focus	✓Strong	Limited
Metered Billing	✓Supported	Not supported

2.2.2 Why Stripe

Decision: Stripe chosen for:

- **Subscription Requirements:** Native support for tiered plans, quotas, prorated changes, automated renewals
- **Developer Experience:** Superior API design, documentation, official SDK for Node.js
- **Embedded Checkout:** Maintains user context, better conversion rates
- **Webhook Reliability:** Ensures payment-database consistency with idempotency
- **Target Audience:** Developers value functionality over PayPal's consumer brand

2.3 Redis Caching: Critical Importance

Redis is essential for both **performance** and **security** in the Gateway Dashboard.

2.3.1 Redis Use Cases

Table 2.3 summarizes Redis applications:

Table 2.3: Redis Usage in Gateway Dashboard

Use Case	**Purpose**	**Performance Gain**	**TTL**
Plan Caching	Reduce DB load	95%+ load reduction	1 hour
Stripe Price Caching	Minimize API calls	Sub-ms retrieval	24 hours

2.3.2 Why Redis is Critical

1. **Performance:** Sub-millisecond access times [8], in-memory storage
2. **Scalability:** Handles millions of requests/second, horizontally scalable
3. **Database Protection:** Shields MongoDB from read-heavy workloads (99% read, 1% write)
4. **Cache Strategy:** Cache-aside pattern [12] with automatic invalidation
5. **Persistence:** RDB snapshots prevent data loss during restarts

Implementation: Cache warming on startup, automatic invalidation on plan updates, TTL-based expiration.

2.4 Token Management Strategy

Token management balances **security**, **scalability**, and **user experience**.

2.4.1 Token Architecture

Table 2.4 details the token strategy:

Table 2.4: Token Management Strategy

Feature	**Implementation**	**Purpose**
Access Token	JWT, 15-min expiry	Minimize compromise window [29]
Refresh Token	7-day expiry, rotation	Seamless re-auth [47]
Blacklisting	MongoDB (TTL Index)	Revocation (Logouts/New Login)
Storage	LocalStorage	XSS protection via sanitization
Stateless Auth	JWT self-contained	Horizontal scalability

2.4.2 Why This Approach

- **Stateless Scalability:** JWTs don't require DB lookup on every request [26]
- **Security Layers:** Short-lived tokens + blacklist + secure cookies
- **User Experience:** Automatic refresh = no frequent logins
- **Immediate Revocation:** Redis blacklist solves JWT's "can't revoke" problem
- **Performance:** Sub-millisecond blacklist checks, no DB bottleneck

2.5 Summary

Table 2.5 summarizes key technology decisions:

Table 2.5: Technology Decision Summary

Component	**Choice**	**Key Reason**
SSO Providers	Google + Apple	95%+ user coverage, Microsoft by other dev
Payment	Stripe	Better API, subscriptions, webhooks vs PayPal
Caching	Redis	High-performance caching for plans and prices
Token Strategy	JWT + MongoDB TTL	Stateless scalability + effective revocation

Core Principles: All choices prioritize developer experience, security, performance, and scalability for the API management domain.

Chapter 3

System Architecture

This chapter provides a comprehensive overview of the Gateway Dashboard system architecture, detailing the technology stack, component interactions, and database design decisions that underpin the platform.

3.1 Overview

The Gateway Dashboard system follows a modern three-tier architecture consisting of a **Vue.js** frontend, a **NestJS** backend API, and integration with external services. This separation of concerns ensures scalability, maintainability, and clear boundaries between presentation, business logic, and data persistence layers.

3.1.1 High-Level Architecture

Figure 3.1 illustrates the overall system architecture. The frontend communicates with the backend through RESTful APIs, while the backend interacts with external services such as Stripe for payment processing and OAuth providers for authentication.

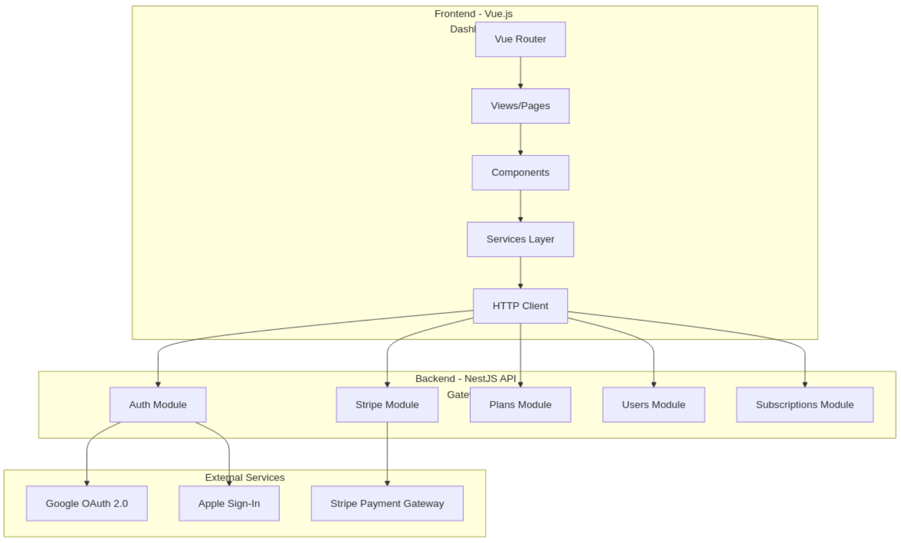


Figure 3.1: High-Level System Architecture

The architecture diagram details the data flow within the system. The **Frontend** layer consists of Vue Router directing requests to Views/Pages, which utilize Components and a Services Layer that communicates via an HTTP Client. The **Backend** layer comprises modular NestJS components: Auth, Stripe, Plans, Users, and Subscriptions modules. The **External Services** layer includes Google OAuth 2.0, Apple Sign-In, and Stripe Payment Gateway for third-party integrations.

3.1.2 Component Overview

The system is composed of the following major components:

- **Frontend Dashboard**: A Single Page Application (SPA) built with Vue.js 3 and Vuetify, providing user interfaces for authentication, subscription management, and administrative functions.
- **Backend API Gateway**: A NestJS-based REST API that handles authentication, authorization, business logic, and orchestration of external services.
- **Database Layer**: MongoDB serves as the primary data store for users, subscriptions, plans, and tokens, with Redis providing caching for frequently accessed data.
- **External Services**: Integration with Google OAuth 2.0, Apple Sign-In, and Stripe for third-party authentication and payment processing.

3.1.3 Communication Flow

The typical request flow proceeds as follows:

1. The user interacts with the Vue.js frontend through the browser.
2. The frontend dispatches HTTP requests to the backend API via Axios interceptors.
3. The backend validates the JWT token, checks authorization, and processes the request.
4. Business logic is executed, interacting with MongoDB, Redis, or external APIs as needed.
5. The response is returned to the frontend, which updates the user interface accordingly.

3.2 Technology Stack

The Gateway Dashboard leverages modern, industry-standard technologies to ensure robustness, scalability, and developer productivity.

3.2.1 Frontend Technologies

Technology	Version	Purpose
Vue.js	3.x	Progressive JavaScript framework for building user interfaces
Vuetify	3.x	Material Design component framework for Vue.js
Vue Router	4.x	Official router for single-page application navigation
Axios	Latest	Promise-based HTTP client for API communication

Table 3.1: Frontend Technology Stack

Vue.js 3 was selected for its Composition API, improved performance, and excellent TypeScript support. **Vuetify 3** provides a comprehensive set of Material Design components, enabling rapid UI development with a professional appearance.

3.2.2 Backend Technologies

Technology	Version	Purpose
NestJS	10.x	Progressive Node.js framework for server-side applications
TypeScript	5.x	Typed superset of JavaScript for enhanced code quality
Passport	0.7.x	Authentication middleware for Node.js
JWT	Latest	JSON Web Token for stateless authentication

Table 3.2: Backend Technology Stack

NestJS provides a modular architecture with built-in dependency injection support, ideal for enterprise-grade applications. TypeScript ensures type safety and improved developer experience. **Passport** offers a flexible authentication framework with extensive strategy support for OAuth providers.

3.2.3 Data Storage and Caching

Technology	Version	Purpose
MongoDB	6.x	NoSQL document database for flexible schema design
Redis	7.x	In-memory data store for caching

Table 3.3: Storage Technologies

MongoDB was chosen for its schema flexibility, horizontal scalability, and native JSON support. **Redis** is primarily used for caching frequently accessed data (plans, prices) to reduce database load and API latency.

Caching Architecture

Figure 3.2 illustrates the caching architecture for the Plan module. The service layer first checks Redis for cached data, falling back to MongoDB on cache misses.

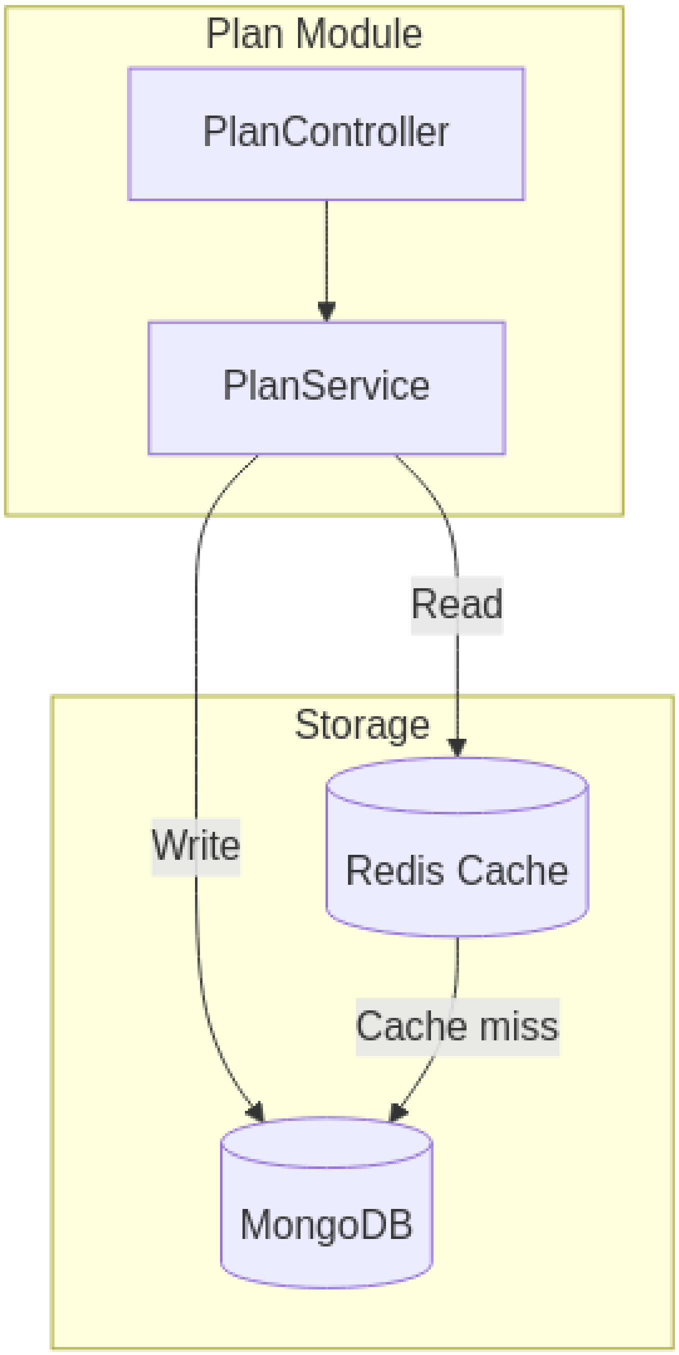


Figure 3.2: Plan Module Caching Architecture

As depicted in Figure 3.2, the Plan Module implements a read-through caching strategy. When a request for plans is received, the `PlanService` first queries the Redis cache. If the data is found (cache hit), it is returned immediately. If not (cache miss), the service retrieves the data from MongoDB, stores it in Redis for future requests, and then returns it to the controller.

Figure 3.3 shows the detailed cache flow for retrieving the latest plans. This strategy includes cache penetration protection by caching NULL values for a short duration when no plans exist.

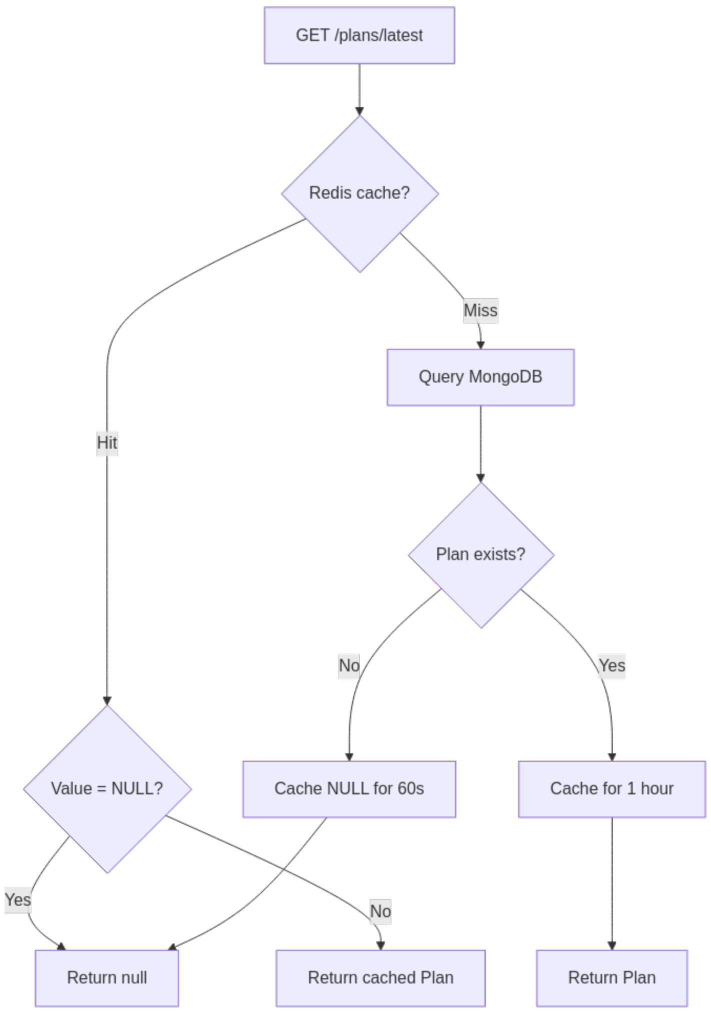


Figure 3.3: Cache Flow for Latest Plans Retrieval

Figure 3.3 provides a granular view of the ”get latest plans” logic. It highlights the cache penetration protection mechanism: if a database query returns no plans, a special `NULL` value is cached for a short duration (e.g., 60 seconds). This prevents repeated queries for non-existent data from overwhelming the database essentially acting as a shield during high-traffic periods.

3.2.4 External Services

- **Stripe**: Payment processing platform for subscription billing, checkout sessions, and webhook handling.
- **Google OAuth 2.0**: Identity provider for social login functionality.
- **Apple Sign-In**: Authentication service for iOS and web users.

These third-party services were selected for their reliability, comprehensive documentation, and industry adoption, reducing development time while ensuring security and compliance.

3.3 Database Design

The database schema is designed to support user management, authentication, subscription tracking, and service plan versioning. MongoDB's document-oriented approach allows for flexible schema evolution.

3.3.1 Core Collections

The system utilizes the following primary collections:

Users Collection

The `users` collection stores user account information and authentication credentials.

Field	**Type**	**Description**
_id	ObjectId	Primary key
email	String	User email (unique)
password	String	Hashed password
name	String	Full name
role	String	User role (user/admin)
type	String	Account type (trial/paid)
isVerified	Boolean	Email verification status

Table 3.4: Users Collection Schema

Subscriptions Collection

The `subscriptions` collection tracks user subscriptions and quota usage.

Field	**Type**	**Description**
_id	ObjectId	Primary key
user	ObjectId	Reference to users collection
stripeSubscriptionId	String	Stripe subscription ID
stripeCustomerId	String	Stripe customer ID
planName	String	Current plan name
priceId	String	Stripe price ID
planId	String	Internal plan identifier
scheduledPriceId	String	Next scheduled price ID
scheduledPlanId	String	Next scheduled plan ID
scheduledPlanName	String	Next scheduled plan name
stripeScheduleId	String	Stripe schedule ID
status	String	Subscription status (active, canceled, etc.)
quota	Object	Service quotas (batch, live duration)
usage	Object	Current usage tracking
startDate	Date	Subscription start date
endDate	Date	Subscription end date

Table 3.5: Subscriptions Collection Schema

The `quota` and `usage` fields store nested objects tracking batch and live processing durations in seconds. A value of -1 indicates unlimited access.

Plans Collection

The `plans` collection maintains versioned service plans.

Field	**Type**	**Description**
_id	ObjectId	Primary key
id	String	Unique plan identifier
plans	String	JSON string of plan details
version	Number	Plan version (auto-increment)
createdAt	Date	Creation timestamp

Table 3.6: Plans Collection Schema

Storing plans as JSON strings enables dynamic schema evolution without database migrations.

3.3.2 Authentication Collections

To ensure secure session management, two additional collections were introduced:

UserTokens Collection

The `usertokens` collection tracks active JWT tokens for each user.

Field	**Type**	**Description**
_id	ObjectId	Primary key
userId	String	User identifier
token	String	JWT token string
expiresAt	Date	Token expiration (TTL indexed)
userAgent	String	Client user agent
ipAddress	String	Client IP address

Table 3.7: UserTokens Collection Schema

MongoDB's TTL (Time-To-Live) index on `expiresAt` automatically removes expired tokens.

TokenBlacklist Collection

The `tokenblacklists` collection stores revoked tokens to prevent reuse.

Field	**Type**	**Description**
_id	ObjectId	Primary key
token	String	Revoked JWT token
userId	String	User identifier
expiresAt	Date	Original token expiration
reason	String	Revocation reason

Table 3.8: TokenBlacklist Collection Schema

3.3.3 Entity Relationships

Figure 3.4 illustrates the relationships between core collections:

- Each `user` has zero or one `subscription`.
- Each `subscription` references a `plan` by Stripe priceId.
- Each `user` may have multiple active `tokens`.
- Revoked tokens are stored in `tokenblacklist`.

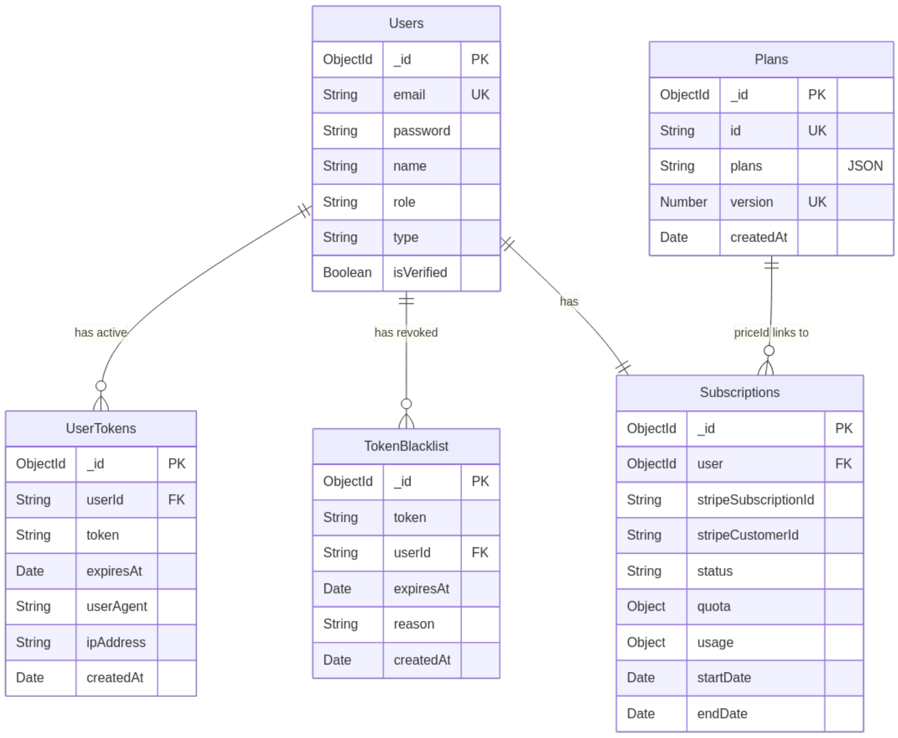


Figure 3.4: Entity Relationship Diagram

The Entity Relationship Diagram in Figure 3.4 showcases the database schema. The `Users` collection is central, linking to `Subscriptions` (1:1 relationship) and multiple `UserTokens`. The `Subscriptions` collection contains embedded objects for `quota` and `usage`, allowing efficient tracking of service limits. The `Plans` collection stands independently but is logically referenced by subscriptions via price IDs. The `TokenBlacklist` stores revoked tokens, ensuring security compliance.

Chapter 4

Detailed Implementation

This chapter provides a comprehensive examination of the key implementation details of the Gateway Dashboard system. It is organized into two main parts: Backend Implementation covering authentication and payment systems, and Frontend Development covering the Vue.js dashboard application.

4.1 Backend Implementation

This section covers the server-side implementation including Single Sign-On (SSO) authentication and payment/subscription management.

4.1.1 SSO Implementation

This subsection provides a comprehensive examination of the authentication system implemented in the Gateway Dashboard. It covers the supported authentication methods, detailed flow descriptions, and key implementation details.

Overview

The Gateway Dashboard supports three authentication methods:

- **Google OAuth 2.0**: Full OAuth flow with Passport.js strategy
- **Apple Sign-In**: POST callback with JWT token verification
- **Traditional Email/Password**: bcrypt-hashed credentials

Figure 4.1 illustrates the SSO architecture showing how both providers integrate with the AuthService.

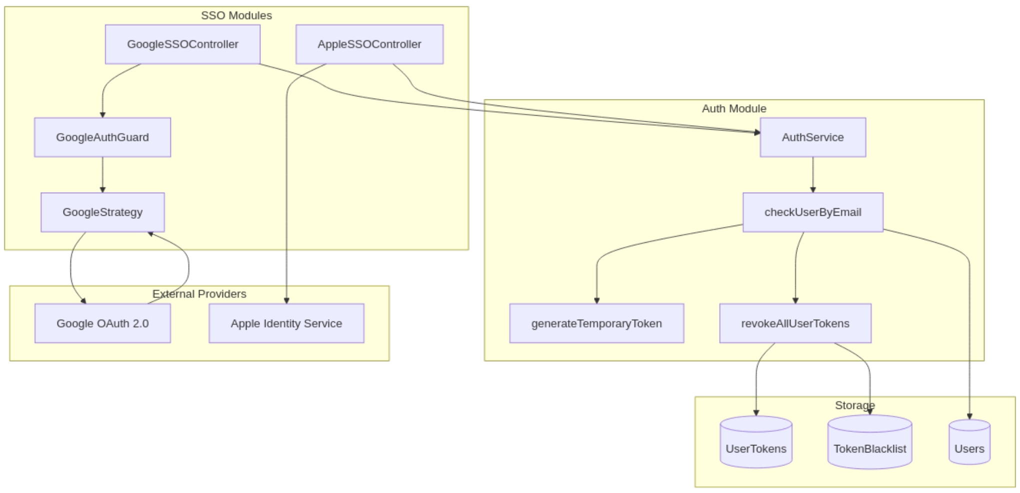


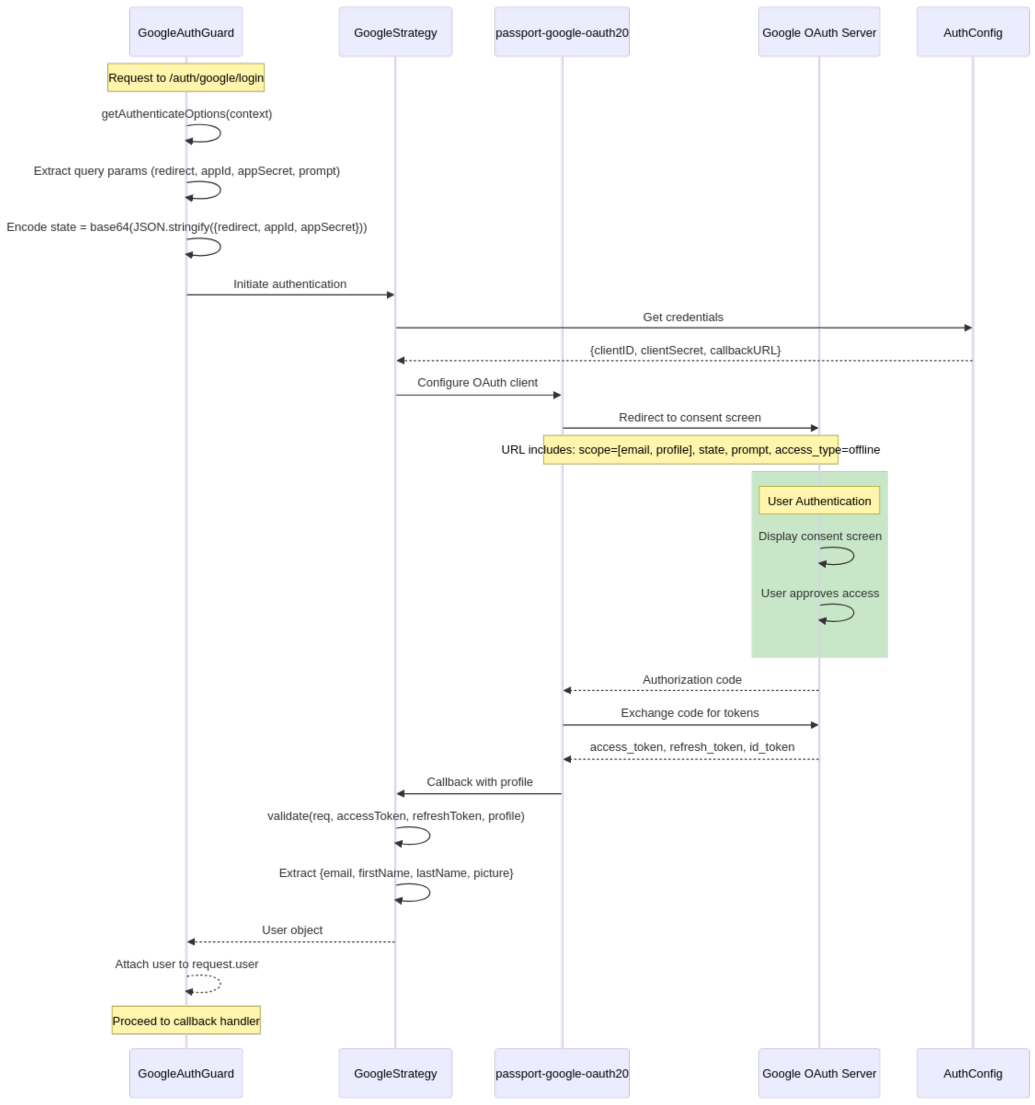
Figure 4.1: SSO Authentication Architecture

Both SSO providers share a common flow: after identity verification, the system checks if the user exists. For new users, a temporary token is generated requiring password setup; for existing users, an access token is issued directly.

Google OAuth 2.0 Implementation

Google SSO uses the `passport-google-oauth20` strategy integrated with NestJS guards.
Google OAuth Flow

Figure 4.2 shows the complete OAuth flow including state parameter handling.



GoogleAuthGuard
GoogleStrategy
passport-google-oauth20
Google OAuth Server
AuthConfig
Request to /auth/google/login
getAuthenticateOptions(context)
Extract query params (redirect, appId, appSecret, prompt)
Encode state = base64(JSON.stringify({redirect, appId, appSecret}))
Initiate authentication
Get credentials
{clientID, clientSecret, callbackURL}
Configure OAuth client
Redirect to consent screen
URL includes: scope=[email, profile], state, prompt, access_type=offline
User Authentication
Display consent screen
User approves access
Authorization code
Exchange code for tokens
access_token, refresh_token, id_token
Callback with profile
validate(req, accessToken, refreshToken, profile)
Extract {email, firstName, lastName, picture}
User object
Attach user to request.user
Proceed to callback handler

Figure 4.2: Google OAuth 2.0 Authentication Flow

Google Strategy

The strategy is configured with OAuth credentials and requests email and profile scopes:

```
@Injectable()
export class GoogleStrategy extends PassportStrategy(Strategy, 'google') {
  constructor(
    @Inject(authConfig.KEY)
    private auth: ConfigType<typeof authConfig>,
  ) {
    super({
      clientID: auth.googleClientId,
      clientSecret: auth.googleClientSecret,
      callbackURL: auth.googleCallbackURL,
      scope: ['email', 'profile'],
      passReqToCallback: true,
    })
  }

  async validate(
    req: any,
    accessToken: string,
    _refreshToken: string,
    profile: any,
    done: VerifyCallback,
  ): Promise<any> {
    const { name, emails, photos } = profile
    const user = {
      email: emails[0].value,
      firstName: name.givenName,
      lastName: name.familyName,
      picture: photos[0].value,
      accessToken,
    }
    done(null, user)
  }
}
```

Listing 4.1: Google Strategy Configuration

State Parameter for Context Preservation

Figure 4.3 illustrates how state parameters are preserved through the OAuth redirect to maintain user session context (e.g., redirect URL).

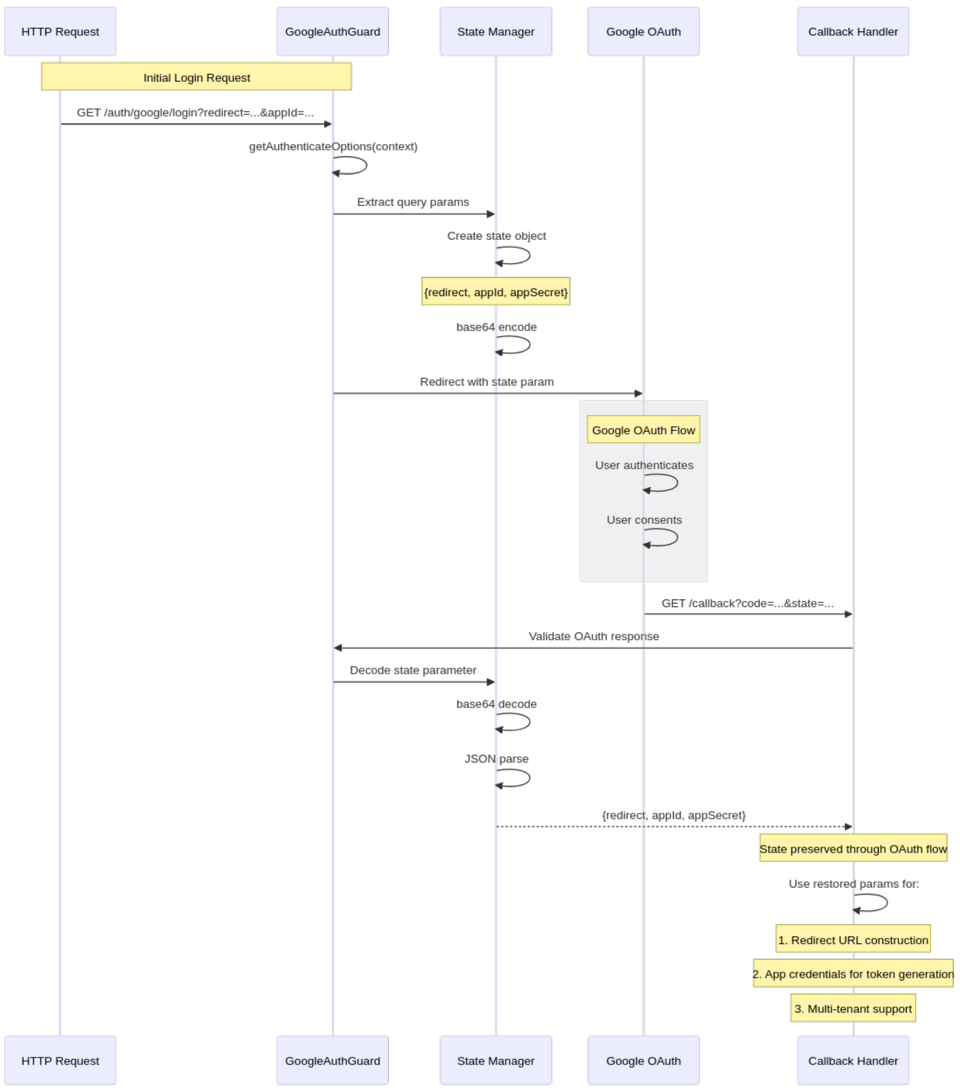


Figure 4.3: State Parameter Encoding Flow

The `GoogleAuthGuard` encodes query parameters into a base64 state parameter:

```
@Injectable()
export class GoogleAuthGuard extends AuthGuard('google') {
  getAuthenticateOptions(context: ExecutionContext) {
    const request = context.switchToHttp().getRequest()
    const { redirect, appId, appSecret, prompt } = request.query

    // Encode query parameters into state to preserve them through OAuth flow
    const state = JSON.stringify({
      redirect: redirect || null,
      appId: appId || null,
      appSecret: appSecret || null,
    })

    return {
      state: Buffer.from(state).toString('base64'),
      prompt: prompt || 'select_account', // Force account selection
      access_type: 'offline', // For refresh tokens
    }
  }
}
```

Listing 4.2: Google Auth Guard with State Encoding

Apple Sign-In Implementation

Figure 4.4 shows the Apple Sign-In flow which uses POST callback instead of redirect-based OAuth.

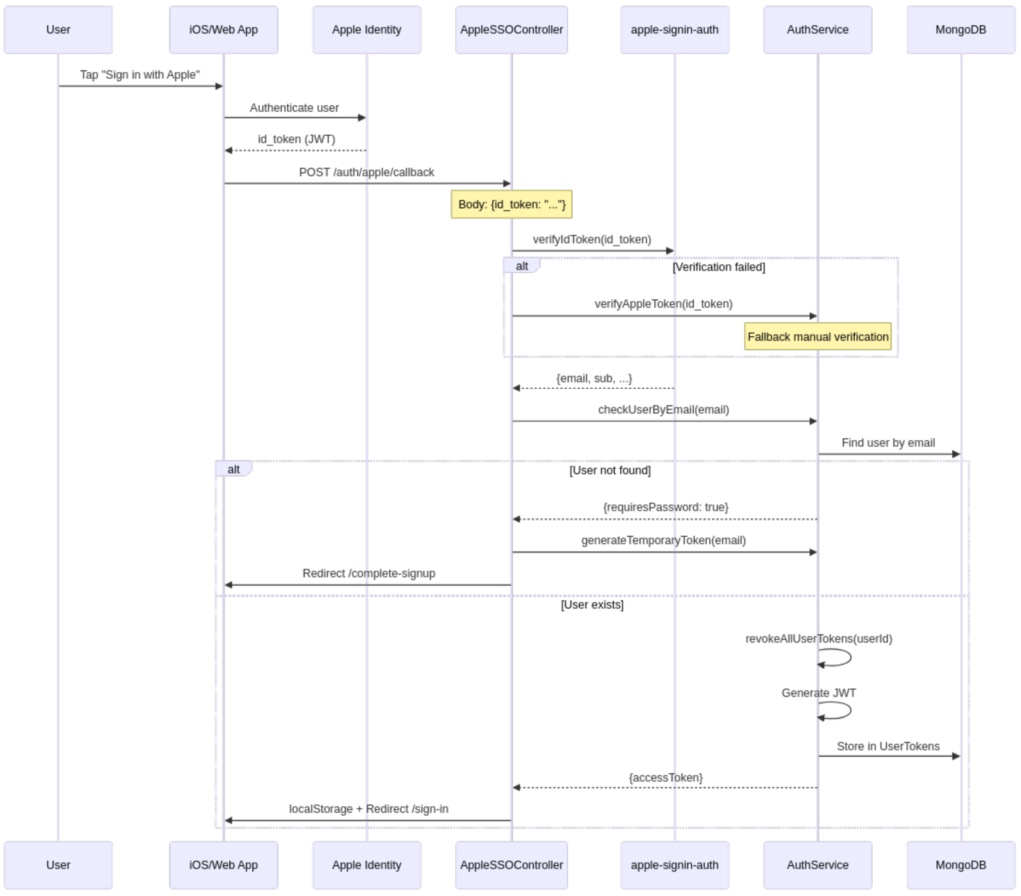


Figure 4.4: Apple Sign-In Authentication Flow

Token Verification

Apple tokens are verified using the `apple-signin-auth` library with fallback to manual verification:

```
@Controller('auth/apple')
export class AppleSSOController {
  constructor(private readonly authService: AuthService) {}

  @Post('callback')
  async appleAuthCallback(@Body() body: AppleAuthDto, @Res() res: Response) {
    if (!body.code && !body.id_token) {
      return res.status(HttpStatus.UNAUTHORIZED).json({
        message: 'Apple authentication failed: No id_token received',
      })
    }

    let appleResponse
    try {
      appleResponse = await appleSignin.verifyIdToken(body.id_token, {
        audience: process.env.APPLE_CLIENT_ID,
        ignoreExpiration: false,
      })
    } catch (verifyError) {
      // Fallback to manual verification
      appleResponse = await this.authService.verifyAppleToken(body.id_token)
    }

    const result = await this.authService.checkUserByEmail(appleResponse.email)
    // Handle new/existing user and redirect
  }
}
```

Listing 4.3: Apple SSO Controller

Token Management

Figure 4.5 illustrates the complete token lifecycle from generation to revocation.

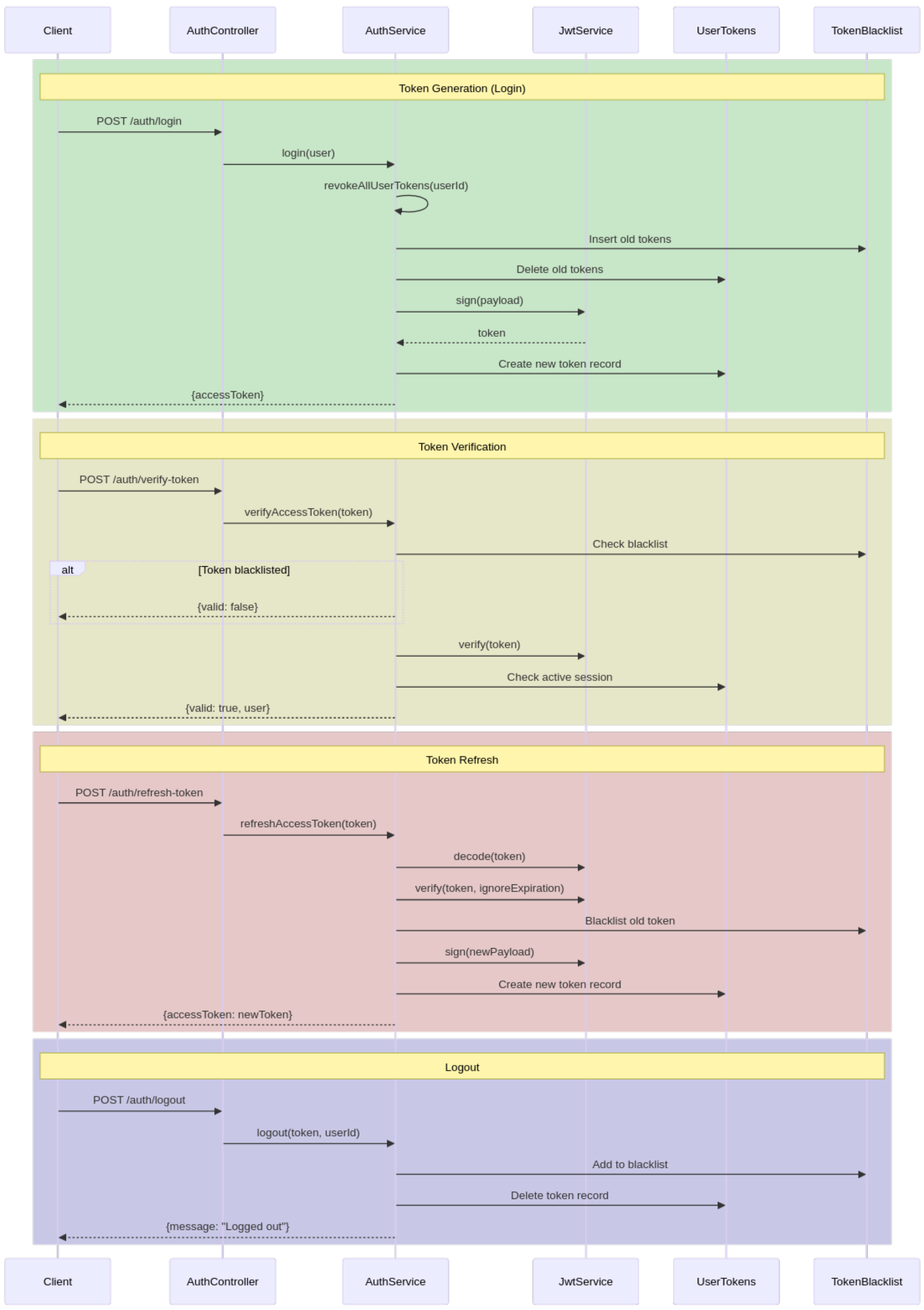


Figure 4.5: JWT Token Lifecycle Management

When users authenticate via SSO:

1. **New Users**: A 15-minute temporary JWT is generated with `need_password: true`. The frontend redirects to `/complete-signup` where the user sets a password.

2. **Existing Users**: All previous tokens are revoked (single-session policy), a new JWT is issued, and stored in the `usertokens` collection.

3. **Token Revocation**: On new login, all active tokens are blacklisted in `tokenblacklists` collection.

Token Blacklisting Flow

Figure 4.6 shows how tokens are blacklisted for security.

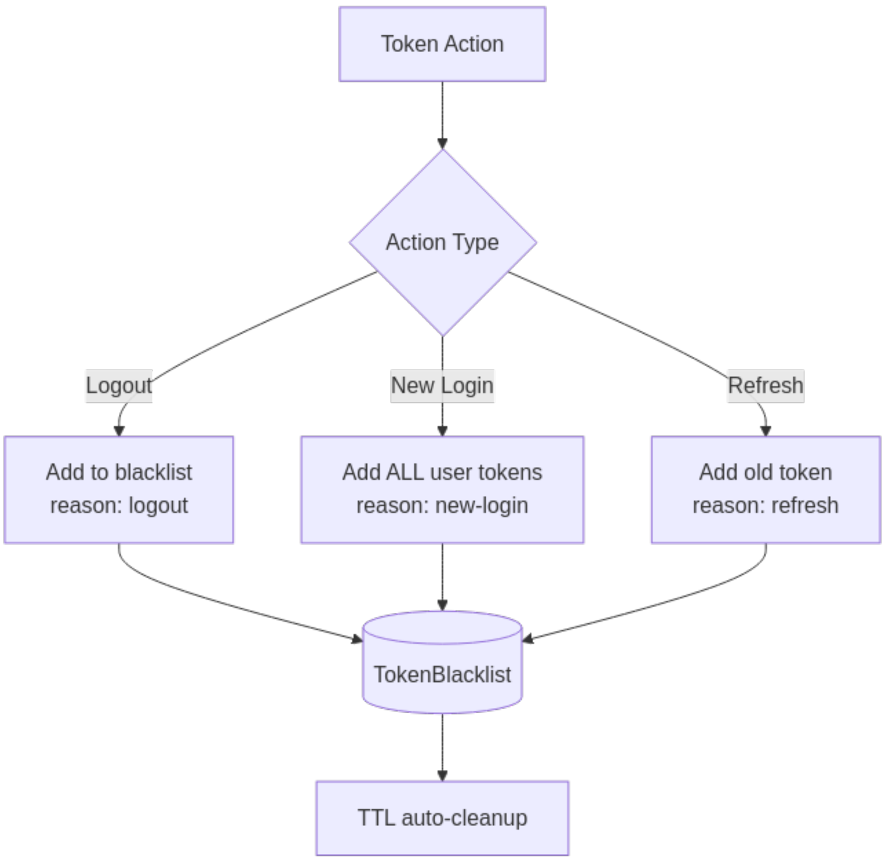

Token Action
Action Type
Logout
New Login
Refresh
Add to blacklist reason: logout
Add ALL user tokens reason: new-login
Add old token reason: refresh
TokenBlacklist
TTL auto-cleanup

Figure 4.6: Token Blacklisting Flow

```
async generateTemporaryToken(email: string, appId?: string): Promise<string> {
  const payload = {
    email: email.toLowerCase(),
    need_password: true,
    appId: appId || null,
  }
  return this.jwtService.sign(payload, { expiresIn: '15m' })
}
```
Listing 4.4: Temporary Token Generation

Module Structure

Figure 4.7 shows the Google SSO module organization.

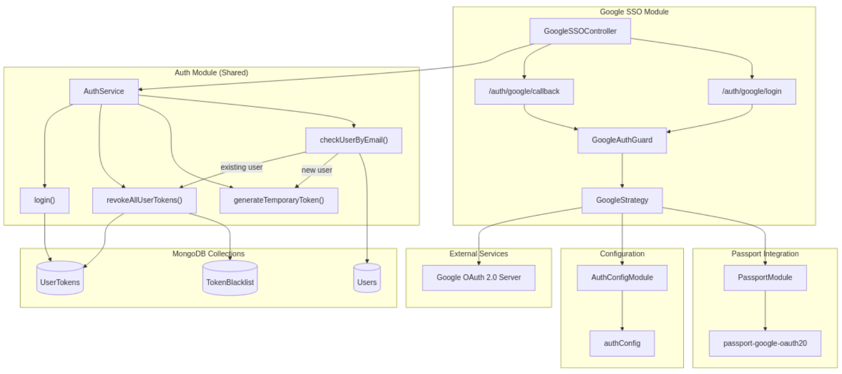


Figure 4.7: Google SSO Module Structure

The SSO modules are organized as independent NestJS modules:

- `GoogleSSOModule`: Imports `PassportModule`, `AuthModule`; provides `GoogleStrategy`
- `AppleSSOModule`: Imports `AuthModule`; uses `apple-signin-auth` library

Both modules delegate user creation and authentication logic to the shared `AuthService`.

4.1.2 Payment & Subscription Management

This subsection documents the payment processing and subscription management system built with Stripe integration, Redis caching, and MongoDB persistence.

Architecture Overview

Figure 4.8 illustrates the payment system architecture showing the interaction between modules.

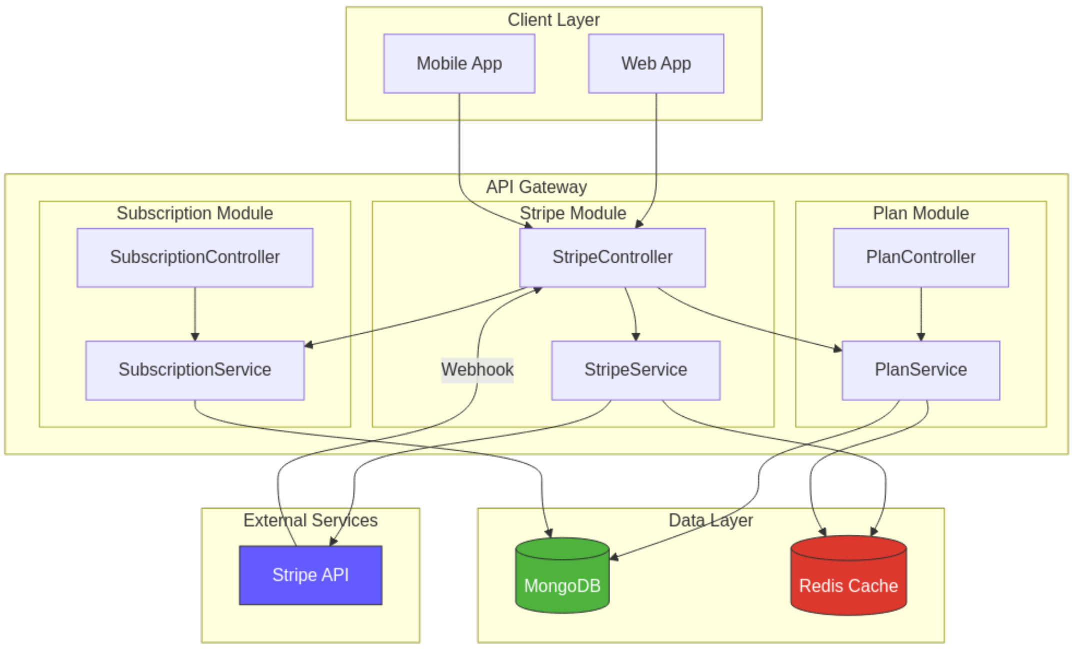


Figure 4.8: Payment System Architecture

The payment system consists of three main modules:

- **StripeModule**: Handles Stripe API interactions, checkout sessions, webhooks
- **PlanModule**: Manages subscription plans with versioning and Redis caching
- **SubscriptionModule**: Tracks user subscriptions, quotas, and usage

Plan Management

Plans are stored as versioned JSON documents, cached in Redis for fast retrieval.
Plan Schema

```
@Schema({ timestamps: { createdAt: true, updatedAt: false } })
export class Plan extends Document {
  @Prop({ required: true, type: String, unique: true })
  id: string;

  @Prop({ required: true, type: String })
  plans: string; // JSON string of plan details

  @Prop({ required: true, type: Number, unique: true })
  version: number;

  createdAt?: Date;
}
```

Listing 4.5: Plan Schema Definition

Plan Versioning

Figure 4.9 shows how plan versions are managed over time.

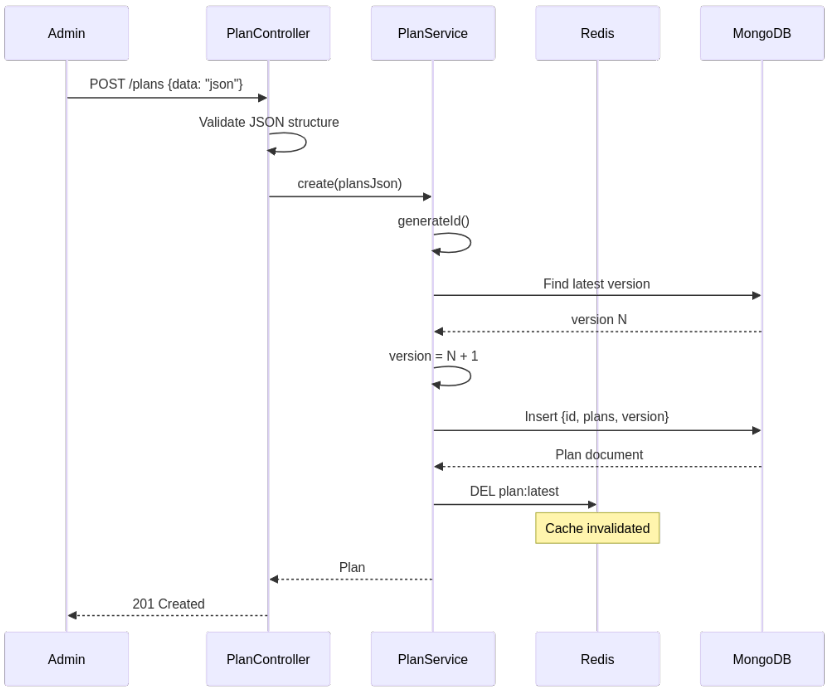
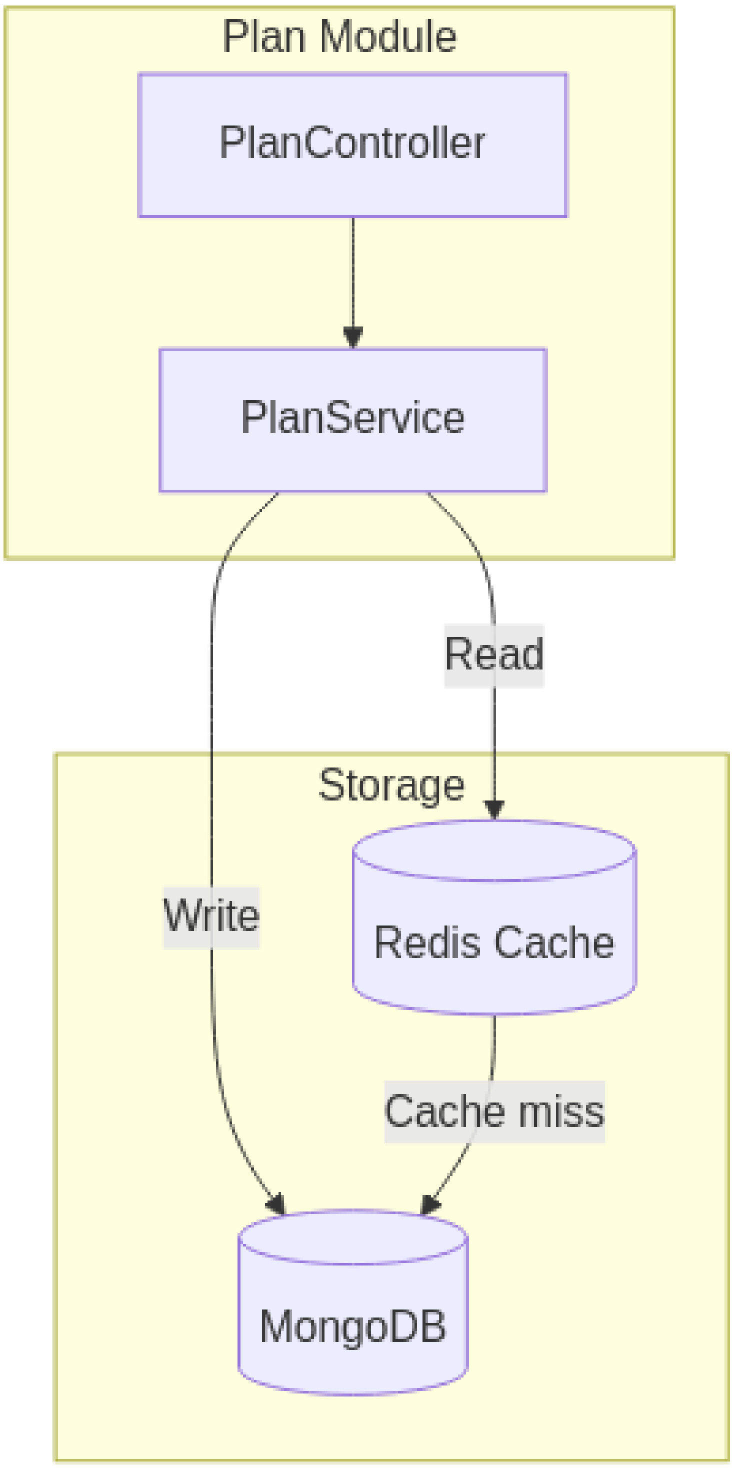


Figure 4.9: Plan Versioning Flow

Redis Caching with Cache Penetration Protection

Figure 3.2 illustrates the cache-aside pattern with NULL value caching.



```
@Injectable()
export class PlanService implements OnModuleInit, OnModuleDestroy {
  private readonly CACHE_KEY = 'plan:latest';
  private readonly CACHE_TTL = 3600; // 1 hour
  private readonly NULL_TTL = 60; // 60 seconds

  async getLatestVersion(): Promise<Plan | null> {
    const cached = await this.redisClient.get(this.CACHE_KEY);
    if (cached) {
      if (cached === 'NULL') return null; // Cache penetration protection
      return JSON.parse(cached) as Plan;
    }

    const latestPlan = await this.planModel
      .findOne().sort({ version: -1 }).exec();

    if (latestPlan) {
      await this.redisClient.set(this.CACHE_KEY, JSON.stringify(latestPlan), {
        EX: this.CACHE_TTL,
      });
    } else {
      await this.redisClient.set(this.CACHE_KEY, 'NULL', {
        EX: this.NULL_TTL,
      });
    }
    return latestPlan;
  }
}
```

Listing 4.6: Plan Caching Implementation

Stripe Integration

Checkout Flow

Figure 4.10 shows the complete Stripe Checkout flow from user request to subscription creation.

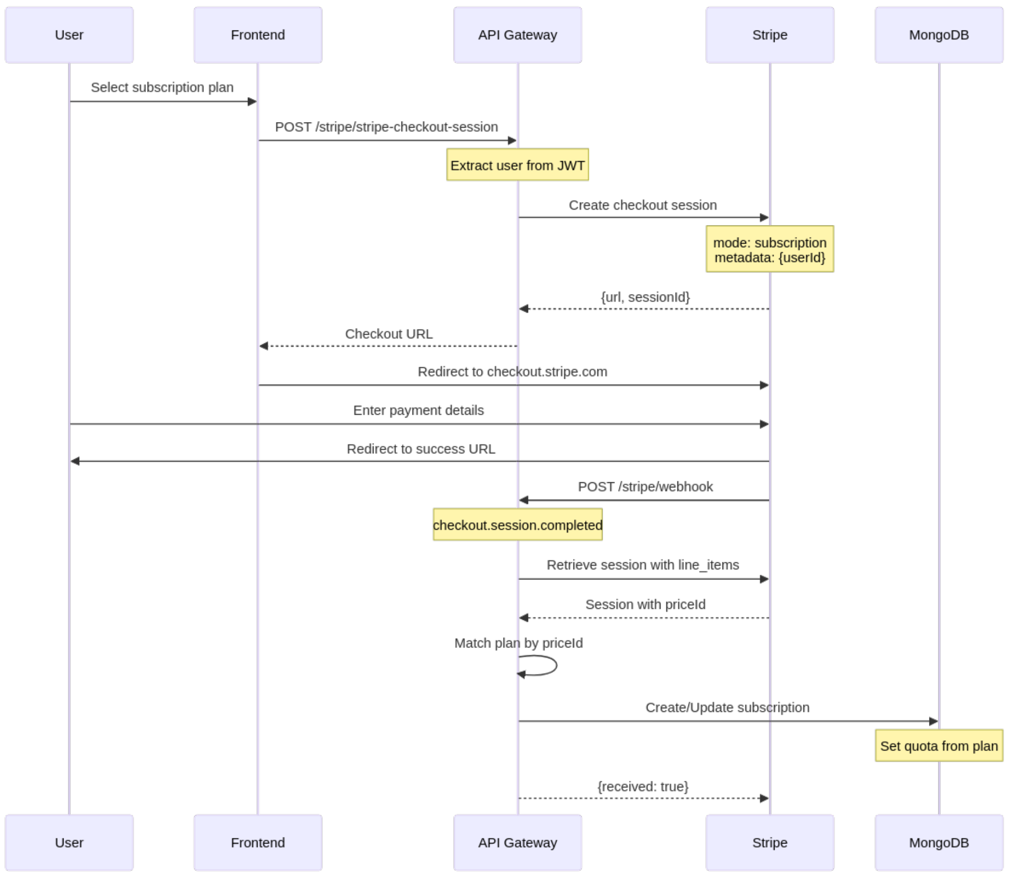


Figure 4.10: Stripe Checkout Session Flow

Checkout Session Creation

```
@UseGuards(JwtAuthGuard)
@Post('stripe-checkout-session')
async createCheckoutSession(@Body() dto: CreateCheckoutSessionDto, @Req() req)
   {
  const userId = req.user?._id?.toString();
  const customerEmail = req.user?.email;

  const result = await this.stripeService.createCheckoutSession(
    dto.priceId,
    customerEmail,
    customerName,
    userId, // Stored in metadata for webhook
  );
  return result;
}
```

Listing 4.7: Checkout Session Creation

Endpoint	`POST /stripe/stripe-checkout-session`
Request	`{ "priceId": "price_123..." }`
Response	`{ "url": "https://...", "sessionId": "cs_test..." }`

Table 4.1: API: Create Checkout Session

Subscription Scheduling

To support plan upgrades and downgrades without immediate billing impact, we implement a scheduling system using Stripe Subscription Schedules.
Scheduling Flow

Figure 4.11 details the sequence for scheduling a plan change.

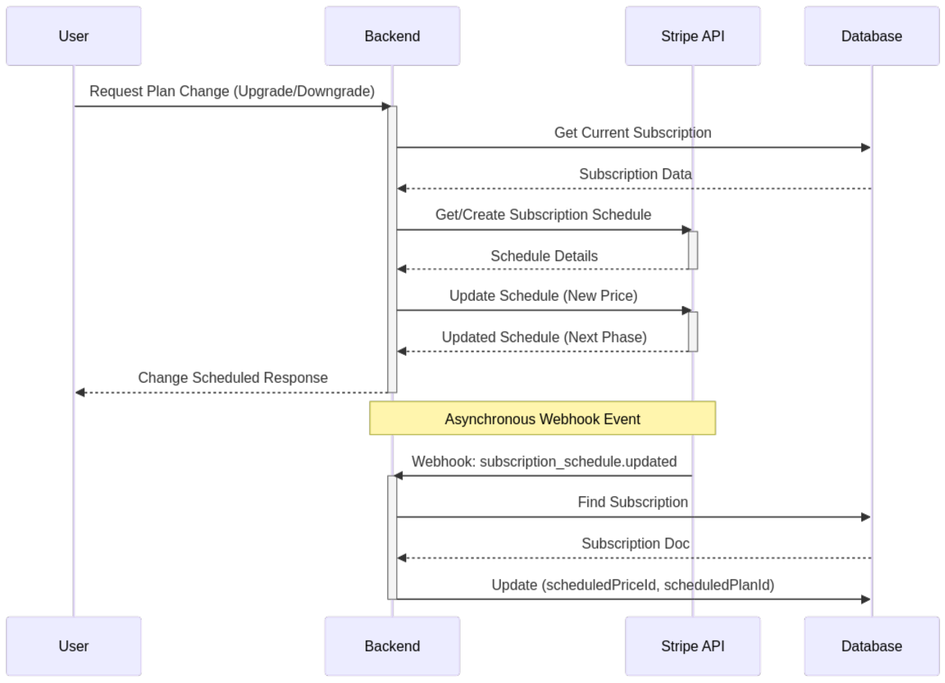

User
Backend
Stripe API
Database
Request Plan Change (Upgrade/Downgrade)
Get Current Subscription
Subscription Data
Get/Create Subscription Schedule
Schedule Details
Update Schedule (New Price)
Updated Schedule (Next Phase)
Change Scheduled Response
Asynchronous Webhook Event
Webhook: subscription_schedule.updated
Find Subscription
Subscription Doc
Update (scheduledPriceId, scheduledPlanId)

Figure 4.11: Subscription Plan Change Sequence

The `StripeService.schedulePlanChange` method handles this logic:

1. Retrieves current subscription details to identify the `current_period_end`.
2. Checks for any existing subscription schedules to prevent conflicts or duplicates.
3. If a schedule exists, it updates the subsequent phase with the new price.
4. If no schedule exists, it creates a new one from the current subscription and appends a new phase for the plan change.

Advanced Scheduling Logic

The implementation handles complex scenarios such as modifying an already scheduled change. As shown in Listing 4.8, the system first checks for an ‘active‘ or ‘`not_started`‘ schedule.

```typescript
async schedulePlanChange(subscriptionId: string, newPriceId: string) {
  // 1. Get current subscription items
  const subscription = await this.stripe.subscriptions.retrieve(
    subscriptionId, { expand: ['items'] }
  );

  // 2. Check for existing schedules
  const schedules = await this.stripe.subscriptionSchedules.list({
    customer: subscription.customer as string,
  });
  const activeSchedule = schedules.data.find(s =>
    s.subscription === subscriptionId &&
    (s.status === 'active' || s.status === 'not_started')
  );

  if (activeSchedule) {
    // 3a. Update existing schedule: keep current phase, update next
    const currentPhase = activeSchedule.phases[0];
    return this.stripe.subscriptionSchedules.update(activeSchedule.id, {
      phases: [
        { ...currentPhase }, // Preserve current billing period
        { items: [{ price: newPriceId, quantity: 1 }] } // New plan starts next
      ]
    });
  }

  // 3b. Create new schedule from subscription
  const schedule = await this.stripe.subscriptionSchedules.create({
    from_subscription: subscriptionId,
  });

  // 4. Update the newly created schedule
  return this.stripe.subscriptionSchedules.update(schedule.id, {
    phases: [
      { ...schedule.phases[0] }, // Current phase
      { items: [{ price: newPriceId, quantity: 1 }] } // Next phase
    ]
  });
}
```

Listing 4.8: Smart Scheduling Logic in StripeService

This approach ensures that user billing remains accurate. The user is not charged immediately; instead, the change takes effect exactly when the current billing cycle renews.

Managing Scheduled Changes

Users retain control over their scheduled changes. The system provides endpoints to retrieve schedule status and cancel pending changes if needed.

```typescript
@Post('get-schedule-info')
async getScheduleInfo(@Body() dto: GetScheduleInfoDto) {
  const schedule = await this.stripeService.getSubscriptionSchedule(
    dto.subscriptionId
  );
  if (!schedule) return { hasSchedule: false };

  const nextPhase = schedule.phases[1];
  return {
    hasSchedule: true,
    nextPriceId: nextPhase?.items[0]?.price,
    startDate: nextPhase?.start_date
  };
}

@Post('cancel-scheduled-change')
async cancelScheduledChange(@Body() dto: CancelScheduledChangeDto) {
  // Releases the schedule, reverting to standard subscription behavior
  return this.stripeService.cancelScheduledChange(dto.scheduleId);
}
```

Listing 4.9: Controller endpoints for Schedule Management

Endpoint	`POST /stripe/schedule-plan-change`
Request	`{ "subscriptionId": "sub_...", "newPriceId": "price_..." }`
Response	`{ "scheduleId": "sub_sched_...", "status": "active" }`

Table 4.2: API: Schedule Plan Change

Endpoint	`POST /stripe/get-schedule-info`
Request	`{ "subscriptionId": "sub_..." }`
Response	`{ "hasSchedule": true, "nextPriceId": "price_..." }`

Table 4.3: API: Get Schedule Info

Webhook Processing Logic

Webhooks are central to maintaining synchronization between Stripe and our database.
Webhook Flowchart

Figure 4.12 illustrates the decision logic for handling various Stripe events.

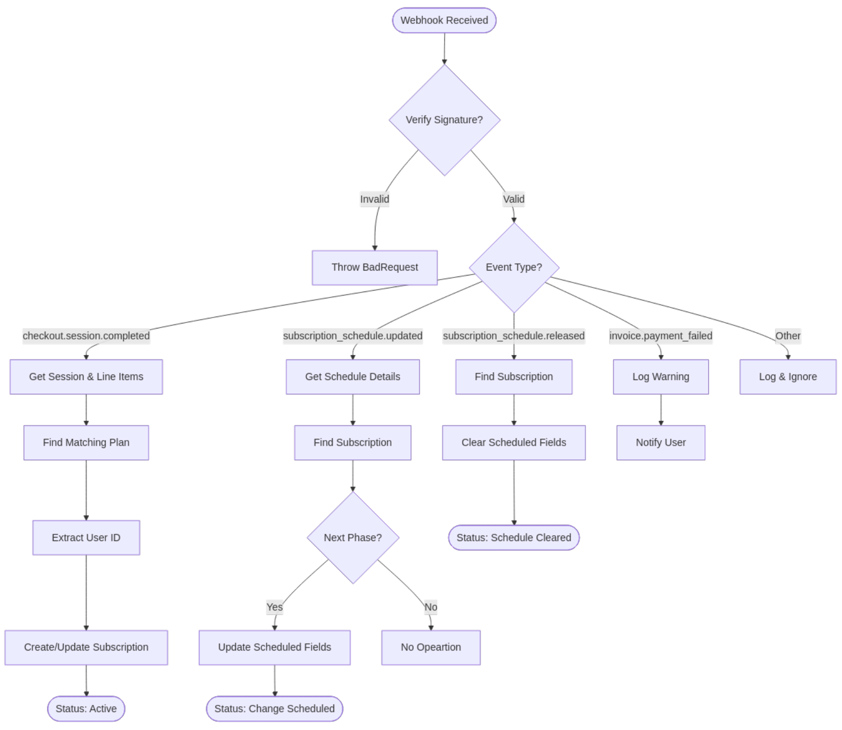


Figure 4.12: Stripe Webhook Processing Logic

The `handleWebhook` method switches on `event.type`:

- `checkout.session.completed`: Activates new subscriptions.
- `subscription_schedule.updated`: Updates local DB with `scheduledPriceId` and `scheduledPlanId`.
- `subscription_schedule.released`: Clears scheduled fields if the user cancels the pending change.

```
@Post('webhook')
async handleWebhook(@Headers('stripe-signature') signature, @Req() req) {
  const payload = req.body as Buffer;
  const event = await this.stripeService.handleWebhook(payload, signature);

  switch (event.type) {
    case 'checkout.session.completed':
      const session = event.data.object;
      const fullSession = await this.stripeService.getSessionWithLineItems(
        session.id
      );
      // ... Processing logic
      break;

    case 'subscription_schedule.updated':
      const schedule = event.data.object;
      const nextPhase = schedule.phases[1];
      if (nextPhase) {
        // Update subscription with scheduled plan details
        await this.subscriptionService.updateById(subId, {
          scheduledPriceId: nextPhase.items[0].price,
          // ...
        });
      }
      break;

    case 'subscription_schedule.released':
      // Clear scheduled fields
      break;
  }
  return { received: true };
}
```

Listing 4.10: Stripe Webhook Handler

Subscription Management

Subscription Schema

```
export class Subscription extends Document {
  @Prop({ required: true, ref: User.name, type: ObjectId })
  user: string | User;

  @Prop({ type: String }) stripeSubscriptionId?: string;
  @Prop({ type: String }) stripeCustomerId?: string;
  @Prop({ type: String }) planName?: string;
  @Prop({ type: String }) priceId?: string;
  @Prop({ type: String }) planId?: string;

  // Scheduled change fields (for plan upgrades/downgrades)
  @Prop({ type: String }) scheduledPriceId?: string;
  @Prop({ type: String }) scheduledPlanId?: string;
  @Prop({ type: String }) scheduledPlanName?: string;
  @Prop({ type: String }) stripeScheduleId?: string;

  @Prop({ type: String, enum: ['active', 'canceled', ...], default: 'active' })
  status: string;

  @Prop(raw({ batchDuration: Number, liveDuration: Number }))
  quota: SubscriptionUnit;

  @Prop(raw({ batchDuration: Number, liveDuration: Number }))
  usage: SubscriptionUnit;

  @Prop({ type: Date }) startDate: Date;
  @Prop({ type: Date }) endDate: Date;
}
```

Listing 4.11: Subscription Schema (Key Fields)

Quota Checking

Figure 4.13 illustrates the subscription and quota validation flow.

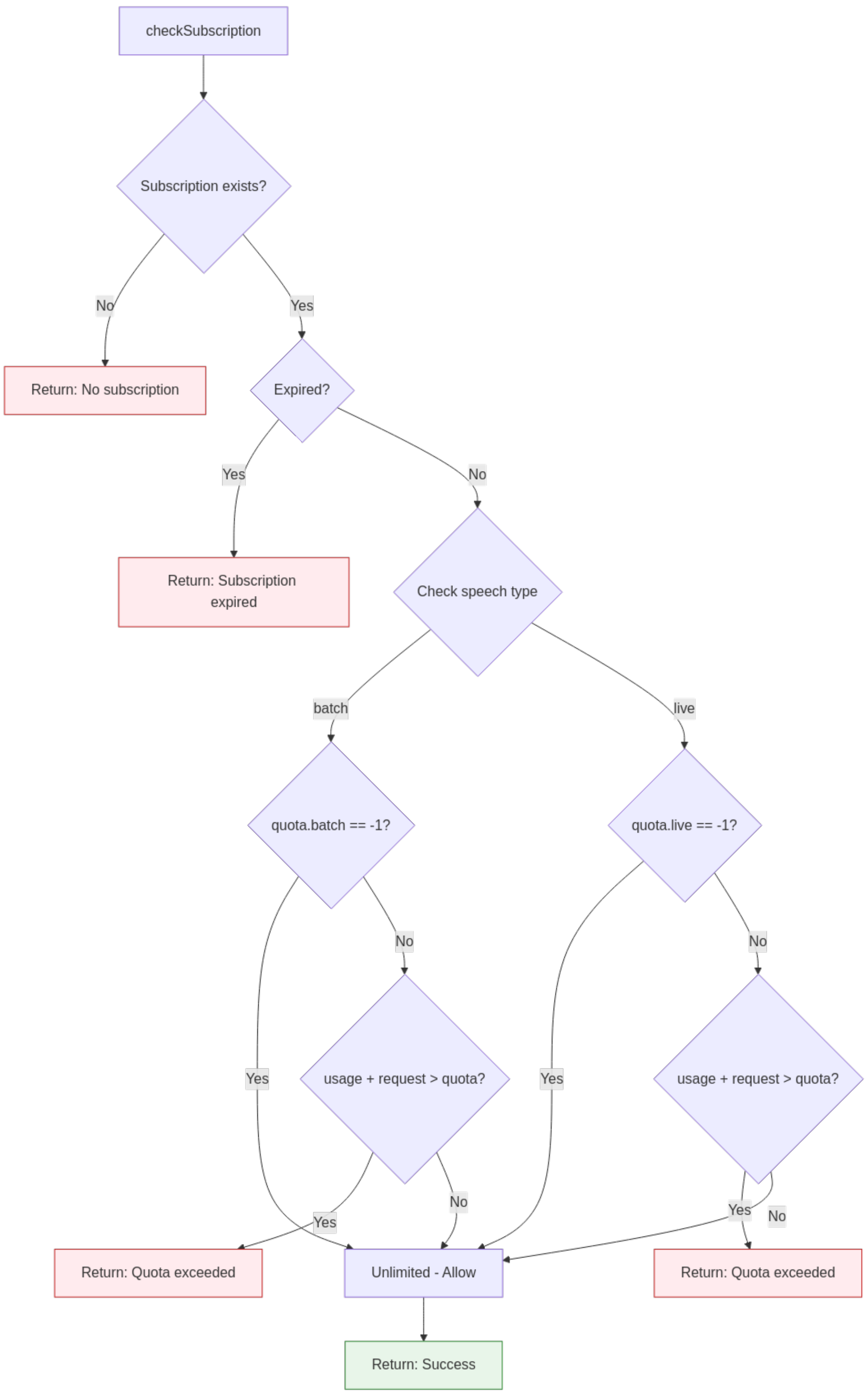


Figure 4.13: Subscription Quota Checking Flow

```
async checkSubscription(userId: string, speechType?: 'live' | 'batch') {
  const sub = await this.subscriptionModel.findOne({ user: userId }).exec();

  if (!sub) return { success: false, message: 'User has no subscription' };

  if (speechType === 'batch' && sub.quota.batchDuration !== -1 &&
      sub.usage.batchDuration > sub.quota.batchDuration) {
    return { success: false, message: 'Batch quota exceeded' };
  }

  return { success: true, subscription: sub };
}
```

Listing 4.12: Subscription Validation

Stripe Price Caching

Figure 4.14 shows the price caching mechanism with cache penetration protection.

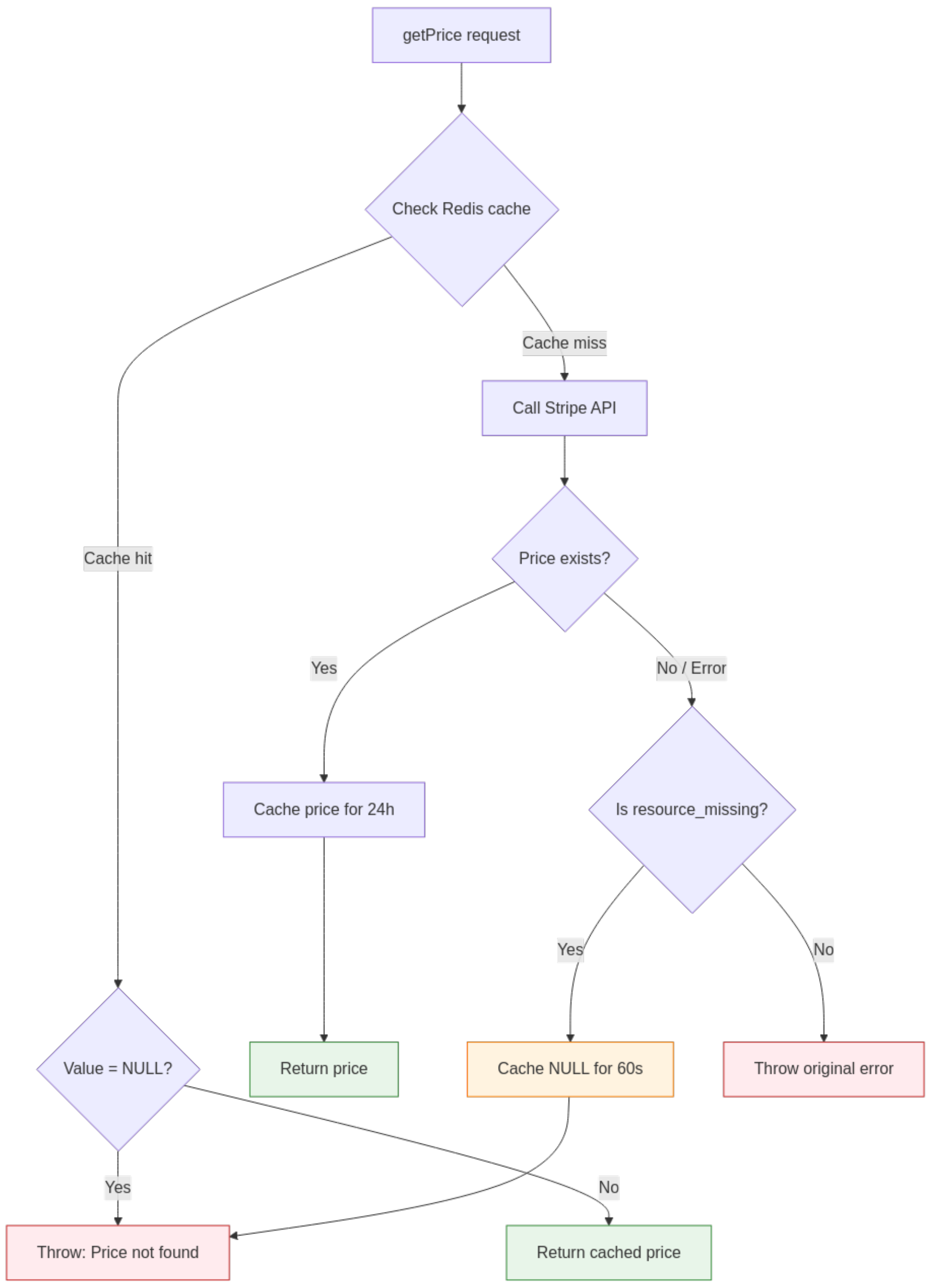


Figure 4.14: Stripe Price Caching with Penetration Protection

```
async getPrice(priceId: string): Promise<Stripe.Price> {
  const cacheKey = `stripe:price:${priceId}`;
  const cached = await this.redisClient.get(cacheKey);

  if (cached) {
    if (cached === 'NULL') throw new Error('Price not found (cached)');
    return JSON.parse(cached) as Stripe.Price;
  }

  try {
    const price = await this.stripe.prices.retrieve(priceId);
    await this.redisClient.set(cacheKey, JSON.stringify(price), {
      EX: this.CACHE_TTL, // 24 hours
    });
    return price;
  } catch (error) {
    if (error?.code === 'resource_missing') {
      await this.redisClient.set(cacheKey, 'NULL', { EX: 60 });
    }
    throw error;
  }
}
\subsubsection{Subscription Lifecycle Management}

Beyond scheduling changes, the system provides full lifecycle management allowing users to cancel and resume their subscriptions.

\noindent\textbf{Cancellation and Resumption Flow}\\

Users can cancel their subscription, which sets the `cancel_at_period_end` flag in Stripe. This keeps the subscription active until the end of the billing cycle. If they change their mind, they can resume it before the cycle ends.

\begin{lstlisting}[language=TypeScript, caption={Subscription Cancellation and Resumption}]
@UseGuards(JwtAuthGuard)
@Post('cancel-subscription')
async cancelSubscription(@Body() dto: CancelSubscriptionDto, @Req() req) {
  // Calls Stripe to update subscription with cancel_at_period_end = true
  return this.stripeService.cancelSubscription(dto.subscriptionId);
}

@Post('resume-subscription')
async resumeSubscription(@Body() dto: ResumeSubscriptionDto) {
  // Reverts cancellation by setting cancel_at_period_end = false
  return this.stripeService.resumeSubscription(dto.subscriptionId);
}
```

Listing 4.13: Stripe Price Caching

Endpoint	`POST /stripe/cancel-subscription`
Request	`{ "subscriptionId": "sub_..." }`
Response	`{ "status": "active", "cancelAtPeriodEnd": true }`

Table 4.4: API: Cancel Subscription

Endpoint	`POST /stripe/resume-subscription`
Request	`{ "subscriptionId": "sub_..." }`
Response	`{ "status": "active", "cancelAtPeriodEnd": false }`

Table 4.5: API: Resume Subscription

Administrative Operations

To support operations, the system includes secured endpoints for administrators to manage plans and user subscriptions.

Plan Management

Administrators can publish new plan versions. The system automatically handles version incrementing and invalidates the Redis cache.

```
@Roles(Role.Admin)
@Post()
async create(@Body() dto: CreatePlansDto) {
  // Validates structure and creates new versioned plan document
  const result = await this.planService.create(dto.data);
  return result;
}
```

Listing 4.14: Admin Plan Creation

User Subscription Administration

Admins can manually intervene to update subscription quotas or extend validity periods for specific users.

```
@Roles(Role.Admin)
@Put('/user/:id')
async updateSubscriptionByUser(@Body() body: UpdateSubscriptionByUserDto,
    @Param() params) {
  // Manually update quota or end date
  return this.subscriptionService.updateByUser(params.id, {
    endDate: new Date(body.endDate),
    'quota.batchDuration': body.batchDuration,
    'quota.liveDuration': body.liveDuration,
  }, true);
}
```

Listing 4.15: Admin Subscription Update

Endpoint	`POST /plans` (Admin)
Request	`{ "data": "{\"plans\": [...]}" }`
Response	`{ "plans": "...", "version": 5 }`

Table 4.6: API: Create Plans

Endpoint	`PUT /subscriptions/user/:id` (Admin)
Request	`{ "endDate": "2024-12-31", ... }`
Response	`{ "_id": "...", "quota": {...}, "endDate": "..." }`

Table 4.7: API: Update User Subscription

Module Dependencies

The Stripe module integrates with Subscription and Plan modules:

```
@Module({
  imports: [
    StripeConfigurationModule,
    MongooseModule.forFeature([
      { name: Subscription.name, schema: SubscriptionSchema },
      { name: Plan.name, schema: PlanSchema },
    ]),
  ],
  controllers: [StripeController],
  providers: [StripeService, SubscriptionService, PlanService],
  exports: [StripeService],
})
export class StripeModule {}
```

Listing 4.16: Stripe Module Configuration

4.2 Frontend Implementation

This section details the frontend implementation of the Gateway Dashboard, including the Vue.js architecture, component structure, routing implementation, and subscription management interface.

4.2.1 Overview

The Gateway Dashboard is a Vue.js 3 web application that provides a management interface for the Speech Gateway API.

Frontend Architecture

Figure 4.15 illustrates the layered architecture of the frontend application.

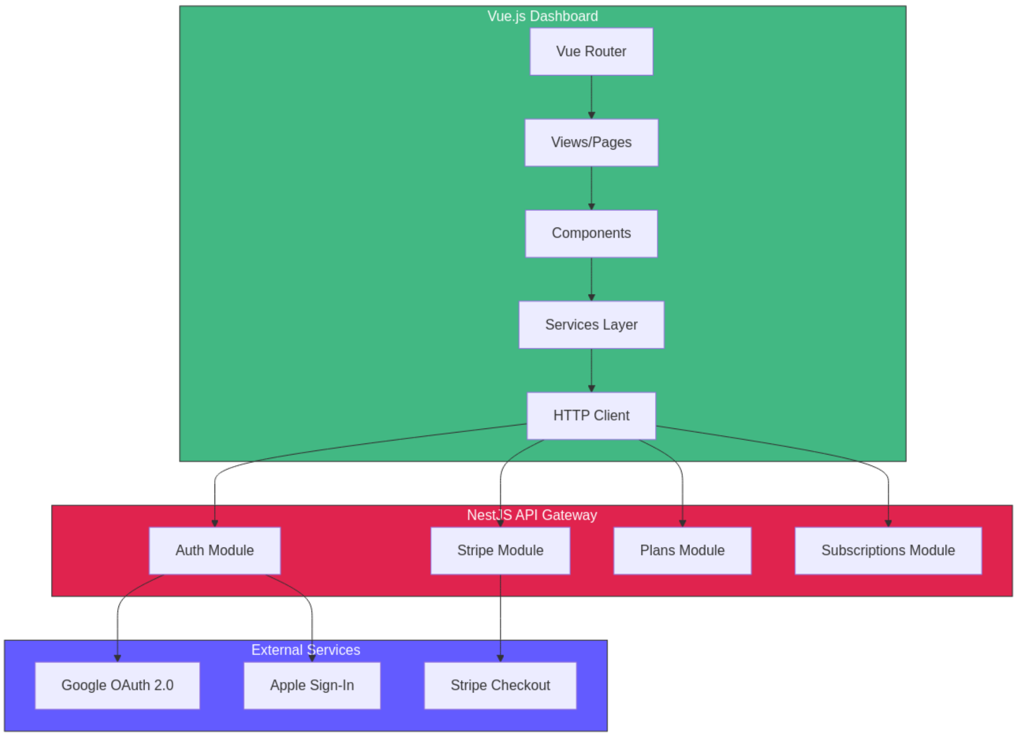


Figure 4.15: Frontend Application Architecture

The frontend follows a layered architecture:

- **Vue Router**: Manages navigation and route guards.
- **Views/Pages**: Page-level components for each route.
- **Components**: Reusable UI components like PlanCard.
- **Services Layer**: API communication logic.
- **HTTP Client**: Axios with interceptors for token handling.

Technology Stack

Layer	**Technology**	**Purpose**
Framework	Vue.js 3.x	Reactive UI framework
UI Library	Vuetify 3.x	Material design components
HTTP Client	Axios	API communication
Router	Vue Router	SPA navigation
State	Vue Instance + Mixins	Application state
Payment	Stripe Checkout	Subscription processing

Table 4.8: Frontend Technology Stack

Project Structure

```
gateway-dashboard/
  src/
  components/
    PlanCard.vue          # Subscription plan display
  layouts/
    Main.vue              # Main app layout
  mixins/
    auth.mixin.js         # Auth functionality mixin
  router/
    index.js              # Route definitions
    hooks.js              # Navigation guards
  services/
    auth.service.js       # Authentication API
    plans.service.js      # Plans API
    stripe.service.js     # Stripe integration
    user.service.js       # User/subscription API
  views/
    SignIn.vue            # Login page
    SignUp.vue            # Registration page
    CompleteSignup.vue    # OAuth completion
    Subscription.vue      # Subscription management
    admin/
      JsonPlansEditor.vue # Admin plans editor
  http.js                 # Axios HTTP client
  main.js                 # App entry point
```

Listing 4.17: Frontend Project Structure

4.2.2 Authentication Frontend

The frontend authentication system supports three login methods: email/password, Google OAuth, and Apple Sign-In.

Auth Service Architecture

The `AuthService` manages all authentication operations and token storage.

Method	**Description**
`login()`	Email/password authentication
`register()`	New account registration
`initiateGoogleLogin()`	Redirect to Google OAuth
`initiateAppleLogin()`	Apple SDK sign-in flow
`refreshToken()`	Refresh expired JWT
`storeAuthData()`	Store token in localStorage
`clearAuthData()`	Clear token on logout

Table 4.9: Auth Service Methods

Token Storage

Authentication data is stored in localStorage for persistence:

```
{
  accessToken: "eyJhbGciOiJIUzI1NiIs...",
  jwt: "eyJhbGciOiJIUzI1NiIs...",    // backward compat
  subscriptionEnd: "1737244800000",  // Unix timestamp
  isVerified: "true"
}
```

Listing 4.18: LocalStorage Token Schema

OAuth Integration

Google OAuth

Google OAuth uses redirect-based authentication:

```
initiateGoogleLogin() {
  const frontendUrl = encodeURIComponent(window.location.origin)
  const redirectUrl = `${API_URL}/auth/google/login` +
    `?redirect=${frontendUrl}/sign-in`

  window.location.href = redirectUrl
}
```

Listing 4.19: Google OAuth Initiation

Apple Sign-In

Apple Sign-In uses the Apple SDK:

```
initializeAppleSignIn(clientId) {
  if (!window.AppleID) {
    console.warn('Apple SDK not loaded')
    return false
  }

  window.AppleID.auth.init({
    clientId: clientId || process.env.VUE_APP_APPLE_CLIENT_ID,
    scope: 'name email',
    redirectURI: `${API_URL}/auth/apple/callback`,
    usePopup: false
  })
  return true
}

async initiateAppleLogin() {
  await window.AppleID.auth.signIn()
}
```

Listing 4.20: Apple Sign-In Initialization

Complete Signup Flow

New OAuth users must complete signup by setting a password:

```
async setPassword(temporaryToken, password, fullname) {
  const response = await http.post('/auth/add-info', {
    token: temporaryToken,
    password,
    fullname
  })

  const { accessToken, subscriptionEnd, isVerified } =
    response.data
  this.storeAuthData(accessToken, subscriptionEnd, isVerified)

  localStorage.removeItem('temporaryToken')
  return response.data
}
```

Listing 4.21: Complete Signup Implementation

Auth Mixin

The auth mixin provides authentication state to components:

```
import { authMixin } from '@/mixins/auth.mixin'

export default {
  mixins: [authMixin],
  // Component now has access to:
  // - this.isAuthenticated
  // - this.accessToken
  // - this.subscriptionEnd
  // - this.logout()
  // - this.verifyAndRefreshToken()
}
```

Listing 4.22: Auth Mixin Usage

The mixin automatically starts token verification on mount and cleans up on destroy.

4.2.3 Routing and Navigation

Vue Router manages navigation with guards that enforce authentication and role-based access control.

Route Configuration

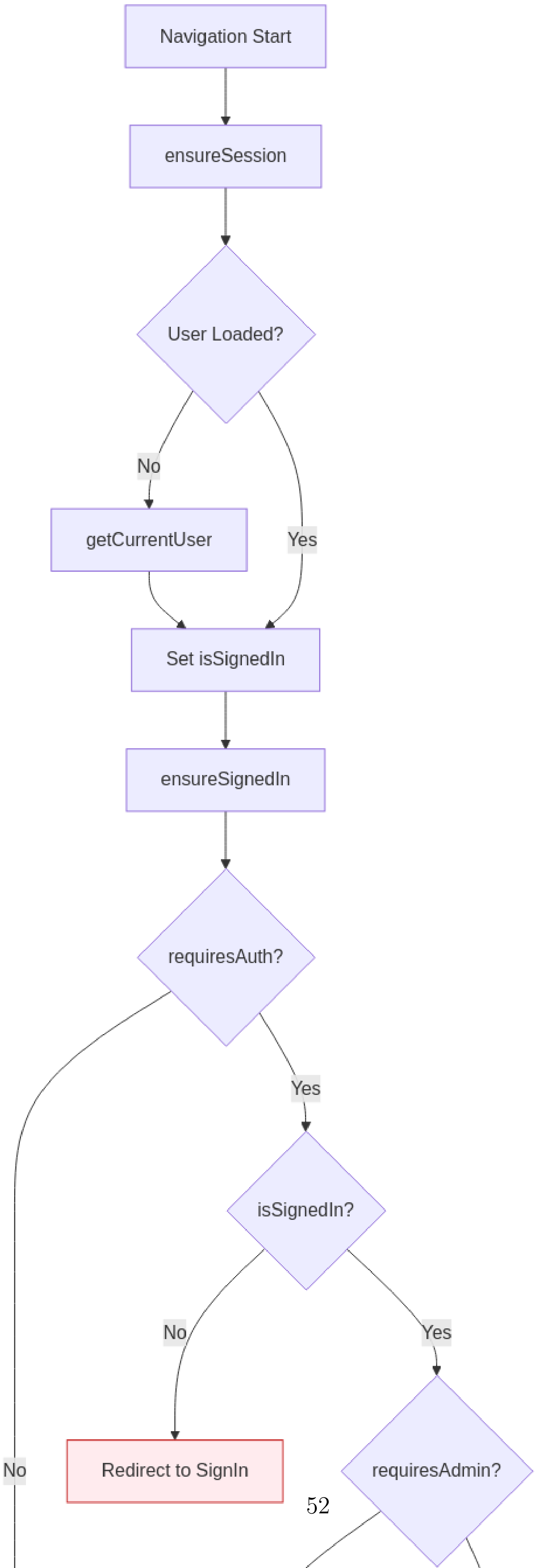
Routes are categorized by authentication requirements:

Path	Auth	Admin	Component
/sign-in	No	No	SignIn.vue
/sign-up	No	No	SignUp.vue
/complete-signup	No	No	CompleteSignup.vue
/success	No	No	Success.vue
/cancel	No	No	Cancel.vue
/speeches	Yes	No	Speeches.vue
/files	Yes	No	Files.vue
/applications	Yes	No	Applications.vue
/subscription	Yes	No	Subscription.vue
/dashboard	Yes	Yes	Dashboard.vue
/users	Yes	Yes	Users.vue
/request-log	Yes	Yes	RequestLog.vue
/settings	Yes	Yes	Settings.vue

Table 4.10: Route Definitions

Navigation Guards Flow

Figure 4.16 illustrates the navigation guard logic.


Navigation Start
ensureSession
User Loaded?
No
Yes
getCurrentUser
Set isSignedIn
ensureSignedIn
requiresAuth?
Yes
No
isSignedIn?
No
Yes
Redirect to SignIn
requiresAdmin?

Guard Implementation

Two navigation guards work together:

Session Guard
Ensures user data is loaded before navigation:

```
export const ensureSession = router => async (to, from, next) => {
  await Vue.nextTick()

  if (!router.app.user && to.name !== 'SignIn') {
    const user = await router.app.getCurrentUser()
    to.meta.isSignedIn = !!user
  } else {
    to.meta.isSignedIn = router.app.user !== null
  }
  next()
}
```

Listing 4.23: Session Guard

Auth Guard
Enforces authentication and admin requirements:

```
export const ensureSignedIn = router => (to, from, next) => {
  const requiresAdmin = anyTrue(to, 'requiresAdmin')
  const requiresAuth = requiresAdmin || anyTrue(to, 'requiresAuth')

  if (requiresAuth) {
    if (!to.meta.isSignedIn) {
      next({ name: 'SignIn' })
    } else if (requiresAdmin &&
                 router.app.user.role !== 'admin') {
      next({ name: 'Speeches' })
    } else {
      next()
    }
  } else {
    next()
  }
}
```

Listing 4.24: Auth Guard

HTTP Interceptors

Figure 4.17 shows the HTTP interceptor flow for automatic token handling.

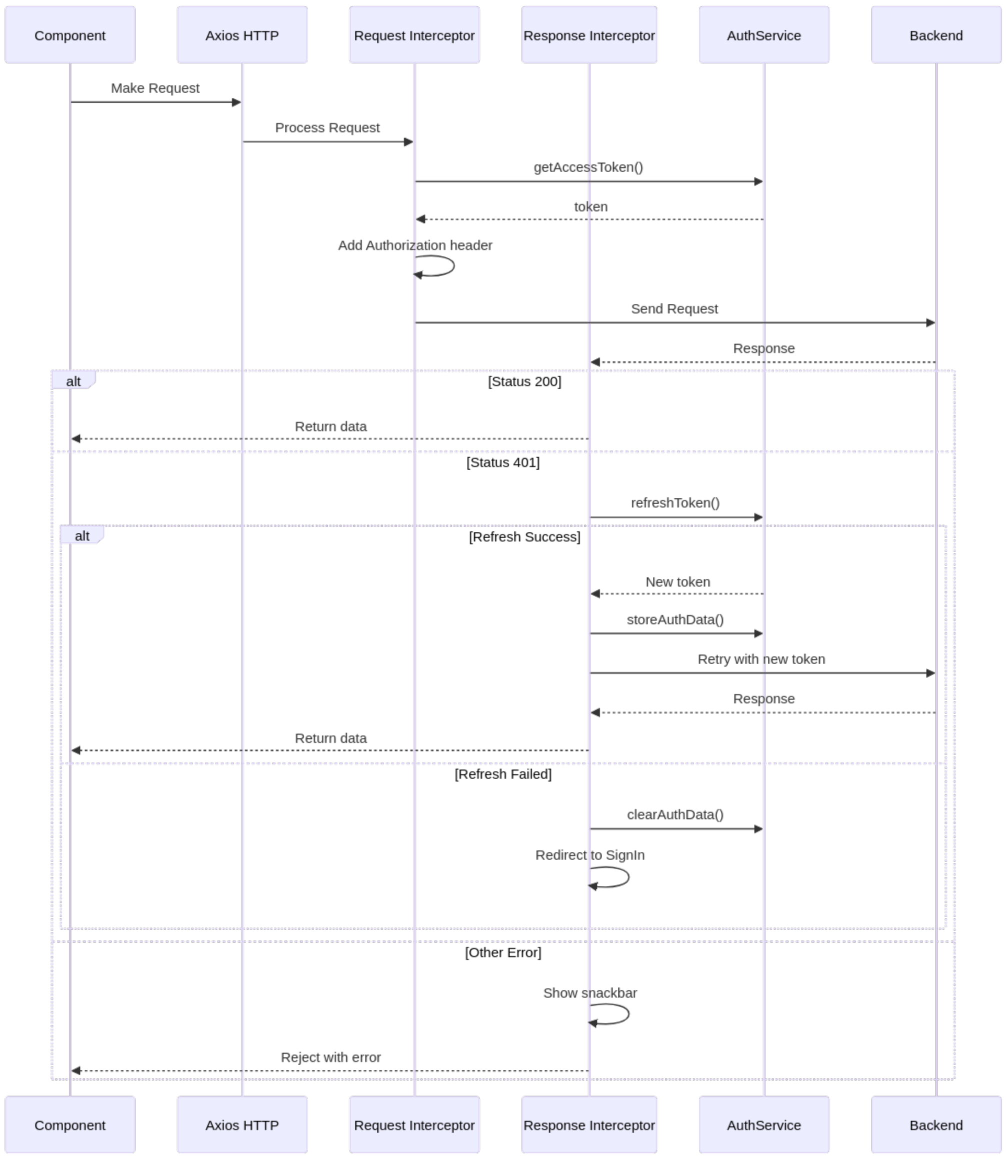


Figure 4.17: HTTP Interceptor Flow with Token Refresh

The interceptors handle:

- **Request**: Automatically attach Authorization header with JWT token.
- **Response 401**: Attempt token refresh; if failed, redirect to login.
- **Other Errors**: Display error message in snackbar.

4.2.4 Subscription Management Interface

The subscription interface provides plan selection, payment processing, and quota monitoring.

Component Architecture

The subscription system consists of interconnected components:

- **Subscription.vue**: Main page with conditional views for users and admins.

- **PlanCard.vue**: Displays plan details with dynamic pricing from Stripe.
- **JsonPlansEditor.vue**: Admin-only JSON editor for plan management.

User Subscription View

For users with active subscriptions, the view displays:

- Subscription period (start/end dates)
- Quota allocation (batch and live processing)
- Usage progress with color-coded indicators
- Cancel/Resume subscription controls

```
calculateUsagePercent(used, quota) {
  if (quota === -1) return 0      // Unlimited
  if (quota === 0) return 100
  return Math.min((used / quota) * 100, 100)
}

getUsageColor(used, quota) {
  if (quota === -1) return 'success'
  const percent = (used / quota) * 100
  if (percent >= 90) return 'error'
  if (percent >= 75) return 'warning'
  return 'success'
}
```

Listing 4.25: Usage Percentage Calculation

PlanCard Component

The PlanCard fetches pricing from Stripe and displays plan features:

Prop	Type	Description
plan	Object	Plan data (id, name, features, priceId)
disabled	Boolean	Disable subscribe button (for admins)

Table 4.11: PlanCard Component Props

```
async fetchPriceInfo() {
  if (!this.plan.priceId) return

  try {
    this.loadingPrice = true
    this.priceInfo = await stripeService.getPriceInfo(
      this.plan.priceId
    )
  } catch (error) {
    this.priceError = 'Failed to load price'
  } finally {
    this.loadingPrice = false
  }
}

// Computed property for display
get formattedPrice() {
  if (!this.priceInfo) return 'Loading...'
  const amount = this.priceInfo.unit_amount / 100
  return `$${amount.toFixed(2)}`
}
```

Listing 4.26: PlanCard Price Fetching

Stripe Checkout Integration

When a user subscribes, the frontend initiates Stripe Checkout:

```
async handleSubscribe(priceId) {
  try {
    const data = await stripeService.createCheckoutSession(
      priceId
    )

    if (data?.url) {
      window.location.href = data.url
    } else {
      this.showError('Failed to redirect. Please try again.')
    }
  } catch (err) {
    console.error('Subscription error', err)
    this.showError('An error occurred during checkout.')
  }
}
```

Listing 4.27: Checkout Session Creation

Cancel and Resume Subscription

Users can manage their subscription lifecycle:

```
async handleCancelSubscription() {
  if (!confirm('Are you sure you want to cancel?')) {
    return
  }

  try {
    this.cancellingSubscription = true
    await stripeService.cancelSubscription(
      this.subscription.stripeSubscriptionId
    )
    await this.checkStripeSubscriptionStatus(
      this.subscription.stripeSubscriptionId
    )

    this.showSuccess('Subscription scheduled for cancellation.')
  } catch (err) {
    this.showError('Failed to cancel subscription.')
  } finally {
    this.cancellingSubscription = false
  }
}
```

Listing 4.28: Cancel Subscription

Admin Plans Editor

Administrators access a JSON editor for managing plans:

- Live JSON validation with syntax highlighting
- Stripe price ID validation before publishing
- Diff comparison with current version
- Version history tracking

The editor validates each plan's `priceId` against Stripe before allowing publication, ensuring only valid pricing configurations are saved.

Chapter 5

Conclusion and Future Work

This chapter summarizes the project achievements, draws conclusions from the implementation, and outlines directions for future work.

5.1 Project Summary

This project successfully designed and implemented a comprehensive **Gateway Dashboard** system to address the challenges faced by the Speech Gateway API ecosystem. The project delivered the following key components:

5.1.1 Authentication System

A robust authentication module was implemented supporting three authentication methods:

- **Email/Password Authentication**: Traditional credential-based login with password hashing using bcrypt.
- **Google OAuth 2.0**: Redirect-based OAuth flow for seamless Google account integration.
- **Apple Sign-In**: SDK-based authentication supporting Apple's privacy-focused identity system.

The authentication system includes advanced security features such as JWT token management, automatic token refresh, token blacklisting using Redis, and session security with device fingerprinting.

5.1.2 Payment and Subscription System

A complete payment processing infrastructure was developed using Stripe, consisting of:

- **Plan Module**: Versioned pricing plans with Redis caching and cache penetration protection.
- **Stripe Integration**: Checkout session creation, webhook handling, and subscription lifecycle management.
- **Subscription Module**: Quota tracking for batch and live processing with automatic access control.

5.1.3 Frontend Dashboard

A Vue.js 2 web application was developed with Vuetify providing:

- Intuitive user interface for subscription and service management.
- Admin portal with JSON-based plans editor and validation.
- Secure navigation guards and HTTP interceptors for token management.
- Responsive design supporting multiple device form factors.

5.2 Conclusions

The Gateway Dashboard project has successfully achieved all stated objectives:

1. **Web-based Dashboard**: A fully functional Vue.js application provides an intuitive interface for users and administrators, eliminating the need for direct API interaction.
2. **Secure Authentication**: The multi-provider SSO system enables seamless user onboarding while maintaining security through industry-standard protocols (OAuth 2.0, JWT, HTTPS).
3. **Subscription Infrastructure**: The Stripe integration enables automated billing, subscription management, and tiered access control, establishing the commercial viability of the Speech Gateway services.
4. **Administrative Tools**: The admin portal with RBAC provides efficient management of users, plans, and system monitoring without manual database intervention.
5. **Enhanced Security**: Token blacklisting, automatic refresh, and session management using Redis provide robust protection against unauthorized access.

The modular architecture adopted in this project promotes maintainability and extensibility. The separation between frontend and backend, combined with the service-oriented design in NestJS, allows for independent scaling and future enhancements.

5.3 Future Work

While the current implementation addresses the core requirements, several areas present opportunities for future development:

5.3.1 Technical Enhancements

- **Multi-language Support**: Implement internationalization (i18n) in the frontend to support multiple languages.
- **Real-time Usage Monitoring**: Add WebSocket-based real-time updates for quota usage and system status.
- **Enhanced Analytics**: Implement comprehensive usage analytics dashboard for administrators.

- **Mobile Application**: Develop native mobile applications for iOS and Android to complement the web dashboard.

5.3.2 Business Features

- **Team/Organization Accounts**: Support for enterprise customers with multiple users under a shared subscription.
- **Usage-based Billing**: Implement pay-as-you-go pricing model in addition to subscription plans.
- **Invoice Management**: Generate downloadable PDF invoices for accounting purposes.
- **Promotional Codes**: Support for discount codes and promotional campaigns.

5.3.3 Infrastructure Improvements

- **Containerization**: Docker containerization for easier deployment and scaling.
- **CI/CD Pipeline**: Automated testing and deployment pipelines for continuous integration.
- **Monitoring and Alerting**: Integration with tools like Prometheus and Grafana for production monitoring.

5.4 Final Remarks

The Gateway Dashboard project demonstrates how modern web technologies can be leveraged to create a comprehensive management system for API-based services. The combination of Vue.js, NestJS, MongoDB, and Redis provides a solid foundation for building scalable, maintainable, and secure web applications.

The project not only addresses the immediate needs of the Speech Gateway ecosystem but also establishes patterns and practices that can be applied to similar enterprise applications. The modular design ensures that the system can evolve to meet future requirements while maintaining backward compatibility.

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Appendix A

Proof

A long proof that you expect no one will read