Computer Science Department

Economics

Bachelor's Thesis

Capstone Project

BeatRate Web Application

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TODOS

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I, undersigned, hereby declare that this capstone project is the result of my own work.

- All ideas, data, figures and text from other authors have been clearly cited and listed in the bibliography.
- No part of this project has been submitted previously for academic credit in this or any other institution.
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Acknowledgements

Individual Contribution Note: This acknowledgements section reflects the personal academic journey and gratitude of Yaroslav Khomych. While this capstone project was completed collaboratively with Maksym Pozdnyakov, the experiences and acknowledgements expressed here are individual to Yaroslav's perspective and learning path at KSE.

During my academic journey at KSE, I encountered numerous brilliant individuals who impacted my life in various ways. I remain grateful to everyone for the knowledge shared and time invested in my development.

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Abstract

The abstract serves as a concise summary of your entire thesis, encapsulating key elements on a single page such as:
- *General background information*
- *Objective(s)*
- *Approach and method*
- *Conclusions*

Keywords:

KSE, Software Engineering, Thesis, BeatRate, Web Application

1 Introduction

In the rapidly evolving landscape of digital music consumption, where streaming platforms have revolutionized how we discover and consume music, a critical gap exists in the space dedicated to music evaluation, critique, and meaningful social interaction around musical content. This capstone project documents the complete development of **BeatRate** - a Music Evaluation Platform designed to serve as a dedicated social space for music enthusiasts, critics, and artists to rate, review, and discover music while fostering an active community of like-minded individuals.

Unlike existing streaming platforms that prioritize consumption, BeatRate addresses the absence of a comprehensive platform that combines in-depth music evaluation with robust social features. Drawing inspiration from successful platforms like Letterboxd for films and IMDb for movies, this project represents the creation of a similar ecosystem specifically tailored for the music domain. The platform merges the elements of a social network with the depth of a sophisticated discovery and evaluation tool, enabling users to rate and review music using both traditional and innovative custom grading methods, curate personalized music lists, and engage in meaningful discussions within a diverse community.

This paper chronicles the journey of two software engineering students who, over an intensive three-month development period, transformed a conceptual solution into a fully functional web application comprising over 55,000 lines of code across multiple technologies and architectural layers. The development process encompassed detailed market research, competitor analysis, solution architecture design, and implementation of a scalable cloud-based system using modern software engineering practices.

1.1 Project Objectives

The primary objectives of this capstone project are:

1. To develop a fully functional web application that facilitates music rating, reviewing, and discovery
2. To implement a dual rating system allowing both simple and comprehensive evaluations
3. To create robust social features enabling community interaction around musical content
4. To integrate with established music services (specifically Spotify) to access comprehensive music metadata
5. To build a scalable architecture capable of supporting growth in both users and features
6. To deploy the application using modern cloud infrastructure and DevOps practices

These objectives guided our development process throughout the project lifecycle, from initial research through implementation and deployment.

1.2 Relevance and Significance

This project holds significance in several dimensions:

Technical Relevance: The development of BeatRate demonstrates the application of modern software engineering practices in creating a complex, feature-rich web application. The project showcases the implementation of microservices architecture, cloud deployment strategies, and integration with third-party APIs within a constrained timeframe.

Market Relevance: Our market research indicates significant growth potential in the music evaluation space, with global music streaming projected to reach US35.45 billion dollars by 2025 (Statista, 2024). The growing emphasis on personalization and community engagement in music consumption supports the need for platforms that facilitate deeper connections between listeners, critics, and artists.

Academic Relevance: This capstone project integrates knowledge from various courses in the Software Engineering and Business Analysis curriculum, including software architecture, database design, web development, user experience, market research, and DevOps. It demonstrates our ability to apply theoretical concepts to practical, real-world problems.

1.3 Methodology

Our approach to developing BeatRate followed a structured methodology combining thorough research with agile development practices:

1. **Discovery Phase**: We conducted extensive research into the domain, analyzing competitor platforms, identifying market opportunities, and defining core requirements.
2. **Iterative Development**: The implementation followed three month-long development sprints, each with specific goals and deliverables:
   - Sprint 1: Core architecture and basic functionality
   - Sprint 2: Advanced features and social components
   - Sprint 3: Refinement, optimization, and deployment
3. **Technology Selection**: We carefully selected our technology stack based on project requirements, team expertise, and industry best practices. The backend uses C# with .NET, while the frontend employs React. AWS provides our cloud infrastructure, with specific services chosen to optimize performance, scalability, and cost.

1.4 Structure of this paper

This thesis is structured to provide both a comprehensive technical reference and an engaging narrative of the development process:

Domain Research and Analysis (Chapter 3) examines the current music evaluation platform ecosystem through competitor analysis, market research, and identification of gaps that justify our solution.

System Design and Architecture (Chapter 4) details our complete solution design, including software architecture decisions, technology stack selection and justification, economic analysis of our platform's viability, and user experience design considerations.

Implementation Journey (Chapter 5) chronicles the three-month development process, documenting each sprint's objectives, challenges, achievements, and retrospective insights.

Validation and Testing (Chapter 6) demonstrates how we verified that our implementation meets initial requirements through comprehensive testing methodologies and user validation.

Conclusions and Future Perspectives (Chapter 7) reflects on the project's achievements, lessons learned, and potential directions for future development.

Throughout this paper, we aim to demonstrate not only the technical implementation of BeatRate but also the thought process behind our decisions and the evolution of the project from concept to deployment. With over 55,000 lines of code and a robust feature set, BeatRate represents the culmination of our software engineering education and our passion for creating meaningful digital experiences.

2 Domain Research and Analysis

2.1 Research Questions and Functional Requirements

The development of BeatRate emerged from a fundamental observation: while platforms for streaming and consuming music are abundant, the music industry lacks a comprehensive platform that prioritizes evaluation, review, and meaningful social interaction around musical content. This chapter presents our systematic investigation into the music evaluation platform landscape to understand existing solutions, identify gaps, and justify the need for our proposed platform.

Our research was guided by the following key questions:

- What existing platforms currently serve the music evaluation and review market?
- How do these platforms approach core functionalities such as rating systems, social features, and music discovery?
- What are the strengths and limitations of current solutions in serving different user segments?
- Where do significant gaps exist that could be addressed by a new platform?
- How can we differentiate our solution while building upon successful patterns from other domains?
- What is the monetization model of the existing platforms? What are their potential earnings?

Through systematic analysis of these questions, we establish the functional requirements that inform BeatRate's design and development approach.

2.2 Market Context and Industry Analysis

2.2.1 Global Music Streaming Landscape

The music evaluation platform market operates within the broader context of the global music streaming industry, which demonstrates significant growth potential. According to Statista (2024), the global music streaming market is projected to reach US$35.45 billion in 2025, with a steady compound annual growth rate (CAGR) of 4.90% between 2025 and 2029. The United States maintains its position as the dominant market player, anticipated to generate US$13,910 million in revenue by 2025.

User adoption metrics reveal promising expansion trajectories, with the global user base expected to reach 1.2 billion by 2029. This growth is accompanied by evolving consumer preferences, particularly evident in the increasing emphasis on personalization and curated content delivery. The industry's shift toward tailored listening experiences reflects a fundamental transformation in how consumers interact with music streaming services, suggesting opportunities for platforms that facilitate deeper engagement with musical content.

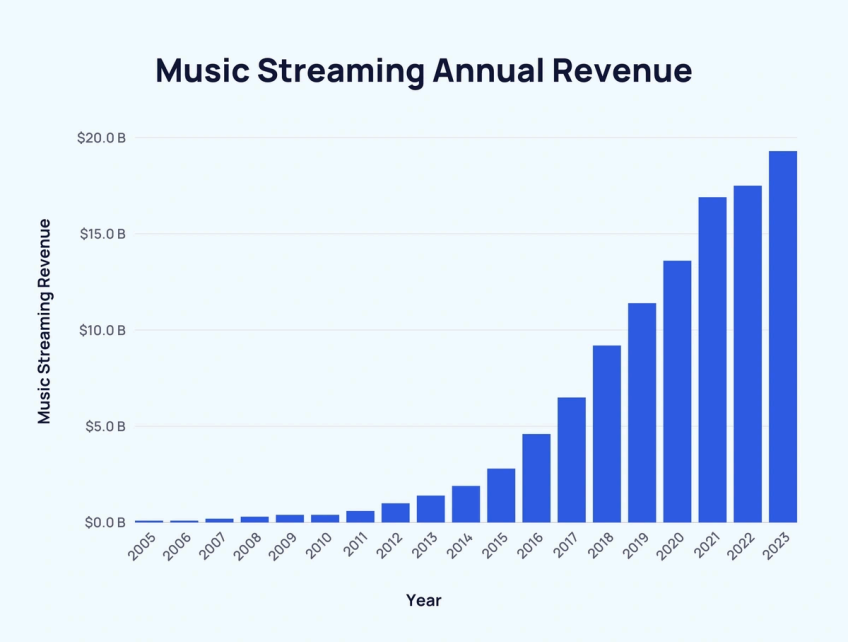

Figure 1: Global Music Streaming Market Growth and Projections

2.2.2 Music Rating Platform Market Analysis

Our analysis of the current market leaders reveals significant user engagement and growth potential in the music evaluation sector. Based on comprehensive data from SimilarWeb (2024), we identified three primary platforms that align with our core requirements: Rate Your Music (RYM), Album of the Year (AOTY), and Musicboard.

Market Leadership and User Engagement:

Rate Your Music emerges as the clear market leader with approximately 15.02 million monthly visits and 15.02 million unique visitors (SimilarWeb, 2024). The platform demonstrates remarkably strong user engagement metrics with an average of 12.40 pages per visit and a low bounce rate of 24.56%, indicating strong user retention and content engagement.

Album of the Year follows with 8.2 million monthly visits, showing similar engagement strength with 10.43 pages per visit and a 28.22% bounce rate (SimilarWeb, 2024). These metrics suggest a highly invested user base across the leading platforms.

Musicboard, as a newer entrant, attracts close to 300,000 monthly visits but represents an emerging competitor with modern design principles and social features that align closely with contemporary user expectations (SimilarWeb, 2024).

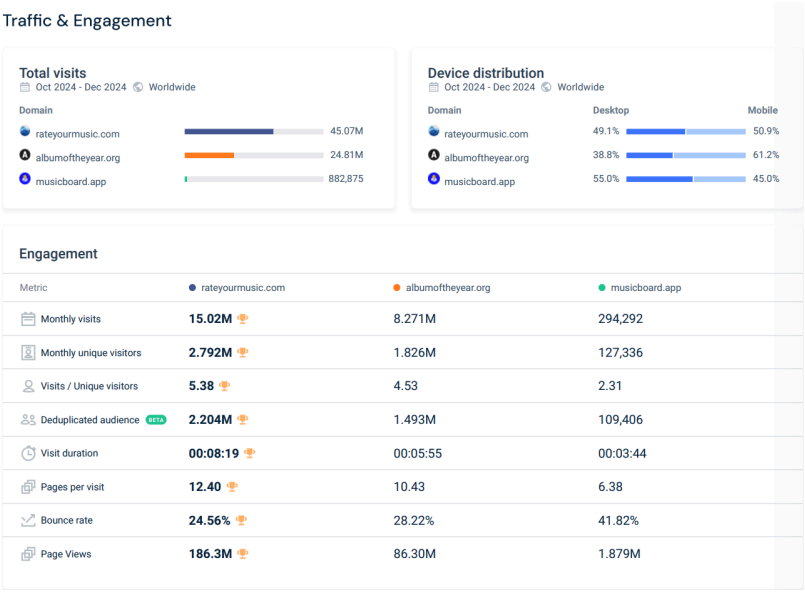

Figure 2: Market Leadership and User Engagement Metrics

Geographic Distribution and Growth Indicators:

Geographic analysis reveals strong presence in key English-speaking markets, with the United States leading at 43.26% of total traffic, followed by the United Kingdom at 8.10% (SimilarWeb, 2024). This distribution suggests both market concentration and significant opportunity for international expansion.

The platforms show robust organic growth, with Rate Your Music capturing 48.17% of traffic through organic search, indicating strong brand recognition and natural user acquisition patterns. Session durations across platforms average between 5-8 minutes, indicating meaningful user interactions and substantive content consumption (SimilarWeb, 2024).

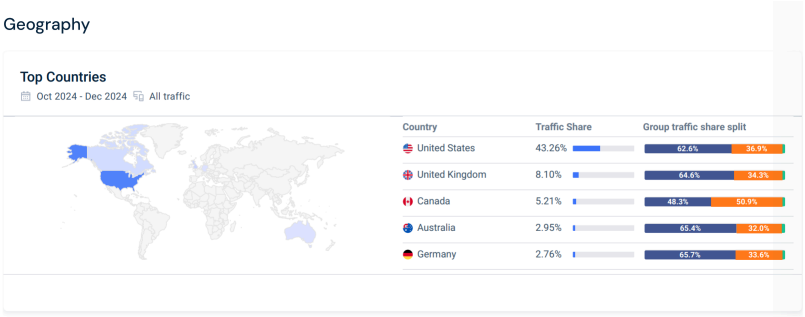

Figure 3: Geographic Distribution of Platform Traffic

2.3 Competitive Analysis

2.3.1 Platform Categories and Architectural Approaches

Through our systematic analysis, we identified distinct categories of platforms based on their architectural approaches and feature focus:

Traditional Database-Driven Platforms: Platforms like Rate Your Music represent the traditional approach, focusing primarily on complex cataloging and basic rating functionality (Rate Your Music, n.d.). These platforms typically employ monolithic architectures with extensive relational databases but limited social interaction capabilities. RYM utilizes basic web technologies including Google Analytics and PayPal integration, but users frequently report query failures and timeouts, suggesting significant backend infrastructure limitations.

Aggregator-Style Platforms: Album of the Year follows an aggregator model similar to Metacritic, distinguishing between critic scores and user scores (Album of the Year, n.d.). This approach emphasizes editorial content alongside user-generated reviews but often lacks social features. AOTY employs a mixed technology stack with JavaScript/jQuery frontend and PHP backend, supplemented by Ruby-based Discourse forums, utilizing multiple web servers including LiteSpeed and Nginx for performance optimization.

Social-First Modern Platforms: Musicboard represents the emerging category of platforms that prioritize social interaction and modern user experience design, drawing inspiration from successful platforms in adjacent domains like Letterboxd for films (Musicboard, n.d.). Musicboard employs a modern modular architecture with React Native/Expo for cross-platform mobile development and FastAPI backend, enabling asynchronous capabilities and automatic API documentation generation.

2.3.2 Detailed Competitor Evaluation

Rate Your Music (RYM)

Strengths:
- Market leadership with extensive user base and high engagement
- Comprehensive music database with detailed metadata
- Robust rating system (0.5 to 5 scale) with statistical depth
- Strong community of dedicated music enthusiasts
- Advanced search and filtering capabilities
- User-generated lists and collection management

Weaknesses:
- Outdated design that feels cluttered and overwhelming
- Poor user experience with unnecessary complexity
- Minimal social interaction features
- No meaningful user following or connection system
- Lack of modern features like listening diaries or activity logging
- Mobile experience is suboptimal

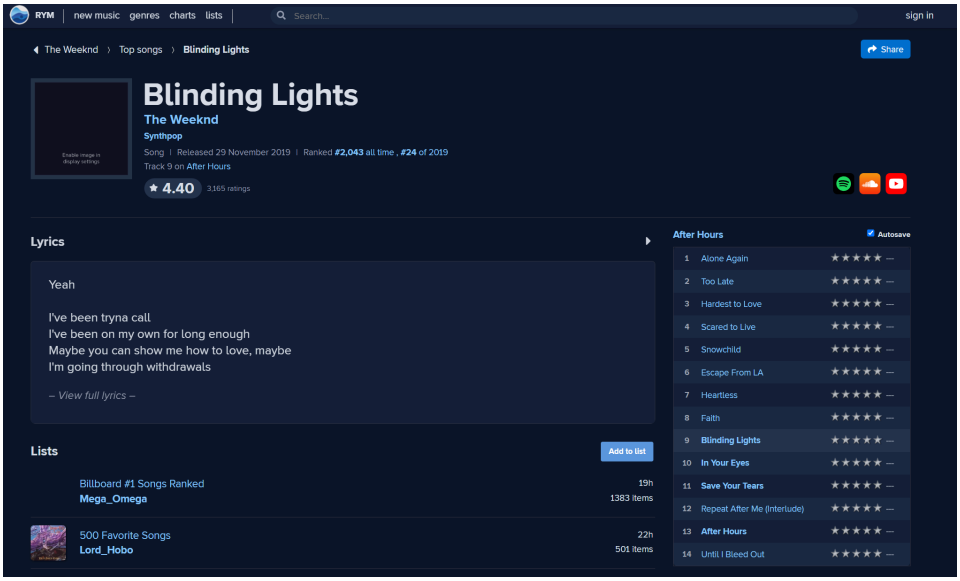

Figure 4: Rate Your Music track page interface showing cluttered design and poor visual hierarchy

Album of the Year (AOTY)

Strengths:

- Clear distinction between critic and user scores (0-100 scale)
- Focus on new releases and contemporary music
- Clean presentation of rating aggregation
- Integration with professional music criticism

Weaknesses:

- Limited social features beyond basic reviewing
- Uninspired design that lacks engagement
- No advanced personalization or discovery features
- Minimal community interaction capabilities
- Limited list creation and curation tools

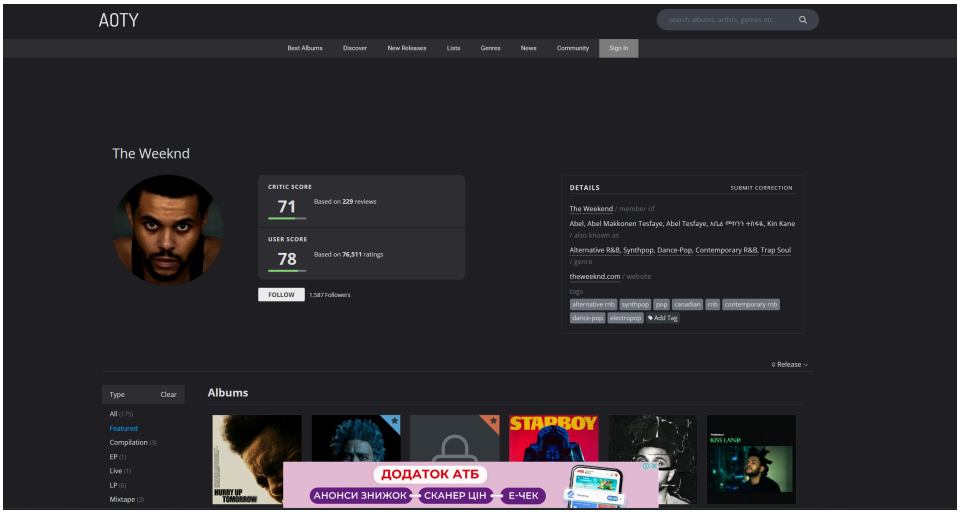

Figure 5: Album of the Year interface showing cleaner but uninspiring design with bad optimisation for desktop resulting in smaller items and empty space

Musicboard

Strengths:

- Modern, clean design inspired by successful platforms like Letterboxd
- Comprehensive social features including following, likes, and comments
- Mixed-media lists combining songs, albums, and artists
- Unique curated charts based on user statistics
- Robust logging and diary functionality
- Strong community engagement features

Weaknesses:

- Limited market penetration due to recent entry
- Frequent advertisement interruptions affecting user experience
- Smaller music database compared to established competitors
- Less sophisticated search and discovery algorithms

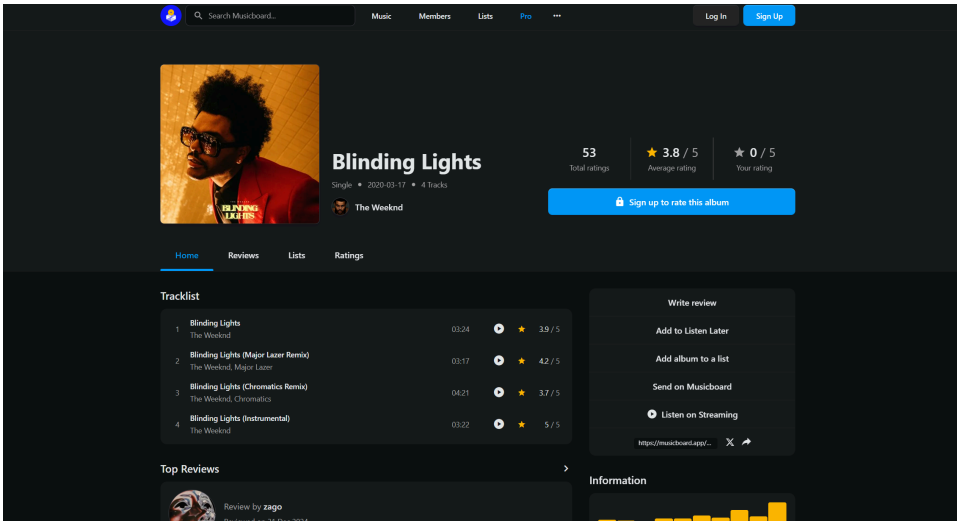

Figure 6: Musicboard interface demonstrating modern design principles but with intrusive advertisement placement that disrupts user flow

2.3.3 Feature Comparison Matrix

Feature Category	**Rate Your Music**	**Album of the Year**	**Musicboard**	**Market Gap**
Rating Systems	✓ (0.5-5 scale)	✓ (0-100 scale)	✓ (0.5-5 scale)	Custom rating methodologies
User Reviews	✓ Basic	✓ Basic	✓ Advanced	Rich multimedia reviews
Social Features	✗ Minimal	✗ None	✓ Comprehensive	Enhanced discussion spaces
Logging/Diary	✗ None	✗ None	✓ Basic	Advanced activity tracking
User Lists	✓ Basic	✗ None	✓ Advanced	Collaborative curation
Mobile Experience	✗ Poor	✗ Basic	✓ Good	Native mobile optimization
API Integration	✓ Limited	✓ Limited	✓ Spotify	Multi-platform integration
Monetization	Free + Ads	Free + Donation	Subscription	Sustainable revenue models

Table 1: Competitive Feature Analysis Matrix

2.4 Gap Analysis and Market Opportunities

2.4.1 Identified Market Gaps

Through our comprehensive analysis, we identified several significant gaps in the current market:

1. **Customizable Rating Systems:** No existing platform offers users the ability to customize their rating methodology. All platforms impose a single rating scale, limiting users who prefer different evaluation approaches or want to rate different aspects of music separately.
2. **Enhanced Social Discovery:** While Musicboard includes social features, most platforms lack sophisticated social discovery mechanisms that help users find like-minded community members or discover music through social connections.
3. **Advanced Discussion Spaces:** Current platforms either lack discussion features entirely or provide only basic commenting. There's an opportunity for structured discussion spaces around specific topics, genres, or musical themes.
4. **Comprehensive Integration:** Most platforms offer limited integration with streaming services. A more comprehensive integration like importing music habbits and history could provide seamless discovery and better user experience.
5. **Modern User Experience:** Several leading platforms suffer from outdated design and poor user experience, particularly on mobile devices. There's a significant opportunity for platforms that prioritize modern UX/UI principles.

2.4.2 Target User Segments and Unmet Needs

Our research identified three primary user segments with distinct unmet needs:

Music Enthusiasts (Casual to Dedicated Listeners)
- **Need:** Better discovery mechanisms that go beyond algorithmic recommendations
- **Gap:** Limited platforms offering community-driven discovery
- **Opportunity:** Social features that connect users with similar tastes

Critics and Reviewers (Amateur and Professional)
- **Need:** Sophisticated tools for detailed music analysis and critique
- **Gap:** Platforms lack advanced review formatting and multimedia support
- **Opportunity:** Professional-grade review tools with community engagement

Musicians and Artists
- **Need:** Direct engagement with audience and feedback collection
- **Gap:** Most platforms don't facilitate artist-audience interaction
- **Opportunity:** Features designed specifically for artist engagement and feedback

2.4.3 Technological Opportunities

Modern Architecture Requirements:
- Microservices architecture for scalability and maintainability
- API-first design enabling future integrations and mobile applications
- Cloud-native deployment for global accessibility and performance

- Real-time features for social interaction and content updates

Integration Opportunities:
- Multi-platform streaming service integration beyond Spotify
- Social media integration for content sharing and user acquisition
- Music recognition and metadata enrichment services
- Analytics and recommendation engines based on user behavior

2.5 Justification for BeatRate Development

2.5.1 Market Positioning Strategy

Based on our analysis, we identified a clear market opportunity for BeatRate that combines the strengths of existing platforms while addressing their fundamental limitations:

Differentiation Strategy:
- **Customizable Rating Systems:** Unlike any existing platform, BeatRate offers both simple and comprehensive rating methodologies, allowing users to choose their preferred evaluation approach
- **Enhanced Social Features:** Building upon Musicboard's social foundation while improving community interaction and discovery
- **Modern UI/UX:** Implementing scalable, cloud-native architecture that existing platforms lack

Competitive Advantages:
- **User Choice:** Flexible rating systems that adapt to user preferences
- **Community Focus:** Advanced social features that foster meaningful connections
- **Technical Excellence:** Modern architecture ensuring superior performance and scalability
- **User Experience:** Contemporary design principles which follows best UI/UX and are visually appealing for users

2.5.2 Requirements Validation

Our domain research validates the core requirements initially identified for BeatRate:

Validated Requirements:
- **Dual Rating System:** Market gap analysis confirms need for customizable evaluation methods
- **Social Features:** User engagement metrics from successful platforms like Musicboard demonstrate value of community features
- **Modern UX/UI:** Poor user experience of market leaders creates opportunity for superior design
- **Streaming Integration:** Limited integration in existing platforms validates need for comprehensive connectivity
- **Scalable Architecture:** Technical limitations of older platforms justify modern architectural approach

Additional Requirements Identified:
- **Advanced Discussion Spaces:** Gap in structured community interaction capabilities

- **Multi-device Optimization:** Mobile experience gaps in leading platforms
- **Artist Engagement Features:** Underserved musician and artist user segment
- **Advanced Analytics:** Opportunity for sophisticated user behavior analysis and recommendations

2.6 Monetization Models and Revenue Analysis

2.6.1 Current Market Monetization Strategies

The analysis of existing platforms reveals diverse approaches to monetization, ranging from advertising-only models to hybrid subscription services. Understanding these revenue streams provides crucial insights into the financial viability of the music evaluation platform market and informs strategic decisions for BeatRate's business model.

Rate Your Music (RYM) - Advertising-Only Model: RYM operates exclusively on advertising revenue without subscription or donation options. With 15.02 million monthly visits generating approximately 186.3 million page views per month, using industry-standard RPM rates of $1-3 for music websites (Rosen, 2025), RYM's estimated monthly ad revenue ranges from $186,300 to $558,900, translating to an annual revenue estimate of $2.2M to $6.7M. This demonstrates the financial viability of the music evaluation market while highlighting potential limitations in revenue diversification.

Album of the Year (AOTY) - Hybrid Model: AOTY combines advertising revenue with optional donations, offering an ad-free experience for $11.99 annually. With 8.271 million monthly visits generating 86.30 million page views, estimated monthly ad revenue ranges from $86,300 to $258,900. Assuming a 1% conversion rate among unique visitors, donation revenue contributes an additional $218,937 per year, resulting in total annual revenue estimates of $1.47M to $3.52M.

Musicboard - Social-Enhanced Subscription Model: Musicboard offers Basic ($1.99/month) and Premium ($4.99/month) subscriptions, leveraging social features to drive adoption. With 127,336 unique monthly visitors and assuming a 5% conversion rate, the platform generates approximately $18,400 monthly from subscriptions. Combined with advertising revenue from 1.879 million page views, total annual revenue estimates range from $243K to $288K. Despite lower absolute numbers, Musicboard's higher conversion rates demonstrate the potential of social features to drive premium subscriptions.

2.6.2 Strategic Implications for BeatRate

Market Size Validation: The combined revenue potential across leading platforms ($4M-$10M annually) validates a sustainable market for music evaluation platforms. The variation in subscription conversion rates (1% for AOTY vs 5% for Musicboard) highlights the importance of social engagement in driving premium adoption.

Monetization Strategy: The success of hybrid models supports BeatRate's approach of implementing advertising-supported free access with premium features. Musicboard's conversion rates demonstrate that social features and user customization drive both engagement and monetization, validating BeatRate's emphasis on community interaction and flexible rating systems.

2.7 Chapter Summary

Our systematic domain research reveals a mature but fragmented market with significant opportunities for innovation. While platforms like Rate Your Music demonstrate strong user engagement in the music evaluation space, fundamental limitations in user experience, social features, and technical architecture create clear opportunities for a new platform.

The analysis of 45+ million monthly visits across leading platforms indicates substantial market demand, while the identified gaps in customizable rating systems, enhanced social features, and modern user experience design validate our approach with BeatRate. The revenue analysis confirms market viability, with existing platforms generating millions annually despite technical limitations, suggesting significant potential for a platform addressing current gaps.

Most critically, our research demonstrates that no existing platform successfully combines comprehensive music evaluation capabilities with robust social features and modern technical architecture. This gap represents the core opportunity that BeatRate addresses, positioning it as a platform that learns from the strengths of existing solutions while fundamentally advancing the state of the art in music evaluation and community engagement.

The requirements validated through this research process directly inform our system design and implementation approach, ensuring that BeatRate addresses real market needs while offering clear differentiation from existing alternatives. This foundation provides the justification and direction for the architectural decisions and implementation strategy detailed in subsequent chapters.

3 System Design and Architecture

3.1 Architecture Overview and Requirements Alignment

The BeatRate platform architecture emerges directly from our functional and non-functional requirements identified in the domain research phase. Our approach prioritizes scalability, maintainability, and developer productivity while addressing the specific challenges of music evaluation and social interaction.

3.1.1 Requirements-Driven Architecture Decisions

Functional Requirements Drive:

- **Dual Rating System:** Our sophisticated rating architecture supports both simple (1-10) and complex multi-component grading systems through polymorphic design patterns
- **Social Features:** Microservices separation enables independent scaling of user interactions, reviews, and list management
- **Music Integration:** Dedicated catalog service optimizes Spotify API integration with intelligent caching strategies
- **Real-time Discovery:** Service separation allows optimized data models for different query patterns

Non-Functional Requirements Drive:

- **Scalability:** Microservices architecture with independent scaling per service based on demand
- **Performance:** Polyglot persistence strategy matching data models to optimal storage engines
- **Maintainability:** Clear service boundaries and technology stack consistency across the platform
- **Security:** Token-based authentication with service-level validation and HTTPS encryption

3.2 System Architecture and Major Decisions

3.2.1 Microservices Architecture Decision

Decision: Implement microservices architecture with four core services instead of a monolithic application.

Justification: Given our two-developer team constraint and the need for parallel development, microservices provide several critical advantages:

- **Parallel Development:** Yaroslav focused on User Service and Music Catalog Service while Maksym developed Music Interaction Service and Music Lists Service, enabling simultaneous feature development
- **Scalability Requirements:** Different services have distinct load patterns - catalog browsing generates different traffic than rating/review creation

- **Technology Optimization:** Each service can optimize for its specific data patterns and performance requirements
- **Code Maintainability:** With over 25,000 lines of code already implemented, a monolithic structure would create maintenance complexity that exceeds our team capacity

Trade-offs Considered: Increased operational complexity and potential latency from service-to-service communication, but these are outweighed by development velocity and future scalability benefits.

3.3 System Context and External Interactions

The system context diagram illustrates BeatRate's position within the broader ecosystem of external services and user interactions. Our platform serves as the central hub connecting users with music evaluation capabilities while integrating with established services for authentication, music data, and cloud infrastructure.

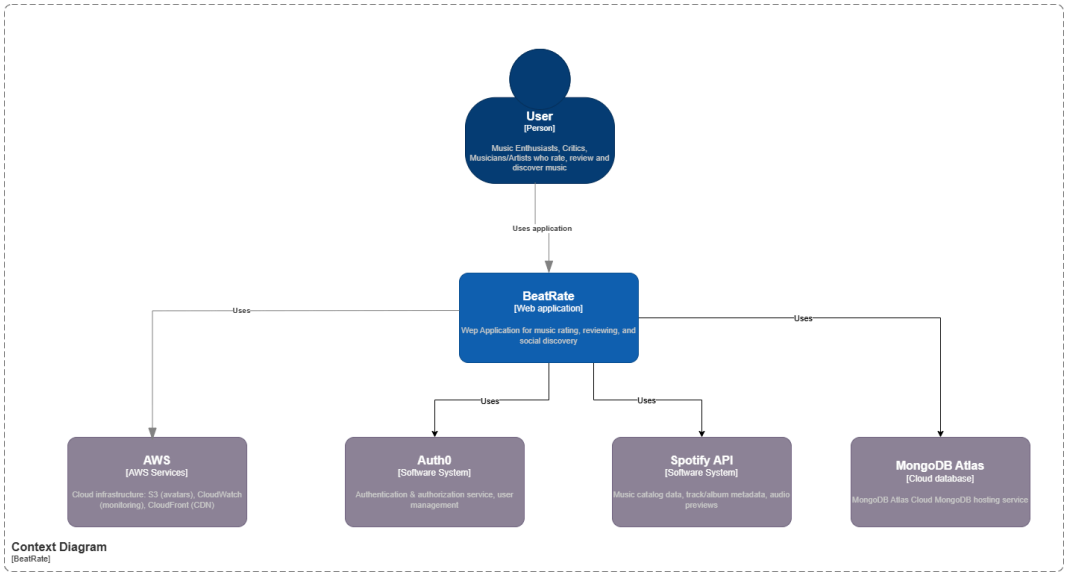

Figure 7: System Context Diagram - BeatRate Platform Ecosystem

Key External Integrations:

- **Spotify API:** Provides comprehensive music catalog data, track metadata, and audio previews with 200 requests per minute rate limit while the app is in development stage
- **Auth0:** Handles authentication and authorization with social login capabilities and user management
- **AWS Services:** Cloud infrastructure including S3 for avatar storage, CloudWatch for monitoring, and CloudFront for content delivery
- **MongoDB Atlas:** Cloud-hosted MongoDB service for music catalog and grading template storage

3.4 Container Architecture and Service Decomposition

The container diagram reveals our microservices architecture with clear separation of concerns across four core services. Each service operates independently while communicating through well-defined APIs routed via Application Load Balancer.

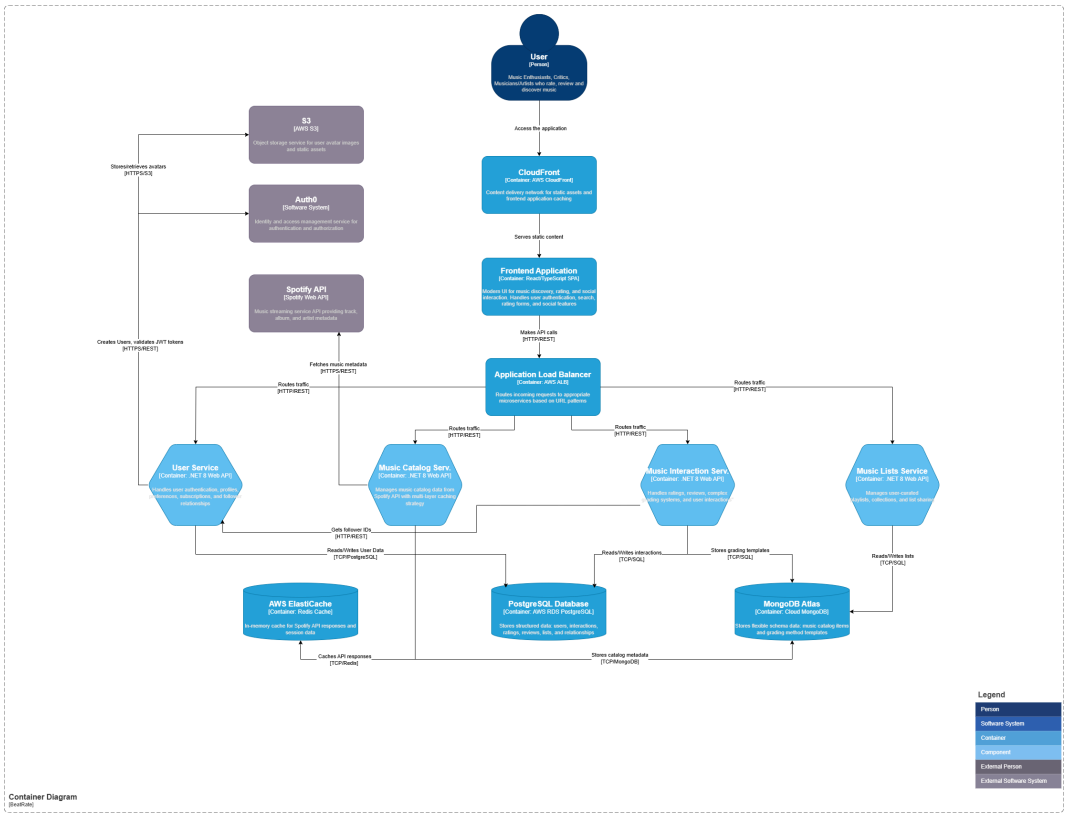

Figure 8: Container Diagram - Microservices Architecture and Data Flow

Service Responsibilities:

- **User Service:** Authentication, user profiles, preferences, and subscription management
- **Music Catalog Service:** Spotify API integration with intelligent caching using Redis ElastiCache
- **Music Interaction Service:** Rating systems, reviews, and complex grading calculations
- **Music Lists Service:** User-curated playlists, collections, and list management

Data Architecture Strategy:

- **PostgreSQL (AWS RDS):** Transactional data requiring ACID compliance - user accounts, ratings, social interactions
- **MongoDB Atlas:** JSON-first storage for music catalog and flexible grading method templates
- **Redis ElastiCache:** High-performance caching for Spotify API responses and session data

3.5 Technology Stack Selection and Justification

3.5.1 Backend: .NET 8 with C#

Decision: Standardize on .NET 8 across all microservices.

Justification:

- **Team Expertise:** Both developers have extensive C# experience, reducing learning curve and increasing development velocity
- **Performance:** .NET 8 provides excellent performance characteristics with minimal memory overhead for our API-heavy workload
- **Ecosystem:** Rich ecosystem with Entity Framework for PostgreSQL integration and robust HTTP client libraries for Spotify API integration
- **Development Experience:** Superior tooling, debugging capabilities, and IntelliSense support accelerate development

Alternative Considered: Node.js was evaluated but rejected due to team expertise and the superior type safety that C# provides for our complex rating system logic.

3.5.2 Frontend: React with TypeScript

Decision: Implement single-page application using React with TypeScript.

Justification:

- **Team Experience:** Proven experience with React ecosystem reducing implementation risk
- **Component Reusability:** React's component model aligns perfectly with our UI requirements for rating widgets, music cards, and social interaction elements
- **TypeScript Benefits:** Type safety crucial for our complex grading system interfaces and API contracts
- **Community Support:** Extensive ecosystem of music-related UI components and libraries

3.5.3 Polyglot Persistence Strategy

Decision: Implement dual database strategy with PostgreSQL for transactional data and MongoDB for catalog data.

PostgreSQL for User and Interaction Data:

- **ACID Compliance:** Critical for user ratings, follows, and social interactions requiring data consistency
- **Relational Integrity:** Complex social relationships (followers, likes, comments) benefit from foreign key constraints
- **Entity Framework Integration:** Seamless C# object mapping without custom serialization overhead
- **Complex Queries:** Efficient JOINs for social features and analytics

MongoDB for Music Catalog Data:

- **JSON-First Design:** Spotify API returns rich nested JSON that MongoDB stores naturally without complex ORM mapping

- **Performance:** Single read operations retrieve complete album/track data instead of multiple JOINs
- **Flexible Schema:** New Spotify fields don't require schema migrations
- **Caching Strategy:** Direct storage of Spotify API responses for rapid retrieval

Cost Optimization Decision: Single database instance per type rather than per-service to control costs ($220 month current deployment cost), with clear migration path to service-specific databases as load increases.

3.6 Component Architecture: Music Interaction Service Deep Dive

The Music Interaction Service represents our most architecturally complex component, implementing the sophisticated dual rating system that differentiates BeatRate from existing platforms. This service demonstrates advanced architectural patterns including CQRS, Domain-Driven Design, and clean architecture principles.

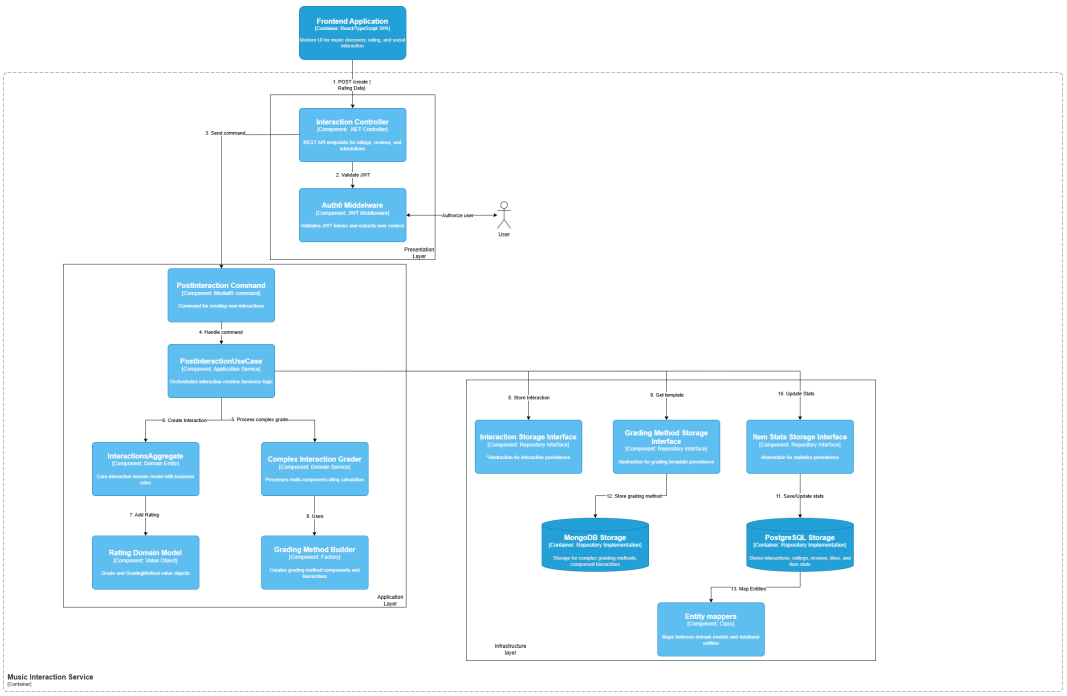

Figure 9: Component Diagram - Music Interaction Service Internal Architecture

3.6.1 Sophisticated Rating System Architecture

Our dual rating system represents a significant technical innovation in music evaluation platforms. The architecture enables both traditional 1-10 ratings and complex multi-component evaluations through a unified `IGradable` interface:

- **Simple Rating Flow:** Direct grade assignment with automatic normalization to 1-10 scale
- **Complex Rating Flow:** Template retrieval from MongoDB ⟶ User input application ⟶ Hierarchical calculation ⟶ PostgreSQL storage

Key Technical Benefits:

- **Unified Interface:** Both rating types implement `IGradable`, enabling polymorphic handling
- **Storage Optimization:** MongoDB for reusable templates, PostgreSQL for user-specific instances
- **Automatic Calculation:** Hierarchical grades calculate automatically when component grades change
- **Template Reusability:** Complex grading methods can be shared between users and adapted per individual

3.6.2 Spotify API Integration Decision

Decision: Integrate exclusively with Spotify API rather than building our own music database or integrating multiple streaming services.

Justification:

- **Comprehensive API:** Spotify provides robust search, metadata, and preview capabilities with well-documented REST API
- **Rate Limits:** Free tier supports 200 requests per minute, sufficient for our initial user base with built-in rate limiting implementation
- **Real-time Updates:** Spotify's catalog stays current without requiring our own data maintenance infrastructure
- **Fallback Strategy:** We implement a hybrid approach - every Spotify fetch populates our MongoDB cache, creating automatic fallback capability for service interruptions

Implementation Detail:

```
builder.Services.AddRateLimiter(options =>
{
    options.GlobalLimiter = PartitionedRateLimiter.Create<HttpContext,
string>(_ =>
    {
        return RateLimitPartition.GetFixedWindowLimiter("global", _ =>
            new FixedWindowRateLimiterOptions
            {
                Window = TimeSpan.FromMinutes(1),
                PermitLimit = spotifySettings?.RateLimitPerMinute ?? 1000,
                QueueLimit = 100
            });
    });
});
```

3.7 Cloud Deployment Architecture and Infrastructure

Our AWS-based infrastructure architecture provides scalable, cost-effective deployment while maintaining operational simplicity. The design leverages managed services to minimize infrastructure management overhead while ensuring high availability and performance.

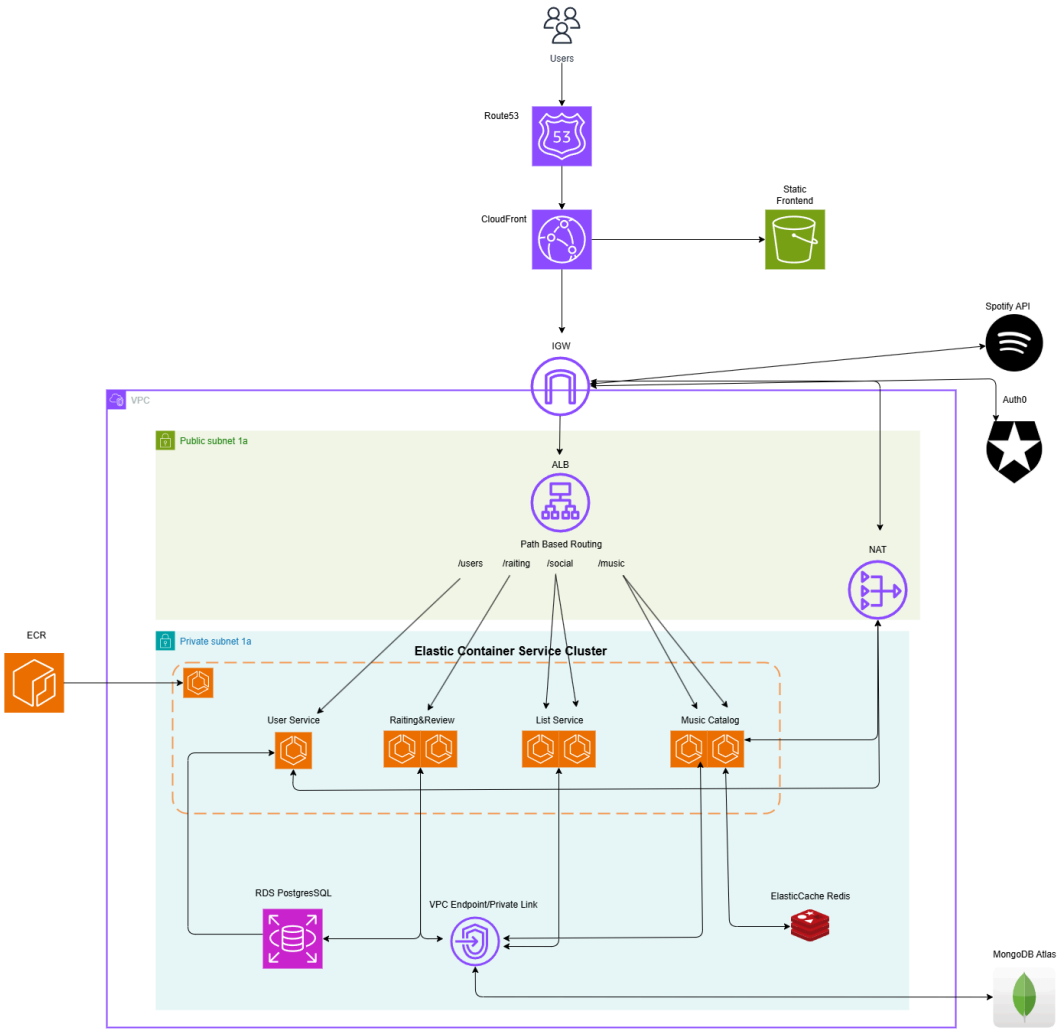

Figure 10: AWS Cloud Deployment Architecture - Production Environment

3.7.1 Infrastructure Architecture Justification

ECS Fargate Selection: We chose ECS with Fargate over EKS or EC2 based on our operational requirements:

- **Low Management Overhead:** Allows focus on application features rather than infrastructure management
- **Cost Efficiency:** Pay-per-use model ideal for our growth stage with current monthly costs of $228
- **Appropriate Scale:** Sufficient for our expected load without Kubernetes complexity
- **AWS Integration:** Native integration with ALB, CloudWatch, and other AWS services

Load Balancing Strategy: Path-based routing through Application Load Balancer enables:

- **Service Independence:** Each microservice receives only relevant traffic
- **Health Monitoring:** Automatic failure detection and traffic rerouting
- **SSL Termination:** Centralized HTTPS handling with CloudFront integration

3.7.2 Service Communication Patterns

Our architecture implements minimal inter-service communication to maintain loose coupling:

- **Primary Data Flow:** Frontend → ALB → Individual Services → Databases
- **Internal Communication:** Only Interaction Service → User Service for follower data retrieval

API Versioning and Contracts:

- **Versioning Strategy:** URL prefix pattern (`/api/v1/`) provides clear API versioning
- **Contract Stability:** Single client (our frontend) reduces versioning complexity
- **Authentication Flow:** Each service validates JWT tokens independently via Auth0 integration

3.8 Cross-Cutting Concerns

3.8.1 Security Implementation

- **Authentication:** Auth0 provides centralized authentication with JWT token validation across all services
- **Authorization:** Service-level token validation ensures proper access control
- **Data Encryption:** HTTPS end-to-end via CloudFront, default encryption for RDS and S3 storage
- **Network Security:** VPC with public/private subnet separation isolates backend services

3.8.2 Monitoring and Observability

- **Logging:** CloudWatch integration provides centralized log aggregation across all services
- **Metrics:** ECS auto-scaling based on CPU >90% and memory >90% thresholds
- **Health Checks:** ALB performs HTTP health checks on `/health` endpoints

3.8.3 Database Migration Strategy

Automated Migrations: All services apply database migrations at startup with retry logic:

```
context.Database.Migrate();
// Retry logic with 3 attempts and 5-second delays
```

Zero-Downtime Deployments: ECS rolling updates ensure continuous service availability during migrations.

3.9 Technology Stack Summary and Trade-offs

Component	Technology	Justification	Trade-offs
Backend APIs	.NET 8 C#	Team expertise, performance, ecosystem	Learning curve for new team members
Frontend	React TypeScript	Component reusability, type safety	Bundle size, complexity for simple UIs
User Data	PostgreSQL	ACID compliance, relational integrity	Less flexible than NoSQL for schema changes
Catalog Data	MongoDB	JSON-first, performance, flexibility	Eventual consistency, learning curve
Caching	Redis ElastiCache	High performance, AWS integration	Additional complexity, memory costs
Authentication	Auth0	Security expertise, social login	Vendor dependency, recurring costs
Music Data	Spotify API	Comprehensive catalog, real-time updates	Rate limits, vendor dependency
Infrastructure	AWS ECS Fargate	Managed scaling, AWS ecosystem	Vendor lock-in, limited container control

Table 2: Technology Stack Justification and Trade-off Analysis

3.10 Chapter Summary

This architecture successfully balances technical complexity with team capabilities, creating a scalable foundation for BeatRate's growth while maintaining development velocity and operational simplicity. The polyglot persistence strategy optimizes each data type for its specific use case, while the microservices architecture enables independent scaling and development of different platform features.

The design decisions documented in this chapter directly address the requirements identified in our domain research, providing a robust technical foundation for the implementation phase detailed in the following chapter. Each architectural choice reflects careful consideration of team constraints, technical requirements, and long-term scalability needs, resulting in a system that can grow with our user base while remaining maintainable by a small development team.

4 Implementation

In this section you translate your component-level designs into working code and systems. Focus on the C4 Component layer and on the details needed to show how your design was realized. Include only the most important code snippets that illustrate key patterns or algorithms, rather than full listings.

1. *Describe the development methodology (for example, Agile or test-driven development) used to guide your implementation*
2. *Explain any prototyping or iterative strategies you applied to refine components before full-scale coding*
3. *Summarize coding standards, naming conventions and architectural patterns followed in your codebase*
4. *Present critical code snippets or configuration templates that highlight how core components were implemented (for example, key classes, interfaces or algorithms)*
5. *Detail your testing approach and quality assurance measures (unit tests, integration tests, coverage metrics)*
6. *Note any performance optimizations or profiling results for components that were bottlenecks*
7. *Outline your deployment and configuration management process for component artifacts (containerization, CI/CD pipelines)*
8. *Highlight documentation deliverables (API references, inline comments, architecture decision records) that support future maintenance*

This section demonstrates how each component specification becomes actual, maintainable code—closing the loop from design to implementation.

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Contents

4.1 Section 1

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4.2 Section 2

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4.3 Conclusion

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5 Validation

Validation (Requirements Verification and Testing)

In this section you demonstrate how your implementation satisfies the initial requirements through clear testing methods and concise examples—suitable for a bachelor-level project:

1. *Restate each key functional and non-functional requirement from your Analysis and Design sections*
2. *Describe the testing approach for each requirement (for example, unit tests, manual acceptance checks or scenario walkthroughs)*
3. *Provide concrete test cases or usage examples that show how you verify each requirement in practice*
4. *Summarize actual versus expected outcomes, indicating pass/fail status for each test*
5. *Include brief snippets of test code or sample console outputs to illustrate your procedures*
6. *Note any gaps or deviations and suggest simple fixes or areas for future improvement*
7. *If a feature wasn't intended for specific scenarios (e.g. high-load), omit unrealistic stress tests and clearly document its current limitations*

This focused structure ties every requirement directly to validation results, using examples and methods you can realistically carry out at the bachelor level.

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Contents

5.1 Section 1

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5.2 Section 2

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5.3 Conclusion

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6 Conclusion

Conclusion

In this final section you bring together your work and reflect on its impact. Keep it concise, restating key points without introducing new information:

1. *Project Summary: Briefly recap objectives, methodology and principal results*
2. *Alignment with Objectives: Discuss how outcomes meet initial goals, referencing requirements and design aims*
3. *Lessons Learned and Challenges: Note any obstacles and how they informed improvements*
4. *Limitations: Acknowledge features or scenarios beyond this scope and clearly state current system boundaries*
5. *Future Work: Suggest practical enhancements or research directions building on your findings*

Avoid introducing new concepts here; refer readers to the Discussion for deeper analysis.

6.1 Project summary

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6.2 Comparison with the initial objectives

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6.3 Encountered difficulties

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6.4 Future perspectives

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Glossary

Bibliography