Price Drop Tracker Backend

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Requirements Gathering

Functional Requirements

Core Price Tracking Functionality: - Enable users to subscribe to product price alerts from multiple e-commerce platforms - Track price changes and maintain historical price data for products - Send notifications when prices drop below user-defined thresholds - Support multiple notification channels (email, SMS, push notifications) - Provide price history analytics and trend visualization

Product Management: - Add products to tracking system via URL or product identifier - Automatically extract product metadata (name, image, category, seller) - Handle product variants and different marketplace listings - Support bulk product import and management - Maintain product availability status and stock tracking

User Experience Features: - User registration and subscription management - Customizable price threshold settings per product - Price drop prediction and trend analysis - Wishlist management and product organization - Historical price charts and analytics dashboard

Administrative Features: - Monitor scraping performance and success rates - Manage blocked domains and rate limiting policies - Analytics on user engagement and notification effectiveness - System health monitoring and alerting

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Non-Functional Requirements

Performance Requirements: - Support 10 million tracked products with hourly price updates - Handle 1 million active user subscriptions - Process 100,000 price checks per minute during peak hours - Notification delivery within 5 minutes of price drop detection - System availability: 99.9% uptime with graceful degradation

Scalability Requirements: - Horizontally scalable web scraping infrastructure - Support for adding new e-commerce platforms and regions - Auto-scaling based on scraping workload and user activity - Linear performance scaling with increased product catalog

Reliability and Consistency: - Eventual consistency acceptable for price updates (up to 1 hour delay) - Strong consistency for user subscription changes - Zero data loss for price history and user preferences - Robust handling of website structure changes and anti-bot measures

Compliance and Ethics: - Respect robots.txt and website terms of service - Implement responsible scraping with appropriate delays - GDPR compliance for user data and privacy - Transparent data usage and retention policies

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Traffic Estimation & Capacity Planning

User Subscription Analysis

User Base Projections: - 1 million registered users baseline - 500,000 active monthly users - Average 10 products tracked per active user - 5 million total product-user subscription pairs

Subscription Patterns: - Peak activity during holiday seasons (3x normal) - Daily pattern: highest activity during lunch and evening hours - Geographic distribution: 60% North America, 25% Europe, 15% Asia-Pacific

Growth Projections: - User base growth: 20% annually - Product catalog growth: 30% annually - Notification volume growth: 25% annually

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Scraping Volume Calculations

Product Scraping Requirements: - 10 million products to track across platforms - Hourly scraping frequency for popular products - Daily scraping for long-tail products - Adaptive frequency based on price volatility

Scraping Load Distribution: - Peak scraping: 50,000 requests per minute - Average scraping: 20,000 requests per minute - Platform distribution: Amazon (40%), eBay (20%), Walmart (15%), Others (25%)

Resource Requirements: - Network bandwidth: 100 Mbps sustained, 500 Mbps peak - Storage: 500 GB daily for price data and metadata - Processing: 1,000 CPU cores for parallel scraping - Memory: 2 TB for caching and URL frontier management

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Notification Traffic Requirements

Notification Volume: - 100,000 price drop alerts per day average - 500,000 alerts during major sale events - 60% email notifications, 30% push notifications, 10% SMS

Delivery Requirements: - 95% of notifications delivered within 5 minutes - Support for notification batching and digest modes - Retry mechanism for failed deliveries - Unsubscribe and preference management

Infrastructure Scaling: - Message queue capacity: 1 million messages in buffer - Email service: 50,000 emails per hour sustained capacity - Push notification service: 100,000 notifications per hour - SMS service: 10,000 messages per hour

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Database Schema Design

Product Price Database Schema

Current Price Table: - Product ID (Primary Key): Unique identifier across platforms - Product URL: Canonical product page URL - Current Price: Latest scraped price with currency - Last Updated: Timestamp of last successful scrape - Seller Information: Merchant name and seller rating - Availability Status: In stock, out of stock, discontinued

Product Metadata Table: - Product ID (Primary Key): Links to price data - Product Name: Clean, normalized product title - Category: Product classification and taxonomy - Brand: Manufacturer or brand information - Image URLs: Product images for display - Specifications: Key product attributes and features

Platform Integration: - Platform ID: Amazon, eBay, Walmart, etc. - Platform Product ID: Native product identifier - Platform-specific metadata: Reviews, ratings, shipping info - Scraping configuration: CSS selectors, parsing rules

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User Subscription Schema

User Management Table: - User ID (Primary Key): Unique user identifier - Email: Primary contact for notifications - Notification Preferences: Channels, frequency, timing - Account Settings: Timezone, currency, language - Registration Date: Account creation timestamp

Subscription Tracking Table: - Subscription ID (Primary Key): Composite key (User + Product) - User ID (Foreign Key): References user table - Product ID (Foreign Key): References product table - Price Threshold: Alert trigger price point - Created Date: Subscription start timestamp - Status: Active, paused, cancelled

Notification History: - Notification ID (Primary Key): Unique notification identifier - Subscription ID: Links to user-product subscription - Notification Type: Price drop, back in stock, error - Sent Timestamp: When notification was dispatched - Delivery Status: Sent, delivered, failed, clicked

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Price History Schema

Historical Price Data: - Price History ID (Primary Key): Unique record identifier - Product ID (Foreign Key): Links to product data - Price: Historical price point with currency - Timestamp: When price was recorded - Price Change: Difference from previous price - Promotion Details: Sale information, discount codes

Aggregated Statistics: - Product ID (Primary Key): Product identifier - Time Period: Daily, weekly, monthly aggregations - Average Price: Mean price for the period - Min/Max Price: Price range for the period - Price Volatility: Statistical measure of price changes - Trend Direction: Increasing, decreasing, stable

Analytics Optimization: - Partitioning: By date and product category - Indexing: Product ID, timestamp, price range - Compression: Historical data compression for storage efficiency - Archival: Long-term storage for old price data

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System API Design

User Management APIs

User Registration and Authentication: - User registration with email verification - Login/logout with session management - Password reset and security features - Account settings and preference management

Subscription Management: - Add/remove product subscriptions - Update price thresholds and notification settings - Bulk subscription import/export - Subscription analytics and history

Notification Preferences: - Configure notification channels and timing - Set digest mode and frequency preferences - Manage unsubscribe and re-subscription - Notification history and delivery status

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Product Tracking APIs

Product Discovery: - Add products by URL or search - Product metadata extraction and validation - Duplicate product detection and merging - Product category and classification

Price Data Access: - Current price and availability status - Historical price data and trends - Price comparison across platforms - Price prediction and analytics

Product Management: - Update product information and metadata - Manage product variants and options - Handle discontinued or unavailable products - Product performance and tracking analytics

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Price Alert APIs

Alert Configuration: - Set up price drop thresholds - Configure notification timing and channels - Manage alert conditions and rules - Test notification delivery

Alert Processing: - Real-time price change detection - Alert generation and queuing - Notification dispatch and tracking - Alert analytics and effectiveness metrics

Administrative APIs: - Monitor scraping performance and health - Manage rate limiting and scraping policies - System analytics and performance metrics - Error handling and debugging tools

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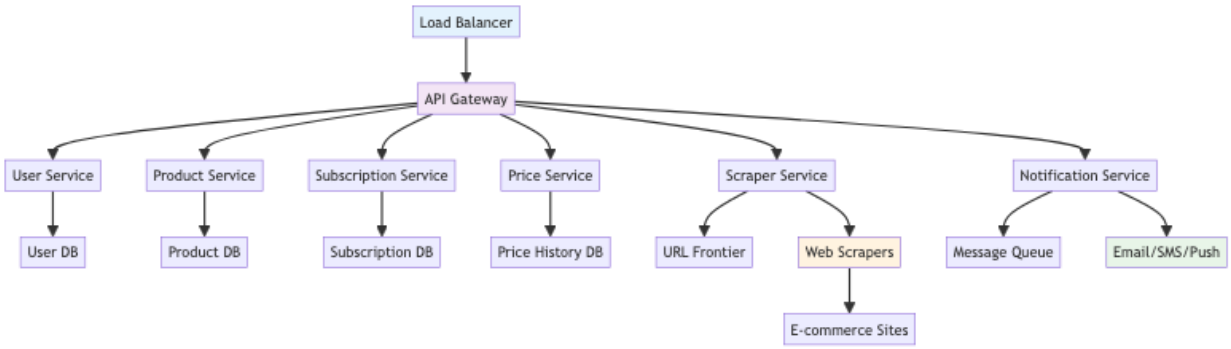
High-Level Design (HLD)

System Architecture Overview

Microservices Architecture:



Core Components: - **User Service**: Authentication, user management, preferences - **Product Service**: Product catalog, metadata management - **Price Service**: Price data storage, history, analytics - **Scraper Service**: Web scraping, data extraction, URL management - **Subscription Service**: User-product relationships, threshold management - **Notification Service**: Alert generation, delivery, tracking

Data Storage Layer: - **Primary Database**: PostgreSQL for transactional data - **Time Series Database**: InfluxDB for price history - **Cache Layer**: Redis for frequent access patterns - **Message Queue**: Apache Kafka for event streaming - **Object Storage**: S3 for product images and static assets

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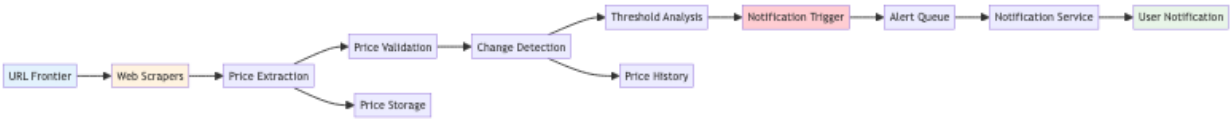
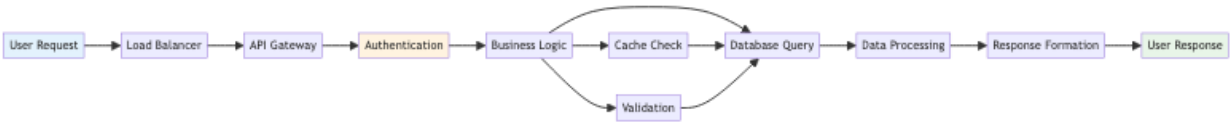
Data Flow Architecture

Price Tracking Data Flow:



User Interaction Flow:



Event-Driven Architecture: 1. **Price Update Events**: Scraped price changes trigger downstream processing 2. **Subscription Events**: User subscription changes update tracking configuration 3. **Notification Events**: Price drops generate notification delivery tasks 4. **System Events**: Health monitoring and performance tracking

Data Pipeline: - **Ingestion**: Continuous scraping and price data collection - **Processing**: Price change detection and threshold analysis - **Storage**: Multi-tier storage for different data access patterns - **Analytics**: Real-time and batch analytics for insights

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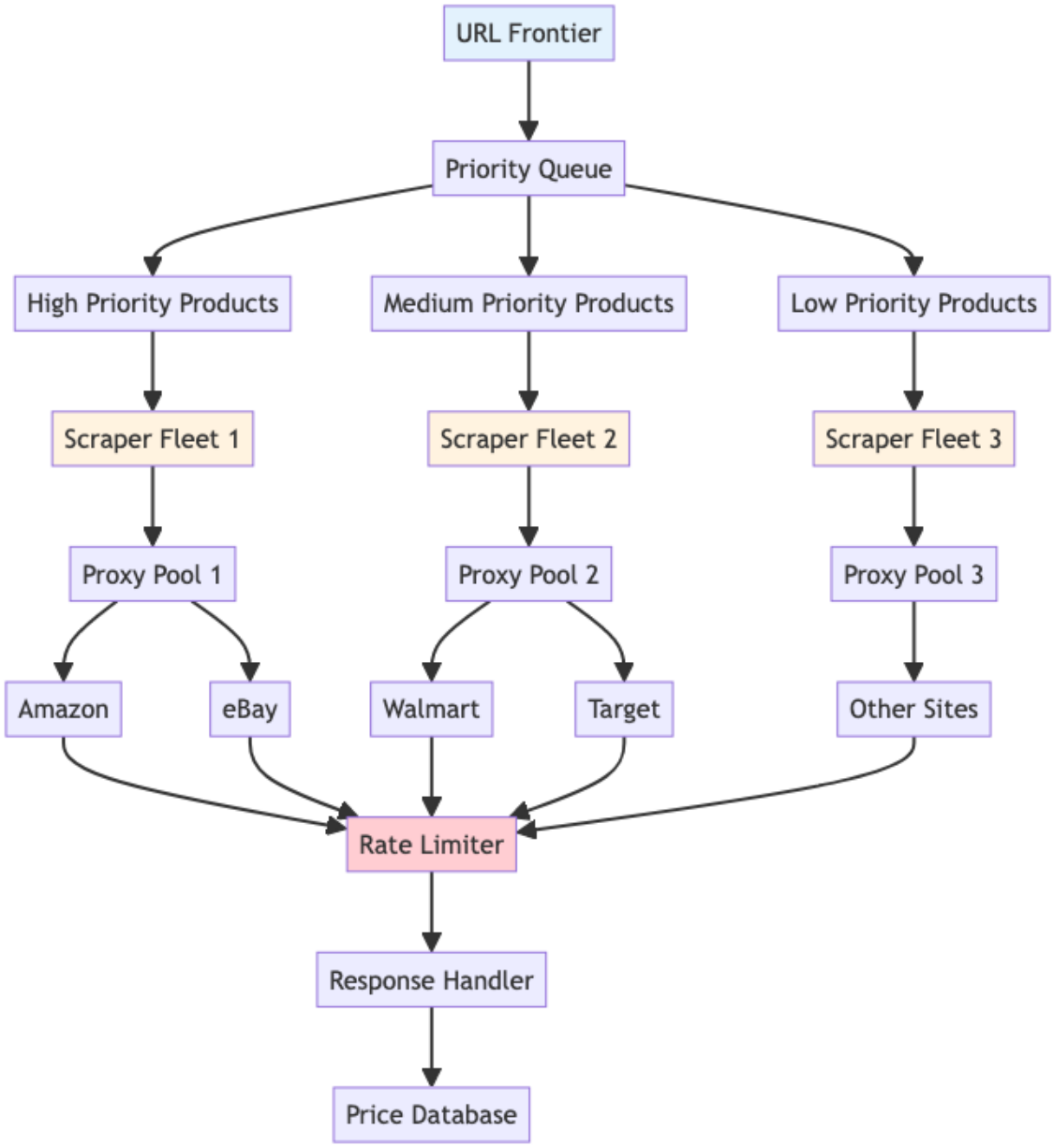
Web Scraping Infrastructure

Distributed Scraping Architecture:



Scraping Coordination: - **Task Distribution**: Load balancing across scraper instances - **Failure Handling**: Retry mechanisms and dead letter queues - **Health Monitoring**: Scraper performance and success rate tracking - **Configuration Management**: Dynamic scraping rules and selectors

Anti-Detection Measures: - **User Agent Rotation**: Realistic browser fingerprinting - **Request Timing**: Human-like browsing patterns - **Session Management**: Maintaining scraping session state - **CAPTCHA Handling**: Automated and manual CAPTCHA solving

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Low-Level Design (LLD)

Web Scraper Service

Scraping Engine Design: - **Worker Pool**: Configurable number of concurrent scraping threads - **Request Management**: HTTP client with connection pooling and timeouts - **Content Parsing**: Robust HTML parsing with fallback selectors - **Data Validation**: Price format validation and sanity checks

URL Frontier Management: - **Priority Scheduling**: High-priority products scraped more frequently - **Deduplication**: Prevent duplicate scraping requests - **Batch Processing**: Group similar requests for efficiency - **State Persistence**: Durable queue state across service restarts

Error Handling and Resilience: - **Exponential Backoff**: Progressive retry delays for failed requests - **Circuit Breaker**: Temporary suspension of problematic targets - **Graceful Degradation**: Partial scraping success handling - **Monitoring Integration**: Real-time alerting for scraping issues

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Price Change Detection Engine

Change Detection Logic: - **Price Comparison**: Current vs. previous price analysis - **Threshold Evaluation**: User-defined price drop detection - **Significance Filtering**: Ignore minor price fluctuations - **Trend Analysis**: Price movement pattern recognition

Event Generation: - **Change Events**: Structured price change notifications - **Event Enrichment**: Adding product and user context - **Event Routing**: Directing events to appropriate consumers - **Event Persistence**: Audit trail for all price changes

Performance Optimization: - **Batch Processing**: Group price updates for efficiency - **Incremental Updates**: Only process actual price changes - **Caching Strategy**: Cache recent prices for quick comparison - **Parallel Processing**: Concurrent change detection across products

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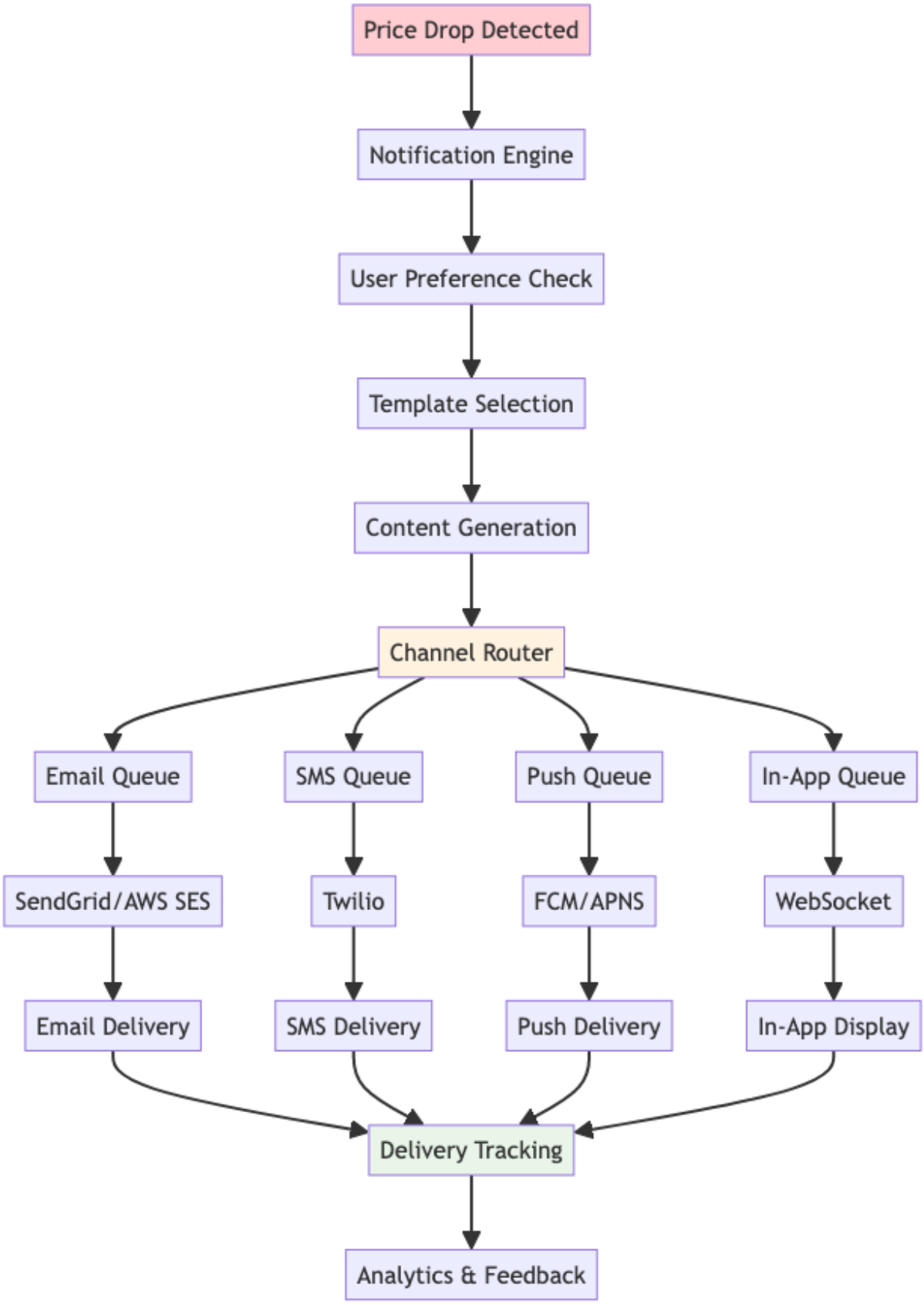
Notification System

Multi-Channel Notification System:


Price Drop Detected
Notification Engine
User Preference Check
Template Selection
Content Generation
Channel Router
Email Queue
SMS Queue
Push Queue
In-App Queue
SendGrid/AWS SES
Twilio
FCM/APNS
WebSocket
Email Delivery
SMS Delivery
Push Delivery
In-App Display
Delivery Tracking
Analytics & Feedback

Notification Pipeline: - **Template Engine**: Dynamic notification content generation - **Personalization**: User-specific content and preferences - **Scheduling**: Optimal delivery timing based on user timezone - **Delivery Tracking**: End-to-end delivery confirmation

Reliability and Scale: - **Message Queue**: Kafka-based notification queue - **Retry Logic**: Failed delivery retry with exponential backoff - **Dead Letter Queue**: Handling persistently failed notifications - **Rate Limiting**: Respect provider limits and user preferences

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Core Algorithms

1. Adaptive Scraping Algorithm

Dynamic Frequency Adjustment: - Monitor price volatility and adjust scraping frequency accordingly - High-volatility products: Scrape every 15-30 minutes - Stable prices: Reduce to daily or weekly scraping - Special events: Increase frequency during sales periods

Resource Optimization: - Load-based scheduling to prevent server overload - Intelligent batching of similar product requests - Geographical scraping distribution for global coverage - Cost-aware scaling based on cloud resource pricing

Priority Scoring: - User subscription count as primary priority factor - Recent price change history influences scoring - Product popularity and category importance - Time since last successful scrape consideration

Failure Recovery: - Exponential backoff for temporarily inaccessible products - Alternative URL discovery for moved product pages - Graceful handling of website structure changes - Fallback to cached data during extended outages

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2. Price Change Detection Algorithm

Multi-Stage Validation: - Initial price extraction with multiple parsing strategies - Price format normalization (currency, decimal handling) - Sanity checks against historical price ranges - Outlier detection to filter erroneous price data

Change Significance Analysis: - Percentage-based threshold filtering (ignore <1% changes) - Absolute price change consideration for low-cost items - Trend analysis to distinguish temporary vs. sustained changes - Sale detection through pattern recognition

Real-time Processing: - Stream processing for immediate price change detection - Sliding window analysis for trend identification - Batch processing for historical analysis and validation - Event-driven architecture for responsive alert generation

Data Quality Assurance: - Cross-validation with multiple data sources when available - Historical consistency checks for price accuracy - Machine learning models for anomaly detection - Manual review processes for high-value discrepancies

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3. Threshold-based Alerting Algorithm

Multi-Criteria Evaluation: - User-defined absolute price thresholds - Percentage-based price drop detection - Historical low price comparisons - Competitive pricing analysis across platforms

Intelligent Filtering: - Duplicate alert prevention within time windows - Escalating alert importance based on drop magnitude - User engagement-based alert frequency adjustment - Seasonal and promotional context consideration

Personalization Engine: - Learning user response patterns to optimize timing - Preference-based alert channel selection - Behavioral analysis for alert frequency tuning - Machine learning for price drop prediction

Business Logic Integration: - Stock availability checks before alert generation - Seller reputation and reliability scoring - Shipping cost and total price calculations - Promotional period detection and handling

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4. URL Frontier Management Algorithm

Priority Queue Implementation: - Multi-level priority queues for different scraping urgencies - Time-based scheduling for regular scraping intervals - Load balancing across geographic regions and domains - Dynamic priority adjustment based on system load

Deduplication Strategy: - URL canonicalization for consistent product identification - Bloom filters for memory-efficient duplicate detection - Time-window based deduplication for periodic rescans - Cross-platform product matching and consolidation

Crawl Politeness: - Domain-specific rate limiting and delay management - Robots.txt compliance and respect for crawl directives - Adaptive delays based on server response times - Distributed crawling to minimize per-domain load

State Management: - Persistent queue state for recovery after system restarts - Progress tracking for long-running scraping jobs - Error state handling and automatic retry scheduling - Performance metrics collection for optimization

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5. Notification Deduplication Algorithm

UUID-based Identification: - Unique notification identifiers for idempotent processing - Content-based deduplication using message fingerprints - Time-window based duplicate detection and suppression - Cross-channel deduplication for multi-channel notifications

Smart Aggregation: - Batching multiple price drops for single products - Daily/weekly digest modes for frequent price changes - User preference-based aggregation rules - Priority-based notification consolidation

Delivery Optimization: - Optimal timing based on user activity patterns - Timezone-aware delivery scheduling - Channel failover for improved delivery rates - A/B testing for notification effectiveness

Feedback Loop Integration: - User engagement tracking for notification optimization - Unsubscribe pattern analysis for content improvement - Delivery success rate monitoring and adjustment - Machine learning for personalized notification strategies

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Performance Optimizations

Scraping Optimization

Concurrent Processing: - Parallel scraping across multiple domains and products - Connection pooling for reduced overhead - Asynchronous request processing for improved throughput - Batch processing for similar product requests

Caching Strategy: - DNS caching for faster domain resolution - HTTP response caching for unchanged content - Product metadata caching to reduce redundant processing - Intelligent cache invalidation based on content changes

Network Optimization: - Geographically distributed scraping infrastructure - Content compression for reduced bandwidth usage - Keep-alive connections for persistent scraping sessions - Adaptive timeout configuration based on target responsiveness

Resource Management: - Dynamic scaling based on scraping workload - Memory pool management for consistent performance - CPU optimization through efficient parsing algorithms - Storage optimization for scraped data and metadata

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Database Optimization

Indexing Strategy: - Composite indexes for complex query patterns - Partial indexes for frequently filtered data - Time-based partitioning for historical price data - Covering indexes to reduce database I/O

Query Optimization: - Read replicas for analytical workloads - Query result caching for repeated requests - Batch operations for bulk data processing - Optimized aggregation queries for analytics

Storage Optimization: - Data compression for historical price storage - Archival strategies for old data - Efficient data types for price and timestamp storage - Partitioning strategies for improved query performance

Connection Management: - Connection pooling for reduced overhead - Load balancing across database replicas - Prepared statements for query optimization - Transaction batching for improved throughput

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Notification Optimization

Delivery Efficiency: - Batch processing for email and SMS delivery - Template caching for notification generation - Asynchronous processing for non-blocking operation - Priority queues for urgent vs. standard notifications

Content Optimization: - Dynamic content generation based on user preferences - Image optimization and CDN usage for rich notifications - Compression for large notification payloads - Localization and personalization optimization

Channel Optimization: - Multi-channel failover for improved delivery rates - Optimal timing analysis for each notification channel - A/B testing for notification content and timing - User engagement tracking for continuous improvement

Scalability Measures: - Horizontal scaling of notification workers - Load balancing across notification service instances - Circuit breakers for external service failures - Graceful degradation during peak load periods

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Security Considerations

Scraping Ethics and Rate Limiting

Responsible Scraping Practices: - Strict adherence to robots.txt directives - Reasonable request delays to avoid server overload - User agent identification and contact information - Monitoring and respecting website terms of service

Anti-Detection Measures: - Human-like browsing patterns and timing - Diverse proxy and IP address rotation - Browser fingerprint randomization - Session management and cookie handling

Legal Compliance: - Regular review of scraping target terms of service - Data usage compliance with website policies - Intellectual property respect for scraped content - Geographic compliance with local scraping regulations

Rate Limiting Implementation: - Domain-specific rate limiting policies - Adaptive rate limiting based on server responses - Global rate limiting for resource protection - Emergency circuit breakers for problematic targets

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Data Privacy

User Data Protection: - Encryption at rest for sensitive user information - Secure transmission protocols for all data exchanges - Minimal data collection and retention policies - Regular security audits and vulnerability assessments

Privacy Compliance: - GDPR compliance for European users - CCPA compliance for California residents - Data subject rights implementation (access, deletion, portability) - Privacy policy transparency and user consent management

Access Control: - Role-based access control for administrative functions - API authentication and authorization - Audit logging for all data access and modifications - Secure key management and rotation

Data Anonymization: - User data anonymization for analytics - Secure aggregation techniques for privacy preservation - Differential privacy for statistical data release - Regular data purging for inactive accounts

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Testing Strategy

Scraper Testing

Unit Testing: - Individual scraping function validation - Price parsing accuracy testing - Error handling and edge case coverage - Performance benchmarking for scraping operations

Integration Testing: - End-to-end scraping workflow testing - Database integration and data persistence testing - Message queue integration testing - External service integration validation

Load Testing: - High-volume scraping performance testing - Concurrent scraping stress testing - Resource utilization monitoring during peak loads - Scalability testing with increased product catalogs

Reliability Testing: - Network failure and recovery testing - Website structure change adaptation testing - Anti-bot detection and circumvention testing - Long-running scraping job stability testing

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End-to-End Testing

User Journey Testing: - Complete user registration and subscription flow - Price drop detection and notification delivery - Notification preference management testing - Account management and data export testing

Data Consistency Testing: - Price data accuracy across different components - Subscription state consistency validation - Notification delivery confirmation testing - Historical data integrity verification

Performance Testing: - System response time under various load conditions - Database performance with large datasets - Notification delivery latency testing - API endpoint performance benchmarking

Disaster Recovery Testing: - System recovery after component failures - Data backup and restoration procedures - Cross-region failover testing - Service degradation and recovery validation

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Trade-offs and Considerations

Scraping Frequency vs Resource Cost

Cost-Benefit Analysis: - Higher frequency scraping increases infrastructure costs - Improved user experience with more timely alerts - Diminishing returns on very frequent scraping for stable prices - Dynamic frequency adjustment based on price volatility

Resource Optimization: - Cloud auto-scaling for cost-effective resource management - Intelligent batching to maximize scraping efficiency - Geographic distribution for reduced latency and costs - Caching strategies to minimize redundant processing

Business Impact: - Competitive advantage through faster price drop detection - User retention and engagement benefits - Revenue impact of notification delivery timing - Operational cost management for sustainable growth

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Real-time vs Batch Notifications

Real-time Benefits: - Immediate price drop alerts for time-sensitive deals - Enhanced user experience and engagement - Competitive advantage in fast-moving markets - Higher conversion rates for price-sensitive users

Batch Processing Advantages: - Reduced notification fatigue through aggregation - Cost savings on notification delivery - Better resource utilization and system performance - Improved content quality through aggregation

Hybrid Approach: - Real-time alerts for significant price drops - Batch processing for regular updates and minor changes - User preference-based notification timing - Intelligent threshold-based real-time triggering

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SQL vs NoSQL for Price Data

SQL Database Benefits: - ACID transactions for data consistency - Complex query capabilities for analytics - Mature ecosystem and tooling - Strong consistency guarantees

NoSQL Advantages: - Horizontal scaling for large datasets - Flexible schema for diverse product data - High write throughput for price updates - Better performance for simple lookup queries

Hybrid Architecture: - SQL for transactional user and subscription data - NoSQL for high-volume price history and analytics - Cache layer for frequently accessed data - Data synchronization between storage systems

Technology Selection: - PostgreSQL for transactional data and complex analytics - Cassandra or DynamoDB for time-series price data - Redis for caching and session management - Elasticsearch for full-text search and analytics

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