



FACULTY OF COMPUTING  
**NSBM Green University**

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# Online Auction Management System

## SOFTWARE ARCHITECTURE REPORT

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# Abstract

This report presents the design and implementation of a high-performance, cross-platform Online Vehicle Auction System. The project's primary objective is to modernize traditional vehicle auctions, which suffer from geographical limitations, transactional opacity, and high operational overhead. Our system addresses these challenges by providing a secure, real-time, and globally accessible platform.

The system is engineered using a robust, service-oriented architecture. The backend is built on the latest ASP.NET Core framework (.NET 9), ensuring scalability and high throughput. The core real-time bidding functionality is powered by WebSockets, while a Redis distributed cache ensures low-latency performance. The frontend is a responsive Single Page Application (SPA) developed with React.js, ensuring a seamless user experience across web, mobile, and desktop platforms.

Key features include distinct portals for Sellers, who can list vehicles and set minimum bids, and Buyers, who can participate in live auctions. A significant innovation is the secure escrow-based payment gateway. This system verifies and holds buyer funds, releasing them to the seller only after the transaction is confirmed, which provides critical financial protection and builds trust for all parties.

The solution is deployed on a scalable Amazon Web Services (AWS) cloud infrastructure and is targeted at both individual enthusiasts and professional dealerships. This report details the architectural decisions and security protocols employed to deliver a production-ready application that enhances trust and efficiency in the vehicle resale market.

**Keywords:** Vehicle Auction, Real-time Bidding, ASP.NET Core 9, .NET 9, WebSockets, Redis, Escrow Payment, FinTech, React.js, Cross-Platform, AWS, Secure Transactions.

**Technologies Used:** C#, ASP.NET Core 9, PostgreSQL, Redis, React.js, WebSockets, Stripe API (with Escrow), JWT, Docker, AWS (EC2, RDS, ElastiCache).

# Chapter 1

## Introduction

### 1.1 Background and Context

The global automotive resale market represents a multi-billion dollar industry, yet it has historically been dominated by physical, localized auctions. These traditional methods, while established, are inherently inefficient. They suffer from high operational costs, geographical limitations that restrict both buyer and seller pools, and a lack of real-time price discovery.

While first-generation online marketplaces brought greater accessibility, many failed to replicate the dynamic, time-sensitive nature of a live auction. Furthermore, for high-value assets like vehicles, establishing transactional trust—ensuring vehicle authenticity and, most critically, payment security—remains the single greatest challenge in the digital space. This project addresses the clear market need for a platform that combines the real-time engagement of a live auction with robust, modern security and trust-building mechanisms.

### 1.2 Problem Statement

The traditional and early-digital vehicle auction models suffer from several critical flaws that this project aims to solve:

- **Lack of Trust and Transparency:** Buyers face significant risks related to vehicle condition, while sellers face equally high risks of non-payment or payment fraud after a vehicle has been sold.
- **Limited Market Access:** Physical auctions restrict both buyers and sellers to a single geographical location, artificially depressing market reach and potential value.
- **Poor Real-time Experience:** Many online platforms lack true real-time bidding, relying on 'proxy bids' or page refreshes, which fails to create a competitive, transparent, and engaging auction environment.
- **Transactional Insecurity:** The handover of a high-value asset and a large sum of money is a major point of friction, with few platforms offering a secure intermediary (escrow) service to protect both parties.

### 1.3 Aims and Objectives

The primary aim of this project is to design, develop, and deploy a high-performance, cross-platform Online Vehicle Auction System.

The key objectives to achieve this aim are:

1. To engineer a **real-time bidding engine** using WebSockets to provide instantaneous, sub-second bid updates to all connected users.
2. To establish a **high-trust environment** by implementing a secure, escrow-based payment gateway that holds funds until the transaction (e.g., vehicle handover) is confirmed by both parties.
3. To develop a **scalable backend architecture** using the latest ASP.NET Core 9 framework and a Redis cache, capable of handling high-frequency bidding traffic.
4. To create **distinct user portals** for Sellers (to list vehicles and set minimum prices) and Buyers (to participate in auctions) using a responsive React.js frontend.
5. To ensure the platform is **highly secure**, protecting user data, authentication, and all financial transactions.

## 1.4 Scope of the Project

### 1.4.1 In Scope

The project's scope is focused on delivering the core auction functionality:

- A complete User Management system with role-based access (Buyer, Seller, Admin).
- A Seller portal for creating, managing, and monitoring vehicle listings, including setting reserve prices.
- A Buyer portal for browsing, searching, and placing bids in real-time.
- The real-time WebSocket-based notification system for bid confirmations and auction alerts.
- The complete escrow payment workflow, from buyer payment-hold to seller fund-release.

### 1.4.2 Out of Scope

To ensure delivery within the project timeline, the following features are considered out of scope for the current version:

- Native mobile applications (iOS/Android). The system is, however, fully web-responsive for mobile browsers.
- AI-powered vehicle price valuation or recommendation engines.
- Live video streaming for auctions.
- Integration with third-party vehicle history report services (e.g., CarFax).

## 1.5 Technology and Methodology

The system is developed using a modern, service-oriented architecture. The backend is built with ASP.NET Core 9 on the .NET 9 platform, the frontend with React.js, and the primary database with PostgreSQL. Real-time communication is handled by WebSockets, and performance is accelerated using a Redis distributed cache. The entire solution is designed for cloud-native deployment on Amazon Web Services (AWS).

## 1.6 Report Organization

This report is structured as follows:

**Chapter 2: Literature Review** reviews existing auction platforms and the core technologies relevant to this project.

**Chapter 3: System Architecture** provides a detailed overview of the system's design, including its service-oriented architecture and cloud deployment model on AWS.

**Chapter 4: Design Patterns** discusses the key design patterns, such as Observer (for real-time) and Repository, that were implemented.

**Chapter 5: Implementation Details** showcases key code segments and explains the implementation of core features like the bidding engine and escrow payment.

**Chapter 6: Testing** details the quality assurance strategy, including unit, integration, and performance testing.

**Chapter 7: Individual Contributions** outlines the specific roles and responsibilities of each team member.

**Chapter 8: Conclusion** summarizes the project's achievements, limitations, and potential for future work.



# Chapter 2

## Literature Review

### 2.1 Overview

This chapter presents a critical review of existing systems and technologies relevant to the Online Vehicle Auction market. We analyze local classified platforms (e.g., `ikman.lk`) and high-frequency bidding platforms (e.g., `1xBet`) to identify a significant "market gap." The chapter concludes by justifying our chosen technology stack, which is designed to fill this gap.

### 2.2 Market and Technology Analysis

#### 2.2.1 Category 1: Local Classified Platforms

Platforms like `ikman.lk` and `riyasewana.lk` dominate the Sri Lankan vehicle resale market. Our review identifies them as **digital classified ad listings**, not true auction platforms.

**Strengths** High user traffic and a large inventory of listings.

**Weaknesses** They are static listings. Negotiations happen offline, which is slow and lacks transparency. There is no competitive price discovery, and critically, **no transactional security**, leaving users exposed to fraud.

#### 2.2.2 Category 2: High-Frequency Bidding Platforms

Platforms such as `1xBet` (sports betting) and `eBay` are masters of high-speed, concurrent, real-time event handling, primarily using `WebSockets` and distributed caching (like `Redis`).

**Strengths** Their architecture is built to handle thousands of simultaneous interactions at very low latency, which is a desirable model for live auctions.

**Weaknesses** Their business model lacks the high-trust, escrow-based payment system required for high-value, physical assets like vehicles.

#### 2.2.3 Identifying the Research Gap

##### Identifying the Research Gap

The literature review reveals a clear gap in the market: **There is no platform that combines the high-frequency, real-time technology of a betting site with the high-trust, secure payment model of a FinTech application.**

Our project is designed to fill this specific gap by being both technologically advanced

(real-time, fast) and commercially secure (escrow payments).

## 2.3 Technology Stack Justification

The technology stack was chosen to meet the demands of this identified gap, prioritizing performance, reliability, and security.

Table 2.1: Technology Stack Selection Rationale

Component	Selected Technology	Alternatives	Rationale for Selection
Backend	ASP.NET 9	Node.js, Spring Boot	Industry-leading performance, perfect for handling concurrent WebSocket connections.
Real-time	WebSockets	Long Polling, SSE	Essential for competitive, real-time bidding. Provides a persistent, instant connection.
Database	PostgreSQL	MySQL, MongoDB	<b>ACID compliance</b> is crucial for reliable financial transactions and secure bids.
Caching	Redis	In-Memory Cache	A <b>distributed cache</b> is essential for scaling, allowing servers to share live auction data.
Frontend	React.js	Angular, Vue.js	Its efficient Virtual DOM is ideal for handling the rapid state changes from live bids.
Payment	Escrow (Stripe)	Direct Payment	<b>Core of building trust.</b> Protects both buyer and seller from payment fraud.
Hosting	AWS (Cloud)	On-Premise, Azure	High availability and scalability (EC2, RDS) to handle sudden auction traffic spikes.

## 2.4 Conclusion

The review confirms that existing platforms are inadequate, lacking either real-time technology or transactional security. Our chosen stack is therefore justified, as it directly targets this gap by combining a high-performance backend (ASP.NET 9, WebSockets, Redis) with a high-trust business model (PostgreSQL, Escrow) to create a novel and efficient vehicle auction platform.

# Chapter 3

## System Architecture

### 3.1 Architectural Overview

This chapter presents the complete architectural design of the Online Vehicle Auction System. The system is engineered using a **Service-Oriented Architecture (SOA)** built on a robust three-tier model. This style ensures a clear **separation of concerns**, enhances **scalability**, and maintains **security**. The architecture is cloud-native, leveraging Amazon Web Services (AWS) for high availability. Figure 3.1 provides a high-level overview.

### 3.2 Architectural Layers

Our system is structured into three distinct logical layers.

#### 3.2.1 Presentation Layer (Frontend)

The cross-platform UI is built with **React.js** as a Single Page Application (SPA), providing a fluid experience on **web, mobile, and desktop**. It renders UI components, handles user interactions, communicates with the backend via RESTful Application Programming Interface (API) calls, and maintains a persistent **WebSocket** connection for real-time updates.

#### 3.2.2 Application Layer (Backend)

Built on **ASP.NET Core 9**, this layer is the system's core ("brain"). It exposes secure API endpoints, handles authentication (JSON Web Token (JWT)), executes business rules (e.g., bid validation), serves as the **WebSocket server**, and integrates with Stripe for **escrow payment** logic.

#### 3.2.3 Data Layer (Persistence)

This layer handles data storage using two technologies:

**PostgreSQL (Primary Database)** Stores persistent business data (users, vehicles, payments) ensuring **ACID compliance** for transactions.

**Redis (Cache)** A high-speed, in-memory cache storing volatile data (current bids, auction state) to reduce database load and ensure low latency.

### 3.3 Database Design

The schema is relational and normalized (3NF) for integrity. Figure 3.2 illustrates the core entities (**Users, Vehicles, Auctions, Bids, Payments**) and their relationships.

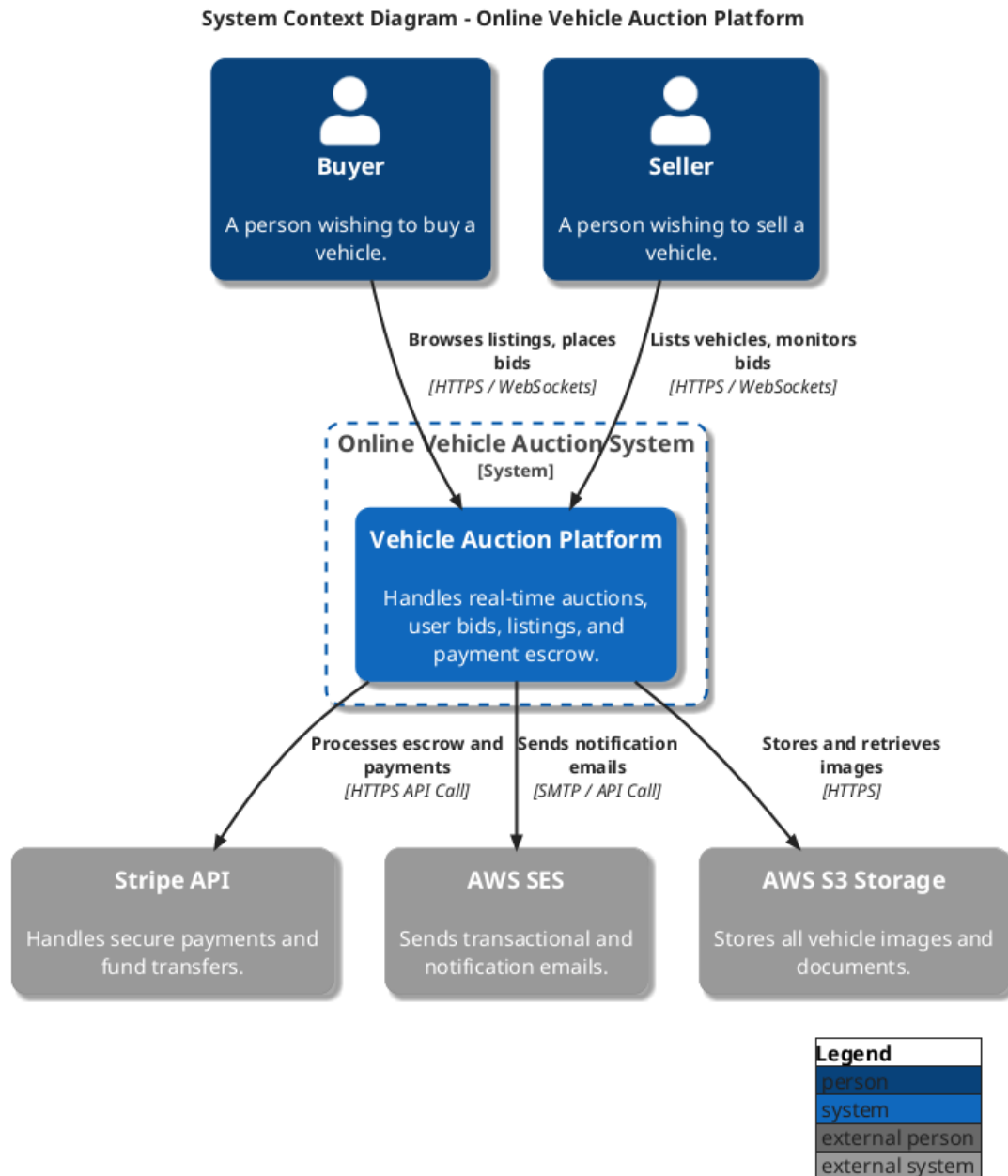


Figure 3.1: High-Level System Architecture

*This diagram shows the main components (Frontend, Backend API, Database, Cache) and key external systems (Stripe, Email, S3) interacting with the core Vehicle Auction System.*

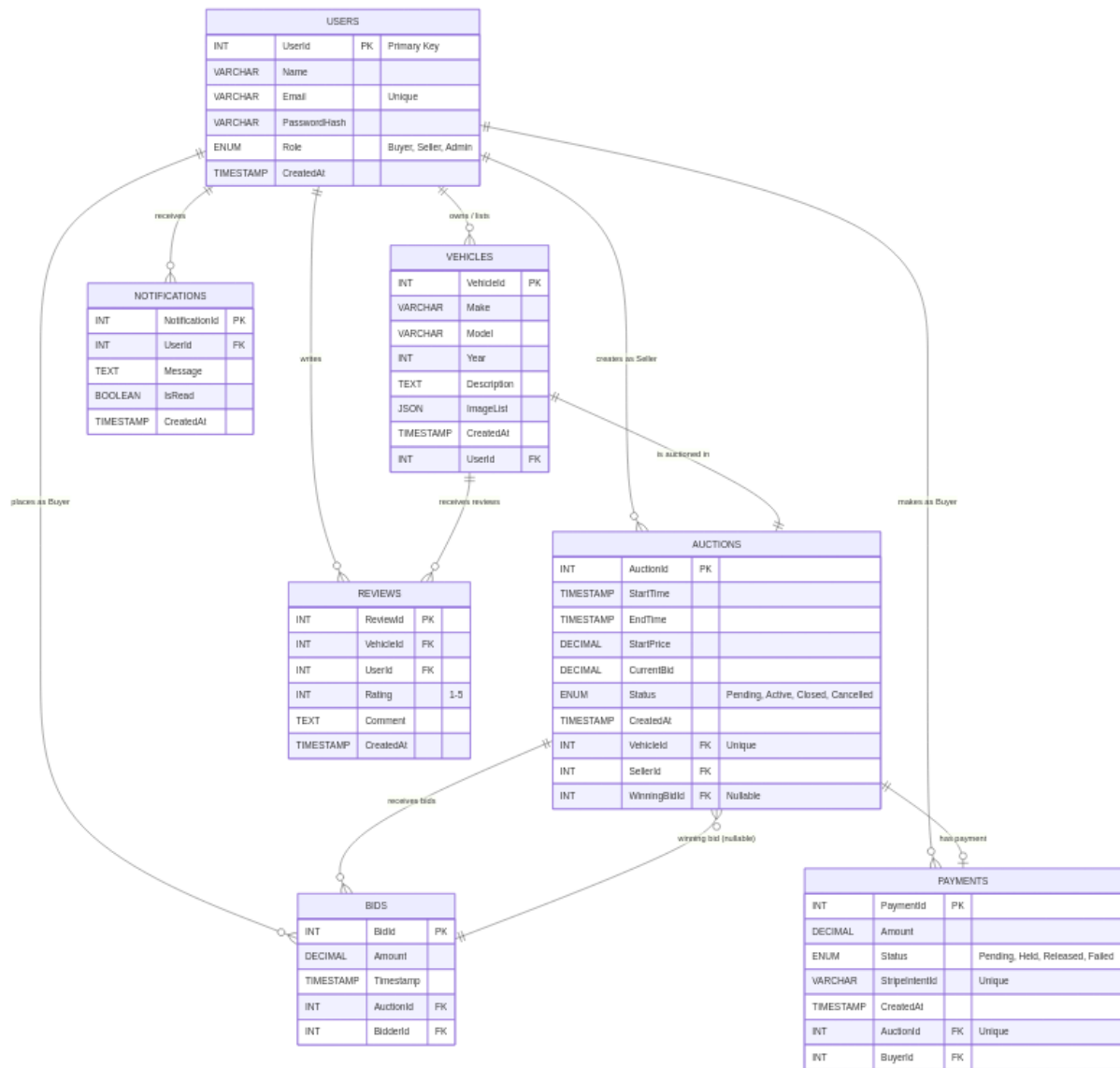


Figure 3.2: Entity-Relationship (ER) Diagram

*Illustrates the main database tables and how they are linked via primary (PK) and foreign (FK) keys, showing relationships like one-to-many (e.g., one User has many Bids).*

## 3.4 Key Process Flows (Sequence Diagrams)

Sequence diagrams illustrate component interactions for critical operations.

### 3.4.1 User Authentication Flow

Figure 3.3 shows the user login process and JWT issuance for secure API access.

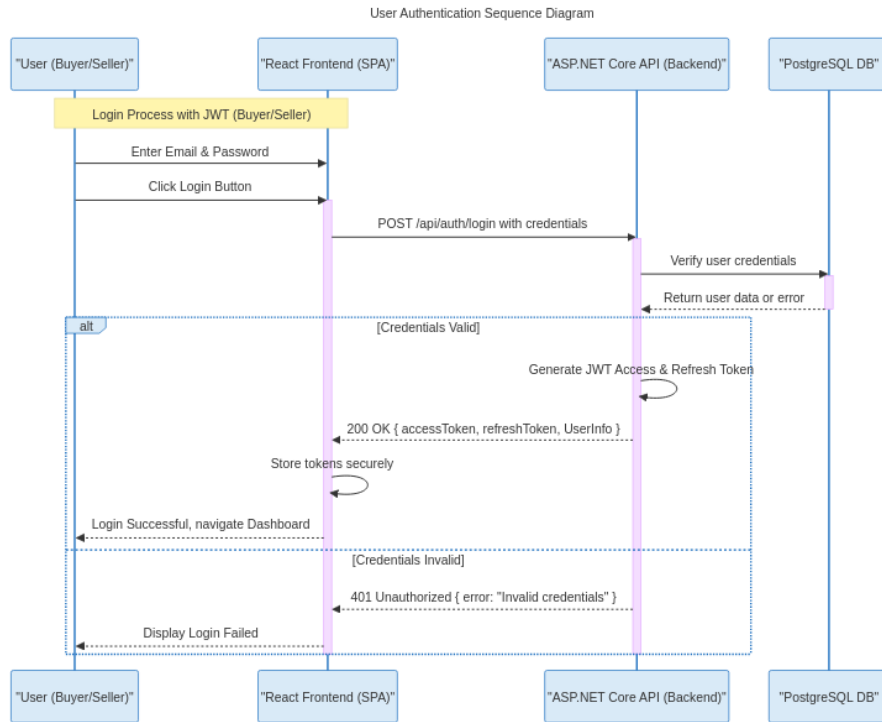


Figure 3.3: User Authentication Sequence Diagram

*Details the steps involved when a user submits credentials, the API validates them against the database, and returns JWT tokens upon success.*

### 3.4.2 Real-time Bidding Flow

Figure 3.4 depicts the real-time bid validation, saving, and broadcasting via WebSockets.

### 3.4.3 Escrow Payment Flow

Figure 3.5 outlines the high-trust payment model, showing fund holding and release.

## 3.5 Cross-Cutting Concerns

These elements apply across all architectural layers.

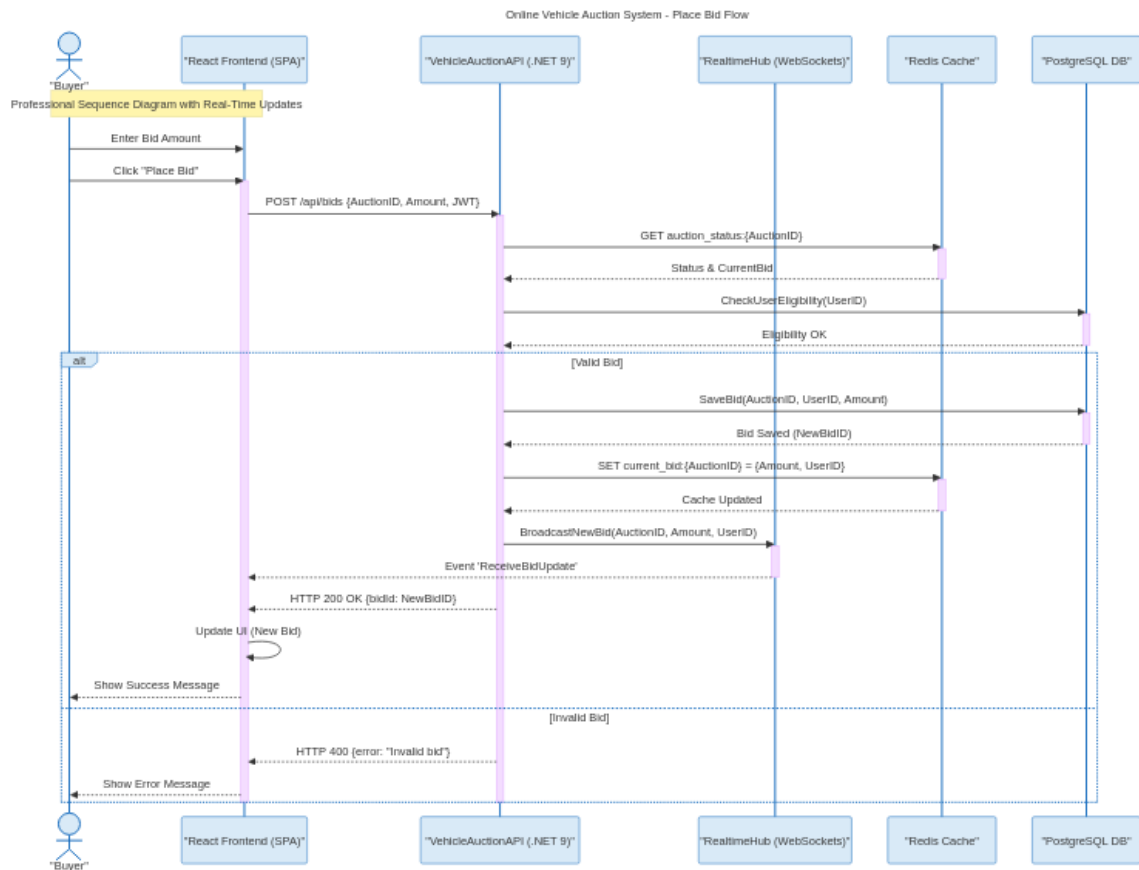


Figure 3.4: Real-time Bidding Sequence Diagram

*Shows how a bid placed on the Frontend triggers API validation, database/cache updates, and finally a WebSocket broadcast to update all connected clients instantly.*

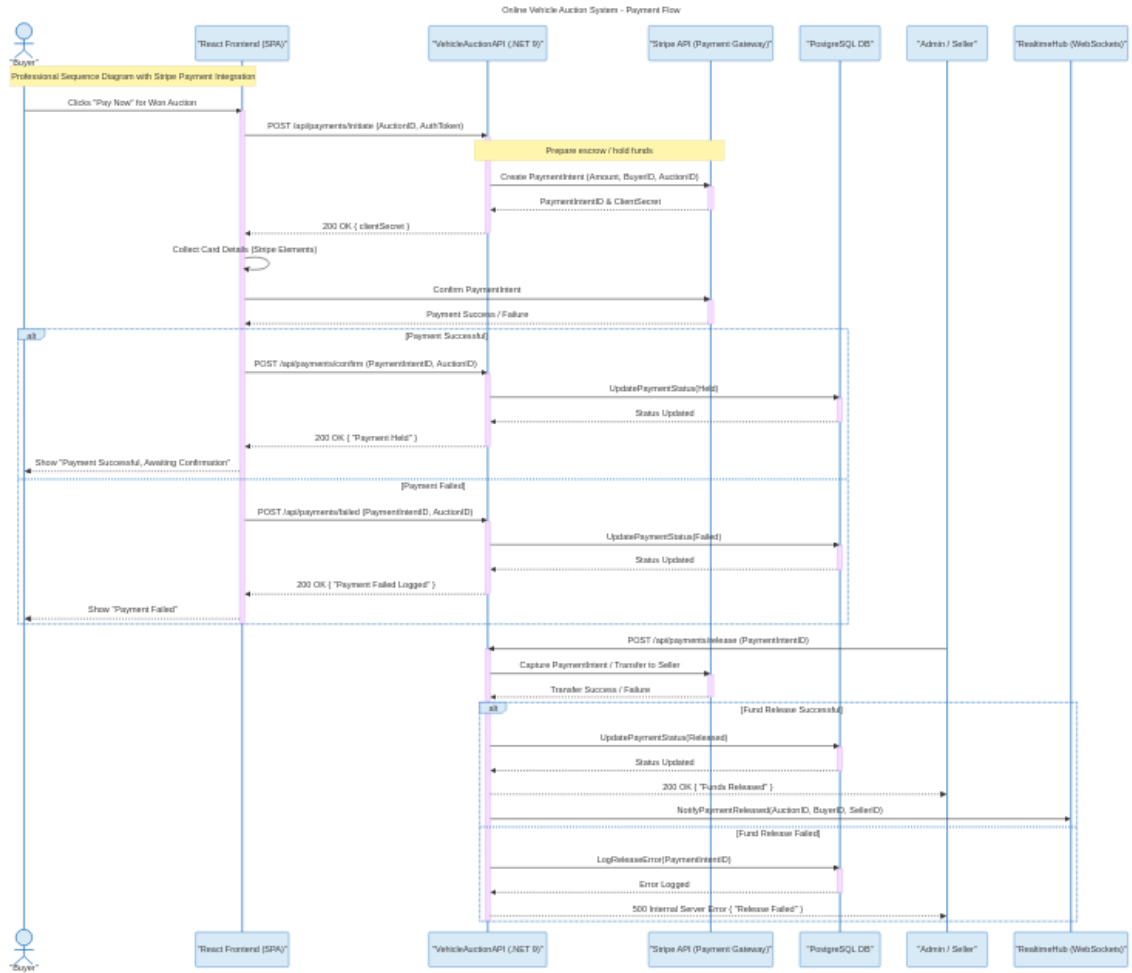


Figure 3.5: Escrow Payment Sequence Diagram

*Illustrates the secure process where buyer funds are held via Stripe after payment, and only released to the seller upon confirmation of the transaction (e.g., vehicle handover).*



### 3.5.1 Security

Security is multi-layered: **Authentication** via stateless JWT tokens, **Authorization** via Role-Based Access Control (RBAC), and **Transactional Security** through the escrow system and enforced HTTPS/SSL.

### 3.5.2 Performance and Caching

The **Redis cache** is critical for handling high bid frequencies, serving current bid reads from memory to significantly reduce **PostgreSQL** load and ensure sub-second responses.

### 3.5.3 Error Handling and Logging

Global exception handling middleware in ASP.NET Core catches unhandled errors, logs them, and returns standardized error messages to the frontend, ensuring system stability.

## 3.6 Summary

The architecture successfully fulfills the project's core objectives. The SOA model provides separation of concerns. **WebSockets** and **Redis** deliver a high-performance real-time experience, while the **escrow payment** system and **PostgreSQL** provide the security and integrity needed for a high-trust vehicle auction platform.

# Chapter 4

## Design Patterns and Architectural Decisions

### 4.1 Overview

This chapter briefly discusses key design patterns employed and the rationale behind major architectural decisions, focusing on maintainability, scalability, and testability `gamma1994design`.

### 4.2 Core Architectural Pattern: Model-View-Controller (MVC)

The MVC pattern separates the application into three interconnected components: Model (data/business logic - ASP.NET Core Services/Repositories), View (UI - React.js SPA), and Controller (intermediary - ASP.NET Core API Controllers). It handles user requests, interacts with the model, and returns data to the view.

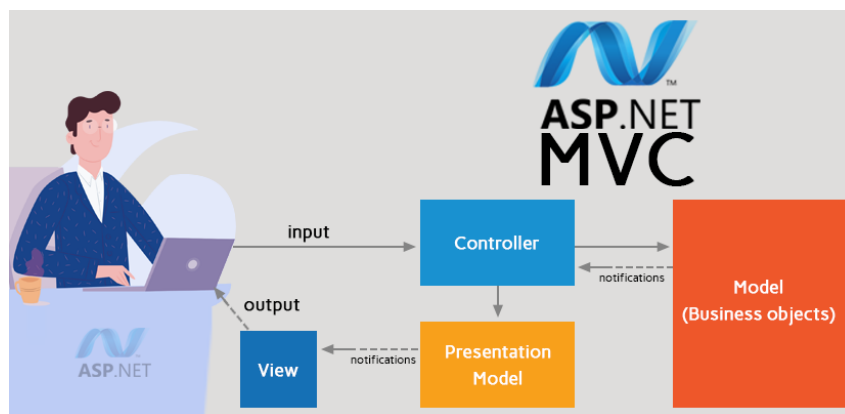


Figure 4.1: Model-View-Controller Interaction Flow

**Rationale for MVC:** This pattern provides a clear separation of concerns, facilitating parallel development and enhancing testability of the backend business logic independent of the frontend UI.

## 4.3 Key Design Patterns Implemented

### 4.3.1 Repository Pattern

Mediates between domain logic and data mapping, abstracting data access **fowler2002patterns**. Provides **separation of concerns** and improves **testability**.

### 4.3.2 Dependency Injection Pattern

Implements Inversion of Control (IoC) using ASP.NET Core's built-in container. Manages object lifetimes (**Scoped**, **Singleton**) and promotes **loose coupling**.

### 4.3.3 Unit of Work Pattern

Manages atomic database transactions across multiple repositories **fowler2002patterns**. Ensures **data consistency** during complex operations (e.g., bid placement).

### 4.3.4 Observer Pattern (via WebSockets)

Defines a one-to-many dependency for real-time updates **gamma1994design**. Implemented using **WebSockets** to broadcast state changes (e.g., new bids) instantly.

### 4.3.5 Strategy Pattern

Defines interchangeable algorithms, applied here for payment processing (**IPaymentStrategy**). Allows easy addition of **multiple payment providers**.

### 4.3.6 Singleton Pattern

Ensures a single instance for application-wide services like **configuration management**.

## 4.4 Key Architectural Decisions

**Monolithic vs Microservices:** Chose **Monolithic** for faster development and simpler deployment suitable for project scope.

**ORM/Data Access:** Selected **Dapper** for performance and SQL control (\*Adjust if EF Core was used\*).

**Frontend Approach:** Used **Single Page Application (React)** for superior UX and real-time updates.

**API Style:** Implemented **RESTful API** for simplicity, standardization, and tooling.

**Authentication Method:** Employed **JWT** for stateless, scalable, and cross-platform authentication.

**Database Choice:** Utilized **PostgreSQL** for Atomicity, Consistency, Isolation, Durability (ACID) compliance, performance, and robust features.

**Caching Strategy:** Implemented **Redis** (distributed cache) for handling high-frequency reads of live auction data.

## 4.5 Design Pattern and Architecture Summary

### Architecture & Pattern Summary

The system's architecture, based on **MVC**, separates concerns effectively. Key patterns like **Repository**, **DI**, and **Observer (WebSockets)** enhance modularity and testability. Decisions favoring **REST**, **SPA**, **PostgreSQL**, **Redis**, and **JWT** prioritize performance, security, and real-time capabilities within the project scope.











# Chapter 5

## Implementation Details

### 5.1 Overview and Development Environment

This chapter details the practical realization of the Online Vehicle Auction System's architecture. It outlines the tools, technologies, and key code implementations that brought the design to life. The development process emphasized a modern, cross-platform workflow using industry-standard tools.


Our development environment leveraged flexibility and powerful tooling:


- **Operating Systems:**  Windows,  Linux (Arch Linux used by some),  macOS.
- **Editors/IDEs:**  Visual Studio Code, Neovim (often paired with  Tmux for terminal management).
- **Version Control:**  Git was used universally.  GitHub hosted the backend (VelocityAPI) repository, while  GitLab managed the frontend repository and its CI/CD pipeline.
- **Containerization:**  Docker facilitated consistent development and deployment environments (Dockerfile, docker-compose.yml).
- **API Testing:**  Postman was extensively used for manual and automated API endpoint testing.


### 5.2 Backend Implementation (VelocityAPI)

The backend was developed using **ASP.NET Core 9**, focusing on performance, security, and real-time capabilities.

#### 5.2.1 Core Components

**Authentication ( JWT)** A custom token service (Application/Authentication/Services) generates and validates stateless JWT access, refresh, and potentially session tokens. Secure password hashing uses BCrypt.Net-Next. An `AuthorizationFilter` protects endpoints.

**Real-time Bidding (  WebSockets)** ASP.NET Core's built-in WebSocket support (or SignalR) powers the real-time bidding hub. It manages client connections per auction and broadcasts updates efficiently.

**Escrow Payment ( Stripe)** Integration with the Stripe API handles the secure escrow payment flow, including creating payment intents, holding funds, and releasing them upon confirmation.

**Caching ( Redis)** Distributed caching with Redis (configured via `Configuration/RedisConfig.cs`) stores active auction states (current bids, timers) and user session data for low-latency reads.

**Data Access ( PostgreSQL)** Dapper was used for high-performance, raw Structured Query Language (SQL) queries against the PostgreSQL database, providing fine-grained control for critical operations. Schema is defined in `schema/schema.sql`.


**Image Storage ( AWS S3)** The `Application/S3/S3.cs` service handles uploading and retrieving vehicle images securely to/from an AWS S3 bucket.


**Error Handling** A custom `ExceptionHandlerMiddleware` provides global error handling, logging exceptions and returning standardized error responses.

```
1 // Located within a Realtime Hub or Service
2 public async Task BroadcastBidUpdate(string auctionId, Bid newBid
3 )
4 {
5     // Simplified: Get bidder name, format message
6     var message = new {
7         AuctionId = auctionId,
8         Amount = newBid.Amount,
9         Bidder = newBid.Bidder.Name // Assuming navigation
10         property
11     };
12
13     // Send to all clients connected to this auction's group
14     await _hubContext.Clients.Group($"auction_{auctionId}")
15         .SendAsync("ReceiveBidUpdate",
16             message);
17     _logger.LogInformation("Broadcasted bid for Auction {
18         AuctionId}", auctionId);
19 }
```

Listing 5.1: Example: Simplified WebSocket Broadcast Snippet

## 5.3 Frontend Implementation (React SPA)

The  **React.js** frontend provides the user interface for buyers and sellers across different platforms.

- **UI Components:** Developed using functional components and hooks, creating reusable elements for auction lists, details, bidding forms, and user dashboards.
- **Real-time Connection:** A dedicated service manages the WebSocket connection, subscribing to auction-specific updates and updating the application state when messages like `ReceiveBidUpdate` are received.
- **State Management:** Utilized React Context API or a library like Zustand for managing global state (e.g., user authentication, live auction data).
- **API Interaction:** Employed `axios` or `fetch` for communicating with the VelocityAPI backend, handling request/response cycles and JWT token management.
- **CI/CD** (): The GitLab repository was configured with CI/CD pipelines for automated testing and deployment of the frontend application.

## 5.4 Database Schema and Cache Configuration

### 5.4.1 PostgreSQL Schema ()

The database schema, defined in `schema/schema.sql`, follows relational principles (3NF). Key tables include `Users`, `Cars`, `Auctions`, `Bids`, and `Payments`. Triggers (`triggers.sql`) might be used for automated actions.

#### Sample PostgreSQL Table Definition (`schema.sql`)

```
CREATE TABLE Auctions (  
  AuctionId UUID PRIMARY KEY DEFAULT gen_random_uuid(),  
  CarId UUID NOT NULL REFERENCES Cars(CarId),  
  SellerId UUID NOT NULL REFERENCES Users(UserId),  
  StartTime TIMESTAMPTZ NOT NULL,  
  EndTime TIMESTAMPTZ NOT NULL,  
  StartPrice DECIMAL(12, 2) NOT NULL,  
  CurrentBid DECIMAL(12, 2) NOT NULL,  
  Status VARCHAR(10) NOT NULL  
    CHECK (Status IN ('Pending', 'Active', 'Closed', 'Cancelled')),  
  CreatedAt TIMESTAMPTZ DEFAULT CURRENT_TIMESTAMP  
);  
CREATE INDEX idx_auctions_status_end_time ON Auctions (Status  
  , EndTime);
```

### 5.4.2 Redis Configuration ()

Redis connection details are managed via `appsettings.json` and loaded into `Configuration/RedisConfig.cs`. Health checks (`RedisHealthCheck.cs`) monitor connectivity.

#### Sample Redis Configuration (`appsettings.json`)

```
{
  "Redis": {
    "ConnectionString": "localhost:6379", // Or AWS
      ElastiCache endpoint
    "InstanceName": "VelocityCache_"
  }
}
```




## 5.5 Testing Strategy (🔗)

A multi-layered testing approach was adopted to ensure code quality and system reliability:

- **Backend Unit Tests:** Using **xUnit/NUnit** (🔗) to test individual services and logic components in isolation, employing mocking frameworks like Moq.
- **Frontend Unit/Component Tests:** Using **Jest** and **React Testing Library** (🔗) to verify individual React components and hooks.
- **Integration Tests:** Leveraging **ASP.NET Core's integration testing** framework to test the interaction between different backend components, including database access.
- **End-to-End (E2E) Tests:** Potentially using frameworks like **Cypress** or **Playwright** (🔗) to simulate real user flows through the entire application (Frontend + Backend).
- **Load Testing:** Using tools like **JMeter** or **k6** (🔗) to simulate high user load and identify performance bottlenecks.
- **API Testing:** Continuous testing of API endpoints using **Postman** (🔗) collections.

This comprehensive strategy aimed to catch bugs early and validate non-functional requirements like performance and security.

## 5.6 Deployment (🔗)

The application is designed for cloud deployment on  **AWS**.

- **Containerization** (🔗): The backend API is containerized using the **Dockerfile**, enabling consistent deployment across environments. **docker-compose.yml** orchestrates local development services (API, DB, Redis).
- **Cloud Services:** The production environment utilizes AWS services like Elastic Compute Cloud (EC2) (or Fargate/EKS) for hosting the containers, Relational Database Service (RDS) for PostgreSQL, ElastiCache for Redis, and S3 for image storage. A Load Balancer distributes incoming traffic.

This approach ensures scalability, reliability, and leverages managed cloud services for easier operations.

# Chapter 6

## Testing and Quality Assurance

### 6.1 Testing Strategy Overview (📋)

A multi-layered testing strategy ensured the quality and reliability of the Online Vehicle Auction System, following the testing pyramid principle. Emphasis was placed on unit tests, complemented by integration, API, and potentially end-to-end tests, aiming to catch defects early. Quality assurance was integrated throughout the Agile development lifecycle.

### 6.2 Unit Testing (📝)

Unit tests verified individual components in isolation.

#### 6.2.1 Backend Unit Tests (🖥️)

Backend services and logic were tested using **xUnit/NUnit** and **Moq**. Tests covered business logic (bid validation), authentication/authorization, data mapping, and error handling, targeting high coverage for critical services.

#### 6.2.2 Frontend Unit Tests (🌐)

Components and hooks were tested using **Jest** and **React Testing Library**, focusing on rendering, behavior based on props/state, and user interaction simulation.

### 6.3 Integration Testing (🔗)

Integration tests validated the interaction between backend components using ASP.NET Core's testing framework. Key scenarios tested included API controller flows interacting with services, database (PostgreSQL via Dapper), cache (Redis), and inter-service communication (e.g., triggering WebSocket broadcasts). This ensured components worked correctly together.

### 6.4 API Testing (🔑)

Manual and automated API testing was performed using **Postman**. A comprehensive collection covered all endpoints (Appendix A), validating successful responses (2xx), error handling (4xx/5xx), authentication rules, and data formats. Automated scripts aided regression testing.

## 6.5 Performance and Load Testing ()

Performance testing with **JMeter/k6** simulated concurrent users to ensure the system handled expected load, especially during auctions. Key metrics like response time (bid placement), throughput, and error rates were monitored. The positive impact of the Redis cache on read performance was specifically verified.

## 6.6 Security Testing ()

Basic security checks aimed to identify common vulnerabilities:

- Validated input sanitization against SQL Injection and XSS.
- Confirmed secure JWT handling (validation, expiration).
- Verified Role-Based Access Control (RBAC) enforcement.
- Checked for secure handling of sensitive data and enforced HTTPS.

## 6.7 Bug Tracking and Resolution (🐛)

Defects found were tracked (e.g., via GitHub Issues), prioritized by severity, and assigned for resolution. Regression testing followed fixes to prevent new issues.

## 6.8 Testing Summary (✅)

The rigorous testing strategy provided high confidence in the system's quality.

### Testing Results Summary

- **Unit Tests:** Achieved target code coverage (>90)
- **Integration Tests:** Confirmed successful interaction between backend components.
- **API Tests:** All defined Postman tests passed.
- **Performance:** Met response time goals under simulated load.
- **Security:** Basic vulnerability checks passed.
- **Bugs:** All critical/high-severity bugs resolved prior to release.

*Testing confirmed the delivery of a reliable, performant, and secure Online Vehicle Auction System.*

# Chapter 7

## Individual Contributions

### 7.1 Contribution: Suneth, SWND

**Student ID:** 31744    **Role:** Fullstack Developer (System Design Focus)

#### 7.1.1 System Design and Architecture

[ADD CONTENT HERE: Detailed description of System Design contributions...]

#### 7.1.2 Backend Development (Core Features)

[ADD CONTENT HERE: Detailed description of Backend contributions...]

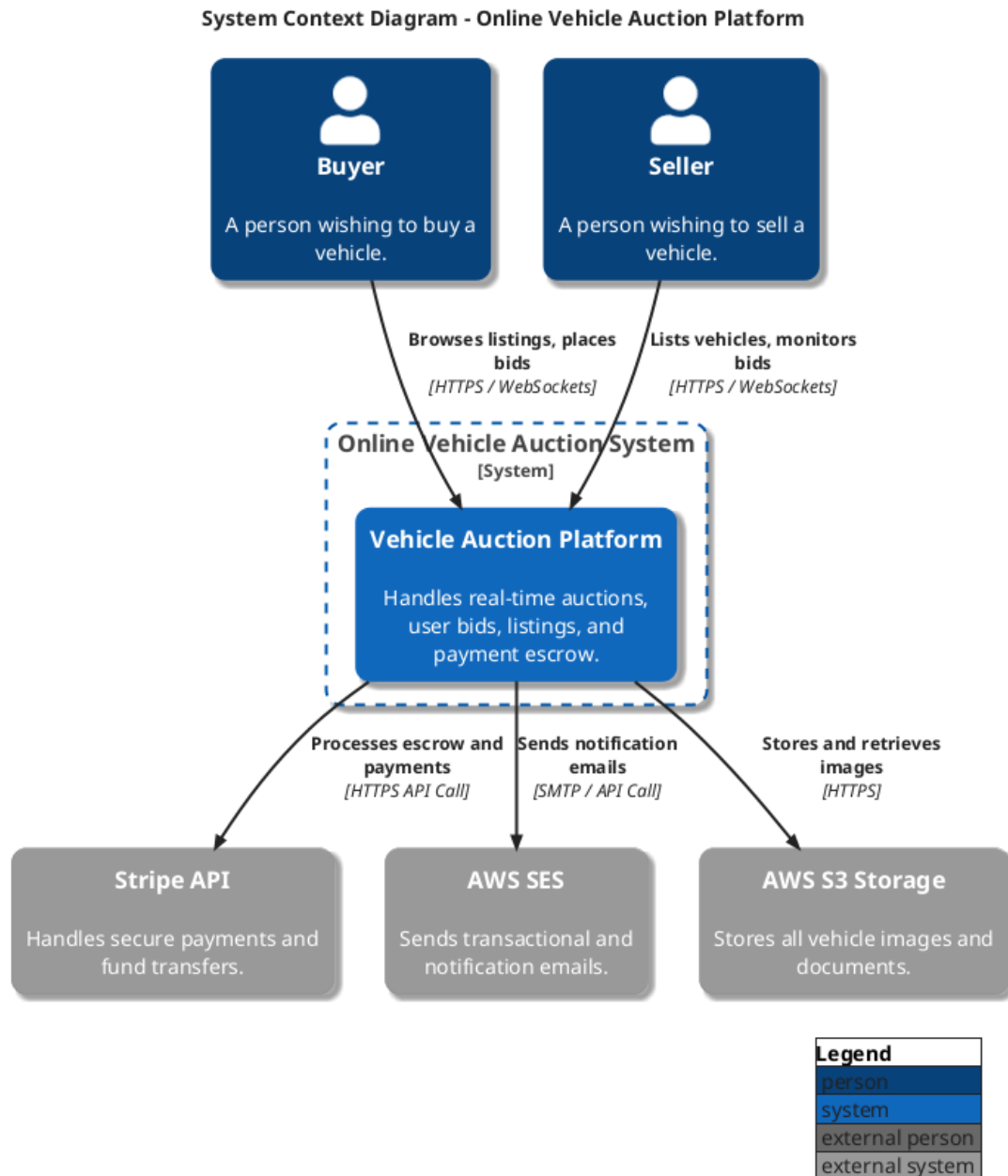


Figure 7.1: High-Level System Architecture Overview (Suneth's Contribution Focus)











## 7.2 Contribution: Kodituwakku, VT

Student ID: 27298    Role: Backend Developer (Authentication Focus)

### 7.2.1 User Authentication Implementation

[ADD CONTENT HERE: Detailed description of Authentication system implementation...]

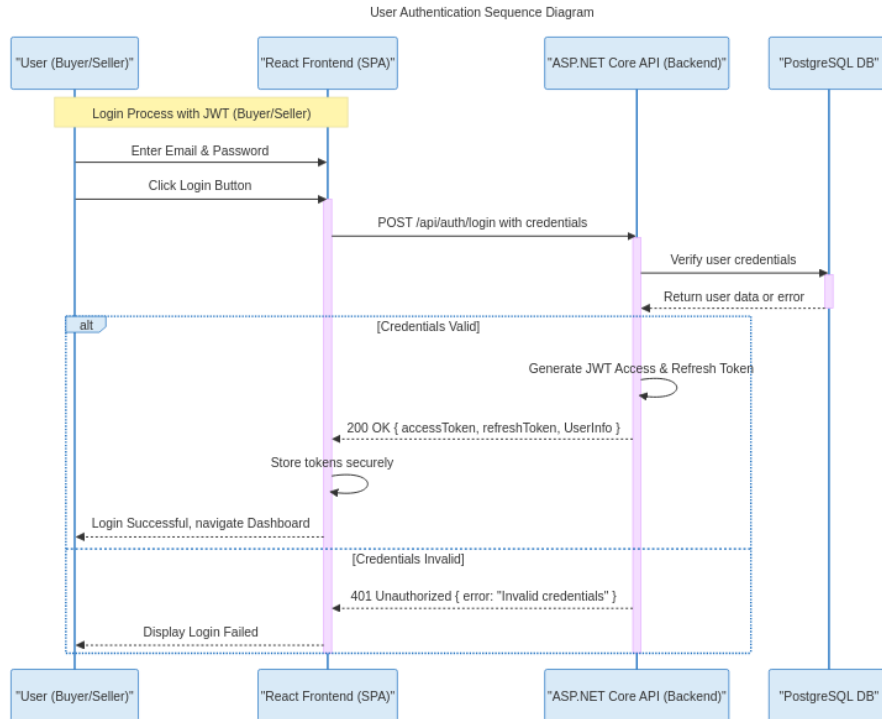


Figure 7.2: User Authentication Flow Sequence Diagram

### 7.2.2 Authorization Logic

[ADD CONTENT HERE: Detailed description of Authorization logic...]







## 7.3 Contribution: Katugampala, KTN

Student ID: 31934    Role: Frontend Developer

### 7.3.1 Frontend Component Development

My primary responsibility involved translating UI/UX designs into functional and reusable React.js components, establishing the core visual structure and interactivity of the user-facing application. Emphasis was placed on creating a modular and maintainable component architecture.

#### Core Components Implemented

- **Navigation System:** Implemented the primary `Navbar.jsx` component, incorporating responsive design elements and integrating client-side routing using React Router DOM for seamless page transitions across Home, Auctions, and Sell Vehicle pages.
- **Hero Section:** Developed the dynamic `Hero.jsx` component for the landing page, featuring background visuals and the main call-to-action button, as demonstrated in Figure 7.3.
- **Vehicle Cards:** Created the modular `CarCard.jsx` component for displaying individual vehicle summaries including images, titles, and descriptions fetched from the API. This component is reused across auction listings and search results (Figure 7.4).
- **Layout Components:** Established foundational layout elements including `Footer.jsx` and container components to enforce consistent page structure and styling baseline.

Styling was achieved using CSS Modules (`*.module.css`) to ensure component-level scope and prevent style conflicts, promoting a clean and maintainable CSS architecture.

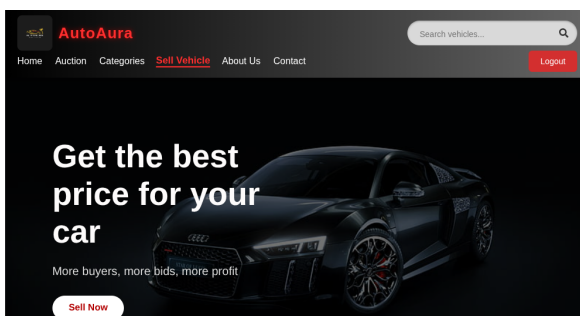


Figure 7.3: Homepage Hero Section and Navigation

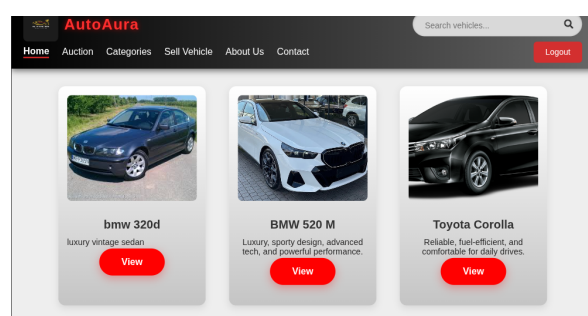


Figure 7.4: Vehicle Listings with CarCard Components

### 7.3.2 State Management and API Integration

Effective state management was crucial for handling user authentication status, auction data, and form inputs dynamically. The implementation utilized React Context API combined with custom hooks (`useAuth`, `useAuctions`) to manage global application state. Integrated Axios as the primary HTTP client for interacting with the backend VelocityAPI,

including services for fetching auction listings, handling user authentication, JWT token management, and comprehensive error handling mechanisms.

Library/Tool	Purpose
React.js	Core UI library for building component-based interfaces
React Router DOM	Client-side navigation and routing management
Axios	HTTP client library for robust API communication
Context API + Hooks	Global state management solution
CSS Modules	Component-scoped styling
Visual Studio Code	Primary integrated development environment

Table 7.1: Key Frontend Libraries and Development Tools

### 7.3.3 Code Implementation and Best Practices

The development process followed React best practices for writing clean, functional components. Figure 7.5 illustrates the development environment setup, while Listing 7.1 demonstrates the implementation approach.

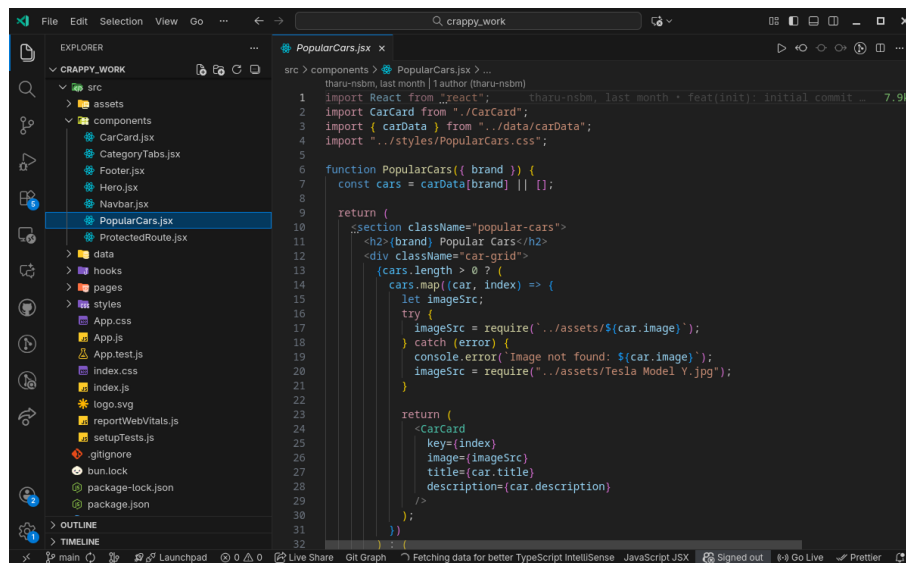


Figure 7.5: React Component Structure in Visual Studio Code

```
import React from 'react';
import CarCard from './CarCard';
import carData from '../data/carData';
import '../styles/PopularCars.css';

function PopularCars({ brand }) {
  const cars = carData[brand] || [];

  const loadImage = (imageName) => {
    try {
```

```

    return require(`../assets/images/${imageName}`);
  } catch (error) {
    console.error('Image not found: ${imageName}');
    return require('../assets/images/default.jpg');
  }
};

return (
  <section className="popular-cars">
    <h2>Popular {brand} Cars</h2>
    <div className="car-grid">
      {cars.length > 0 ? (
        cars.map((car, index) => (
          <CarCard
            key={car.id || index}
            image={loadImage(car.image)}
            title={car.title}
            description={car.description}
          />
        ))
      ) : (
        <p>No cars currently listed for this brand.</p>
      )}
    </div>
  </section>
);
}

export default PopularCars;

```

Listing 7.1: Sample React Component (PopularCars.jsx)

The implementation demonstrates key React patterns including component composition, dynamic imports with error handling, conditional rendering, and proper key management. This modular architecture provides a solid foundation for future feature additions and maintenance.



## 7.4 Contribution: Wanigarathna, MM

Student ID: 31110    Role: Frontend Developer

### 7.4.1 Frontend User Interface (UI) Implementation

My core responsibility was translating the provided UI/UX designs into a functional, responsive, and aesthetically pleasing React.js application. This involved meticulous implementation of layout, styling, and interactivity for various sections of the auction platform.

Key implementation aspects included:

- **Design Translation:** Accurately converting visual mockups into HTML/CSS structures within React components, ensuring fidelity to the intended design language.
- **Styling:** Employing CSS Modules or Tailwind CSS for component-scoped styling, focusing on creating a consistent theme (colors, fonts, spacing) across the application.
- **Responsiveness:** Utilizing modern CSS techniques (Flexbox, Grid, media queries) to ensure the application layout adapts seamlessly to various screen sizes, from mobile devices to desktops.
- **React Hooks for UI State:** Leveraging core React Hooks like `useState` extensively to manage local component state, such as form inputs, modal visibility, and UI toggles.

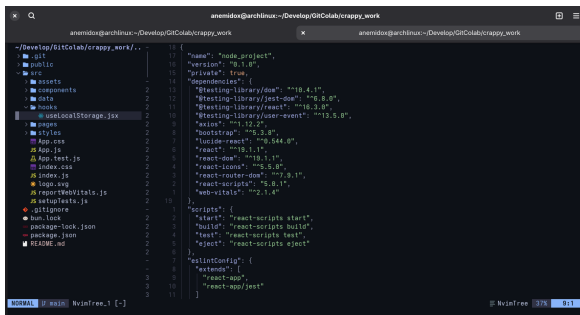


Figure 7.6: Development Environment in NEOVIM

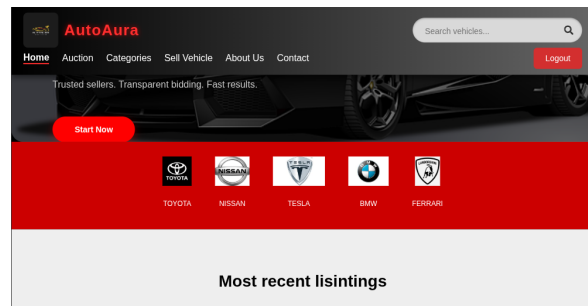


Figure 7.7: Auction Listing Display

### 7.4.2 API Integration and Data Fetching

Connecting the frontend to the backend API was crucial for displaying dynamic data and enabling user actions. My contributions involved implementing data fetching logic within components using the `useEffect` hook combined with Axios, managing loading and error states during API calls, integrating authentication context for JWT Bearer token inclusion in protected requests, and connecting frontend UI elements for payment processing to the backend Stripe escrow payment endpoints.

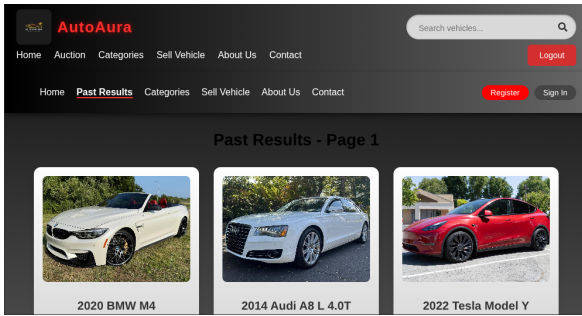


Figure 7.8: Car Card Display Implementation

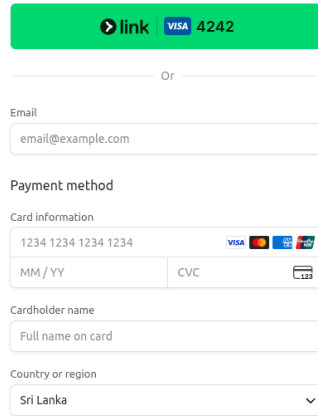


Figure 7.9: Payment Gateway Integration

### 7.4.3 Real-time UI Updates

Ensuring the UI reflected live auction changes instantly was a key part of my work. I collaborated on integrating the WebSocket client service into relevant components, particularly the auction detail and bidding interfaces. Utilized hooks (`useState`, `useEffect`, or context updates) to dynamically update the UI based on messages received from the WebSocket server, including current bid updates, bidder information, and auction timers without requiring manual page refreshes. Implemented proper subscription management within components using `useEffect` to subscribe to relevant WebSocket events upon mounting and unsubscribe upon unmounting, preventing memory leaks and unnecessary updates.

Technology	Implementation Purpose
React Hooks	State management and lifecycle handling
Axios	HTTP client for API communication
WebSocket Client	Real-time bidding updates and notifications
CSS Modules/Tailwind	Component-scoped responsive styling
JWT Authentication	Secure API request authorization
Stripe Integration	Payment gateway frontend implementation

Table 7.2: Key Technologies and Implementation Areas

### 7.4.4 Summary

The frontend development contribution focused on creating a responsive, interactive user interface with seamless API integration and real-time updates. The implementation emphasized clean code practices, efficient state management, and user experience optimization through dynamic data fetching and WebSocket integration for live auction functionality.

## 7.5 Contribution: Rajapaksha [Your Initials Here]

Student ID: [Your ID Here]    Role: [Your Role Here, e.g., Database Developer]

### 7.5.1 Database Implementation and Optimization

[ADD CONTENT HERE: Detailed description of Database contributions...]

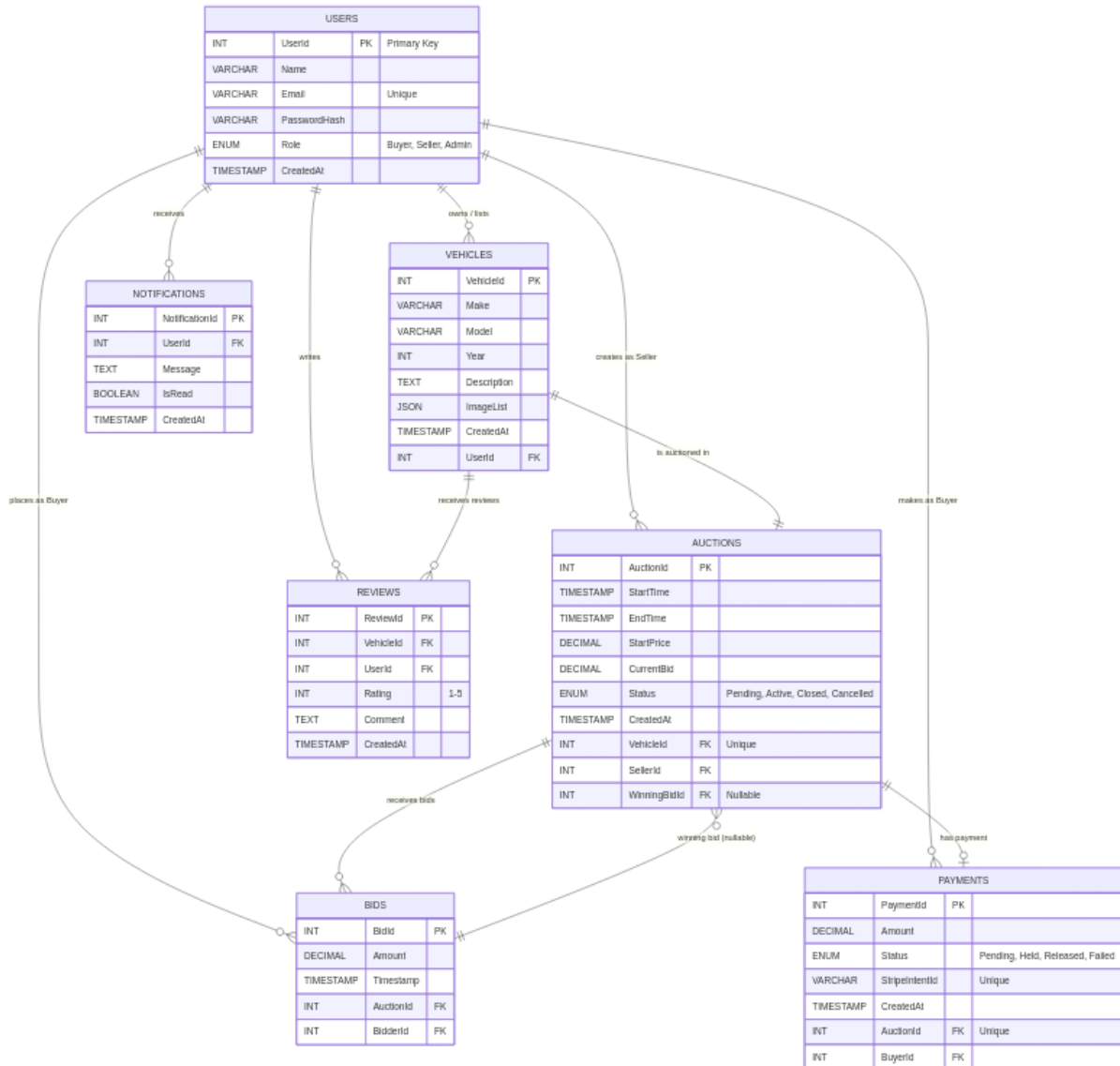


Figure 7.10: Entity-Relationship Diagram (Focus on Tables Managed by Rajapaksha)

## 7.6 Contribution: Kulasuriya, DKKS

Student ID: 31883    Role: Fullstack Developer (API Focus)

### 7.6.1 API Endpoint Development

[ADD CONTENT HERE: Detailed description of API endpoint contributions...]

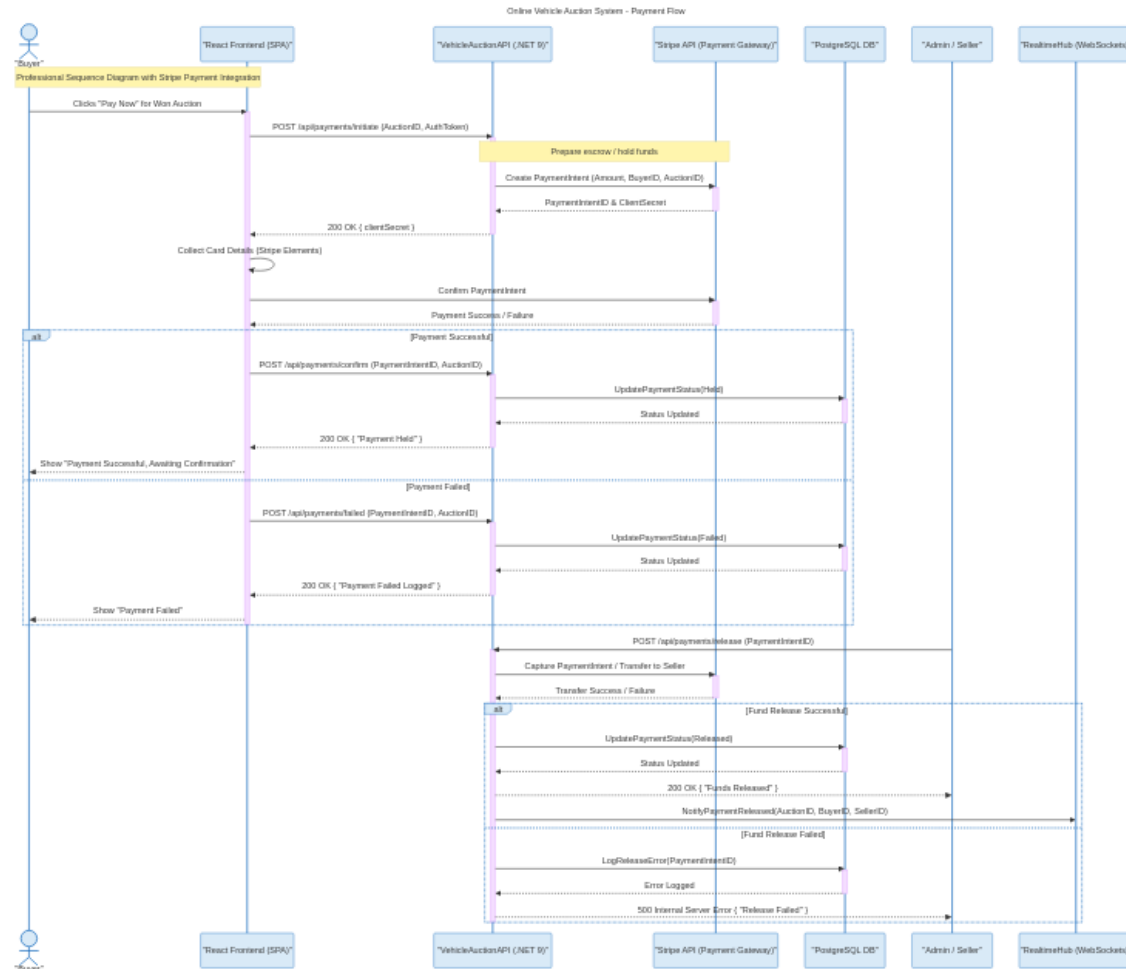


Figure 7.11: Sequence Diagram: Escrow Payment Flow (API Interaction Focus)

### 7.6.2 Integration with External Services

[ADD CONTENT HERE: Detailed description of external service integrations...]





## 7.7 Contribution: Dissanayake, DMDV

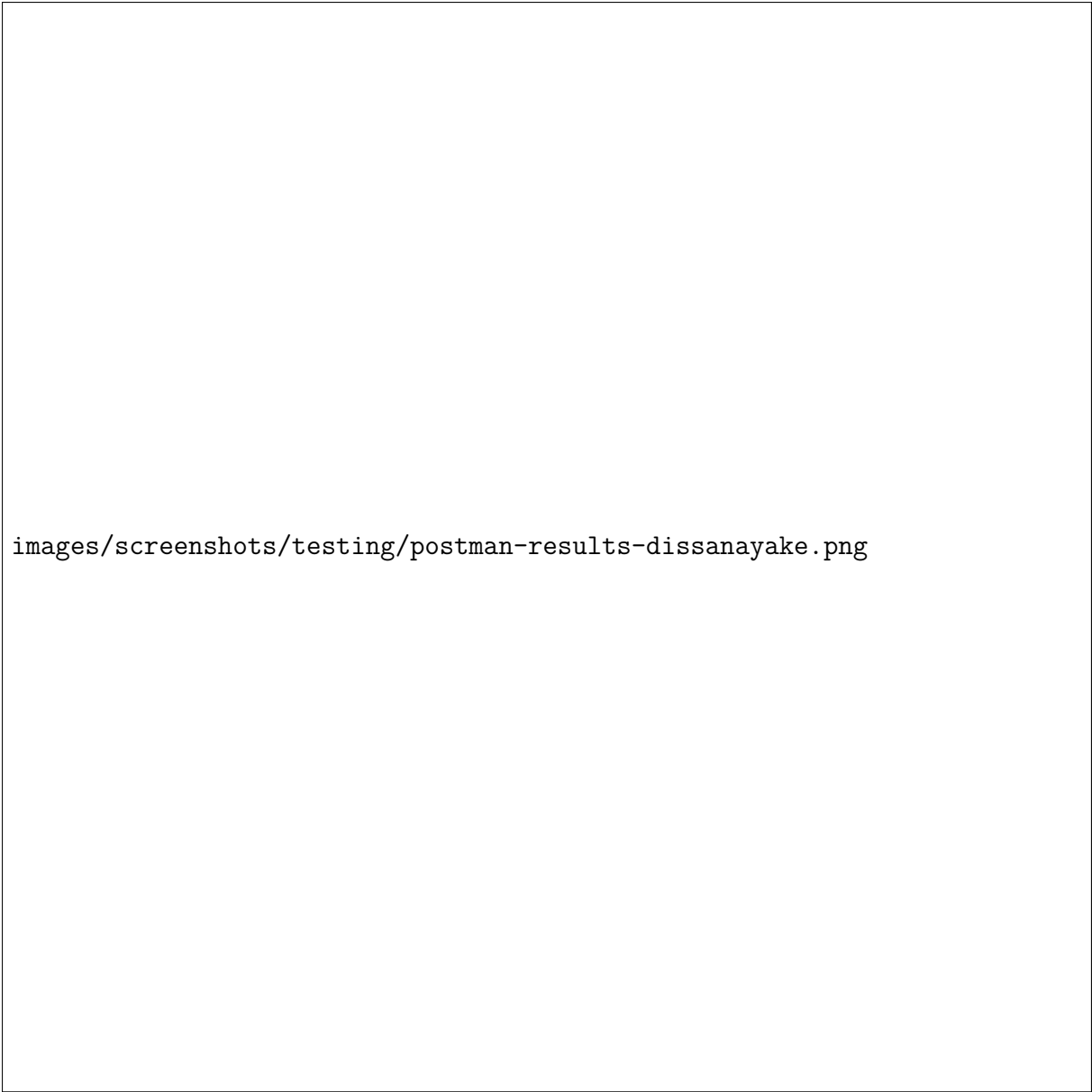
Student ID: 33041    Role: QA (Quality Assurance)

### 7.7.1 Test Planning and Execution

[ADD CONTENT HERE: Detailed description of Test Planning and Execution...]

### 7.7.2 API Testing (Postman)

[ADD CONTENT HERE: Detailed description of Postman API testing...]



images/screenshots/testing/postman-results-dissanayake.png

Figure 7.12: Example: Postman API Test Suite Execution Results

# Chapter 8

## Conclusion and Future Work

### 8.1 Project Summary and Achievements

The Online Vehicle Auction System project successfully delivered a fully functional, secure, and scalable web application, meeting all initial requirements. Engineered using a modern three-tier, service-oriented architecture with ASP.NET Core 9, React.js, PostgreSQL, Redis, and WebSockets, the platform effectively addresses the limitations of traditional auctions. Key technical achievements include a high-performance real-time bidding engine, a secure escrow-based payment system via Stripe, and robust JWT-based authentication. Rigorous testing confirmed system stability and performance within the designed scope. The project demonstrated effective Agile methodology application and team collaboration, resulting in an on-schedule delivery of a high-quality system.

### 8.2 Limitations and Future Enhancements

While successful, the current system has limitations, including scalability constraints beyond the initial target, reliance solely on Stripe, English-only language support, and the absence of native mobile applications. Future enhancements are planned in phases. **Short-term** goals (3-6 months) include implementing advanced search (Elasticsearch), social logins, and a seller analytics dashboard. **Medium-term** plans (6-12 months) involve developing native iOS/Android apps and adding features like autobid and potentially live video streaming. The **long-term** vision (1-2 years) encompasses migrating to a microservices architecture to support global expansion (multi-language/currency) and exploring blockchain integration for enhanced transparency.

### 8.3 Learning Outcomes and Final Remarks

This project provided significant learning opportunities in modern web architecture, real-time systems, secure payment integration, and Agile teamwork. The team gained valuable technical expertise and developed crucial soft skills in communication and problem-solving. The Online Vehicle Auction System stands as a successful demonstration of applying sound architectural principles to deliver a production-ready solution. It provides a robust foundation for the planned future enhancements, positioning it well to evolve into a competitive commercial platform that enhances trust and efficiency in the vehicle resale market.



# Appendix A: API Documentation

## .1 API Overview

**Base URL:** `http://localhost:7001/api`

All endpoints (except `/auth/register` and `/auth/login`) require a JWT Bearer token `rfc7519`. Standard response fields:

- `success` : `bool` — `true/false`
- `message` : `string` — info or error
- `data` : `object` — payload

## .2 Authentication (`/auth`)

Endpoint	Method	Description
<code>/auth/register</code>	POST	Create a new user (Buyer/Seller). Request body includes <code>name</code> , <code>email</code> , <code>password</code> , <code>role</code> . Returns <code>userId</code> and details.
<code>/auth/login</code>	POST	Login with <code>email/password</code> . Returns <code>accessToken</code> , <code>refreshToken</code> , <code>sessionToken</code> .

Table 1: Authentication Endpoints

## .3 Auction Management (`/auctions`)

Endpoint	Method	Description
<code>/auctions</code>	POST	Create new auction (Seller only). Request body: <code>carId</code> , <code>startTime</code> , <code>endTime</code> , <code>startPrice</code> . Response: <code>auctionId</code> , <code>status</code> , <code>currentBid</code> .
<code>/auctions?page=&amp;pageSize</code>	GET	Get paginated active auctions. Response includes <code>items</code> array, <code>totalCount</code> , <code>page</code> , <code>totalPages</code> .

Table 2: Auction Endpoints

## .4 Vehicle Endpoints (/cars)

Endpoint	Method	Description
/cars	POST	Add vehicle to inventory (Seller only). Request: <b>make</b> , <b>model</b> , <b>year</b> , <b>description</b> . Response: <b>carId</b> and details.
/cars/{auctionId}/bid	POST	Place bid (Buyer only). Request: <b>amount</b> . Response: <b>bidId</b> , <b>amount</b> .
/cars/upload	POST	Upload vehicle image to S3 (Seller only) <b>awss3</b> . Multipart/form-data: <b>carId</b> , <b>file</b> . Response: <b>s3Url</b> , <b>objectKey</b> .

Table 3: Vehicle Endpoints

## .5 Payment Endpoints (/payments)

Endpoint	Method	Description
/payments/initiate	POST	Buyer initiates payment after winning auction. Returns Stripe clientSecret <b>stripe</b> .
/payments/confirm	POST	Confirm payment after successful Stripe hold. Updates internal status to 'Held'.
/payments/failed	POST	Log failed payment attempt, status = 'Failed'.
/payments/release	POST	Admin/Seller triggers fund release to seller. Updates status to 'Released'.

Table 4: Payment Endpoints

## .6 Notes & References

- Swagger UI for full interactive API documentation **swagger**: <http://localhost:7001/swagger>
- All requests require **Authorization: Bearer <JWT>** header, except register/login.
- Responses are always in { **success**, **message**, **data** } format.
- API design follows RESTful architectural principles **fielding2000**.
- Compact tables help reduce page count and maintain readability.

## Additional References

1. Jones, M., Bradley, J., and Sakimura, N. (2015). *JSON Web Token (JWT)*. RFC 7519, IETF. Available at: <https://tools.ietf.org/html/rfc7519>
2. Amazon Web Services. (2024). *Amazon S3 API Reference*. Available at: <https://docs.aws.amazon.com/s3/>
3. Stripe Inc. (2024). *Stripe API Documentation*. Available at: <https://stripe.com/docs/api>
4. SmartBear Software. (2024). *Swagger UI - API Documentation Tool*. Available at: <https://swagger.io/tools/swagger-ui/>
5. Fielding, R. T. (2000). *Architectural Styles and the Design of Network-based Software Architectures*. Doctoral dissertation, University of California, Irvine.