Social Media Backend System

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* Privacy vs Personalization
* Scalability vs Consistency

Requirements Gathering

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Functional Requirements

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Core Social Features: - User registration and profile management - Create, read, update, delete posts (text, images, videos) - Follow/unfollow other users - Like, comment, and share posts - News feed generation (timeline) - Direct messaging between users - Notifications for activities - Search users and content - Story creation and viewing (24-hour expiry) - Live streaming capabilities - Groups and pages creation - Event creation and management

Content Management: - Photo and video uploads (up to 4K resolution) - Content moderation and filtering - Hashtag system and trending topics - Content recommendation algorithm - Content reporting and flagging - Privacy settings for posts and profiles - Content archiving and deletion

Advanced Features: - Real-time chat and messaging - Voice and video calling - Location-based features - Content analytics for creators - Advertising platform integration - Third-party app integrations - Multi-language support - Accessibility features

Non-Functional Requirements

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Performance: - News feed loading < 2 seconds - Support 500 million daily active users - Handle 10 billion posts per day - 99.9% uptime SLA - Real-time updates < 100ms

Scalability: - Horizontal scaling across all services - Handle viral content traffic spikes - Global distribution across regions - Auto-scaling based on demand - Support 100x user growth

Security: - End-to-end encryption for messages - OAuth 2.0 authentication - Content encryption at rest - Privacy controls and data protection - Anti-spam and bot detection - GDPR and privacy compliance

Reliability: - Zero data loss for user content - Disaster recovery and backup - Multi-region data replication - Circuit breaker patterns - Graceful degradation

Traffic Estimation & Capacity Planning

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User Base Analysis

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- **Total Users:** 1 billion registered users
- **Daily Active Users (DAU):** 500 million users
- **Peak Concurrent Users:** 100 million users
- **Posts per User per Day:** 2 posts average
- **Feed Views per User per Day:** 50 views average
- **Messages per User per Day:** 20 messages average

Traffic Calculations

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Content Operations:

```
Daily Posts Created:
- Total posts = 500M DAU × 2 posts = 1B posts/day
- Peak posting rate = 1B × 3 / (24 × 3600) = 34,722 posts/sec
- Average posting rate = 1B / (24 × 3600) = 11,574 posts/sec

Feed Generation:
- Daily feed views = 500M DAU × 50 views = 25B feed requests/day
- Peak feed rate = 25B × 3 / (24 × 3600) = 868,055 requests/sec
- Average feed rate = 25B / (24 × 3600) = 289,351 requests/sec

Social Interactions:
- Likes per day = 500M × 20 = 10B likes/day
- Comments per day = 500M × 5 = 2.5B comments/day
- Shares per day = 500M × 2 = 1B shares/day
```

Storage Requirements:

```
User Data:
```

```
- User profiles = 1B users × 2KB = 2TB
- Social graph = 1B users × 100 connections × 50B = 5TB

Content Storage:
- Text posts = 1B posts × 500B = 500GB/day
- Image posts (30%) = 300M × 2MB = 600TB/day
- Video posts (10%) = 100M × 50MB = 5PB/day
- Annual content storage = (600TB + 5PB) × 365 = 2EB/year

Feed Cache:
- Active user feeds = 100M users × 20 posts × 1KB = 2TB
- Trending content cache = 50GB
- User activity cache = 100GB
```

Infrastructure Sizing:

```
Application Servers:
- Feed generation service: 200 servers
- Post service: 100 servers
- User service: 50 servers
- Media processing: 500 servers
- Real-time messaging: 300 servers

Database Requirements:
- User database: 100 shards, 64GB RAM each
- Posts database: 500 shards, 32GB RAM each
- Social graph database: 200 shards, 128GB RAM each
- Media metadata database: 50 shards, 16GB RAM each

Cache Infrastructure:
- Redis clusters: 10TB total memory
- Feed cache: 2TB
- User session cache: 1TB
- Content cache: 5TB
- Social graph cache: 2TB
```

Database Schema Design

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User Database Schema

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```sql
-- Users table
CREATE TABLE users (
    user_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    username VARCHAR(50) UNIQUE NOT NULL,
    email VARCHAR(255) UNIQUE NOT NULL,
    phone_number VARCHAR(20) UNIQUE,
    password_hash VARCHAR(255) NOT NULL,
    first_name VARCHAR(100),
    last_name VARCHAR(100),
    bio TEXT,
    profile_picture_url VARCHAR(512),
    cover_photo_url VARCHAR(512),
    birth_date DATE,
    gender ENUM('male', 'female', 'other', 'prefer_not_to_say'),
    location VARCHAR(255),
    website VARCHAR(255),
    verification_status ENUM('none', 'verified', 'business') DEFAULT 'none',
    privacy_settings JSON,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
    last_active TIMESTAMP,
    is_active BOOLEAN DEFAULT TRUE,
    follower_count INT DEFAULT 0,
    following_count INT DEFAULT 0,
    post_count INT DEFAULT 0,

    INDEX idx_username (username),
    INDEX idx_email (email),
    INDEX idx_last_active (last_active),
    INDEX idx_verification (verification_status)
);

-- User relationships (followers/following)
CREATE TABLE user_relationships (
    follower_id BIGINT NOT NULL,
    following_id BIGINT NOT NULL,
    relationship_type ENUM('follow', 'block', 'mute') NOT NULL,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,

    PRIMARY KEY (follower_id, following_id, relationship_type),
    INDEX idx_follower (follower_id),
    INDEX idx_following (following_id),
    FOREIGN KEY (follower_id) REFERENCES users(user_id),
```

```
    FOREIGN KEY (following_id) REFERENCES users(user_id)
);
```

Posts Database Schema

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```
-- Posts table (sharded by user_id)
CREATE TABLE posts (
    post_id BIGINT PRIMARY KEY,
    user_id BIGINT NOT NULL,
    content TEXT,
    post_type ENUM('text', 'image', 'video', 'story', 'live') NOT NULL,
    media_urls JSON, -- Array of media file URLs
    hashtags JSON, -- Array of hashtags
    mentions JSON, -- Array of mentioned user_ids
    location VARCHAR(255),
    privacy_setting ENUM('public', 'friends', 'private') DEFAULT 'public',
    is_deleted BOOLEAN DEFAULT FALSE,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
    like_count INT DEFAULT 0,
    comment_count INT DEFAULT 0,
    share_count INT DEFAULT 0,
    view_count BIGINT DEFAULT 0,

    INDEX idx_user_created (user_id, created_at),
    INDEX idx_created_at (created_at),
    INDEX idx_post_type (post_type),
    FOREIGN KEY (user_id) REFERENCES users(user_id)
);

-- Comments table
CREATE TABLE comments (
    comment_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    post_id BIGINT NOT NULL,
    user_id BIGINT NOT NULL,
    parent_comment_id BIGINT NULL, -- For nested comments
    content TEXT NOT NULL,
    is_deleted BOOLEAN DEFAULT FALSE,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
    like_count INT DEFAULT 0,
```

```
    INDEX idx_post_created (post_id, created_at),
    INDEX idx_user_created (user_id, created_at),
    INDEX idx_parent_comment (parent_comment_id),
    FOREIGN KEY (post_id) REFERENCES posts(post_id),
    FOREIGN KEY (user_id) REFERENCES users(user_id),
    FOREIGN KEY (parent_comment_id) REFERENCES comments(comment_id)
);

-- Likes table (for posts and comments)
CREATE TABLE likes (
    like_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    user_id BIGINT NOT NULL,
    target_id BIGINT NOT NULL, -- post_id or comment_id
    target_type ENUM('post', 'comment') NOT NULL,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,

    UNIQUE KEY unique_user_target (user_id, target_id, target_type),
    INDEX idx_target (target_id, target_type),
    INDEX idx_user_created (user_id, created_at),
    FOREIGN KEY (user_id) REFERENCES users(user_id)
);
```

Feed Database Schema

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```
-- News feed table (pre-computed feeds)
CREATE TABLE news_feeds (
    feed_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    user_id BIGINT NOT NULL,
    post_id BIGINT NOT NULL,
    score DECIMAL(10,6) NOT NULL, -- Relevance score for ranking
    feed_type ENUM('timeline', 'discover', 'trending') NOT NULL,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    expires_at TIMESTAMP NOT NULL,

    INDEX idx_user_score (user_id, score DESC),
    INDEX idx_user_type (user_id, feed_type),
    INDEX idx_expires_at (expires_at),
    FOREIGN KEY (user_id) REFERENCES users(user_id),
    FOREIGN KEY (post_id) REFERENCES posts(post_id)
);

-- Media files metadata
```

```sql
CREATE TABLE media_files (
    file_id VARCHAR(128) PRIMARY KEY, -- UUID
    user_id BIGINT NOT NULL,
    original_filename VARCHAR(255),
    file_type ENUM('image', 'video', 'audio') NOT NULL,
    file_size BIGINT NOT NULL,
    mime_type VARCHAR(100),
    storage_url VARCHAR(512) NOT NULL,
    thumbnail_url VARCHAR(512),
    duration INT NULL, -- For videos/audio in seconds
    resolution VARCHAR(20), -- e.g., "1920x1080"
    is_processed BOOLEAN DEFAULT FALSE,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,

    INDEX idx_user_created (user_id, created_at),
    INDEX idx_file_type (file_type),
    FOREIGN KEY (user_id) REFERENCES users(user_id)
);
```

Sample API Endpoints

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Authentication APIs

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```
POST /api/v1/auth/register
Content-Type: application/json

{
    "username": "johndoe",
    "email": "john@example.com",
    "password": "securePassword123",
    "first_name": "John",
    "last_name": "Doe"
}

Response (201 Created):
{
    "success": true,
    "data": {
```

```
        "user_id": 12345,
        "username": "johndoe",
        "access_token": "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9...",
        "refresh_token": "eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9...",
        "expires_in": 3600
    }
}
```

User Profile APIs

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```
GET /api/v1/users/{user_id}
Authorization: Bearer <access_token>

Response (200 OK):
{
    "success": true,
    "data": {
        "user_id": 12345,
        "username": "johndoe",
        "first_name": "John",
        "last_name": "Doe",
        "bio": "Software developer and coffee enthusiast",
        "profile_picture_url": "https://cdn.example.com/profiles/12345.jpg",
        "follower_count": 1547,
        "following_count": 892,
        "post_count": 234,
        "verification_status": "verified",
        "is_following": false,
        "is_followed_by": false
    }
}
```

Post Creation APIs

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```
POST /api/v1/posts
Authorization: Bearer <access_token>
Content-Type: multipart/form-data

Form Data:
```

```
- content: "Beautiful sunset at the beach! #sunset #photography"
- post_type: "image"
- media: [image file]
- privacy_setting: "public"
- location: "Malibu Beach, CA"

Response (201 Created):
{
    "success": true,
    "data": {
        "post_id": 567890,
        "user_id": 12345,
        "content": "Beautiful sunset at the beach! #sunset #photography",
        "post_type": "image",
        "media_urls": [
            "https://cdn.example.com/posts/567890_1.jpg"
        ],
        "hashtags": ["sunset", "photography"],
        "location": "Malibu Beach, CA",
        "created_at": "2024-01-15T18:30:00Z",
        "like_count": 0,
        "comment_count": 0
    }
}
```

News Feed APIs

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```
GET /api/v1/feed?limit=20&offset=0
Authorization: Bearer <access_token>

Response (200 OK):
{
    "success": true,
    "data": {
        "posts": [
            {
                "post_id": 567889,
                "user": {
                    "user_id": 12346,
                    "username": "janesmith",
                    "profile_picture_url": "https://cdn.example.com/profiles/12346.jpg",
                    "verification_status": "verified"
```

```
                },
                "content": "Just launched my new startup! So excited! ",
                "post_type": "text",
                "created_at": "2024-01-15T17:45:00Z",
                "like_count": 45,
                "comment_count": 12,
                "share_count": 8,
                "is_liked": false,
                "hashtags": ["startup", "entrepreneur"]
            }
        ],
        "has_more": true,
        "next_offset": 20
    }
}
```

Social Interaction APIs

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```
POST /api/v1/posts/{post_id}/like
Authorization: Bearer <access_token>

Response (200 OK):
{
    "success": true,
    "data": {
        "is_liked": true,
        "like_count": 46
    }
}
```

```
POST /api/v1/posts/{post_id}/comments
Authorization: Bearer <access_token>
Content-Type: application/json

{
    "content": "Congratulations! Wishing you all the best! ",
    "parent_comment_id": null
}

Response (201 Created):
{
    "success": true,
```

```
    "data": {
        "comment_id": 123456,
        "post_id": 567889,
        "user": {
            "user_id": 12345,
            "username": "johndoe",
            "profile_picture_url": "https://cdn.example.com/profiles/12345.jpg"
        },
        "content": "Congratulations! Wishing you all the best! ",
        "created_at": "2024-01-15T18:00:00Z",
        "like_count": 0
    }
}
```

Search APIs

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```
GET /api/v1/search?q=photography&type=posts&limit=20
Authorization: Bearer <access_token>

Response (200 OK):
{
    "success": true,
    "data": {
        "posts": [
            {
                "post_id": 567890,
                "user": {
                    "user_id": 12345,
                    "username": "johndoe",
                    "profile_picture_url": "https://cdn.example.com/profiles/12345.jpg"
                },
                "content": "Beautiful sunset at the beach! #sunset #photography",
                "media_urls": ["https://cdn.example.com/posts/567890_1.jpg"],
                "created_at": "2024-01-15T18:30:00Z",
                "like_count": 15
            }
        ],
        "total_results": 1547,
        "has_more": true
    }
}
```

High-Level Design (HLD)

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System Architecture Overview

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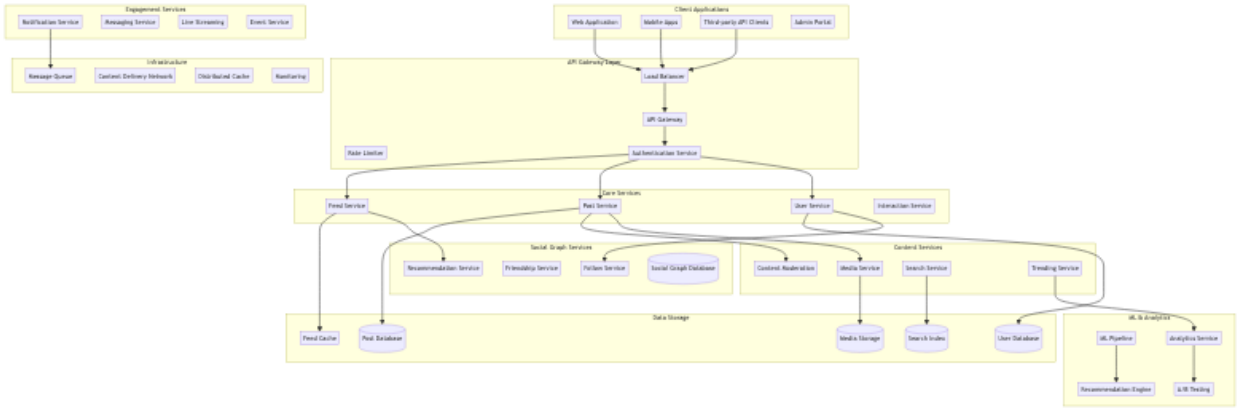

Social Media Data Flow

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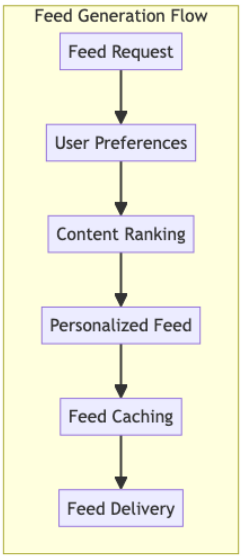
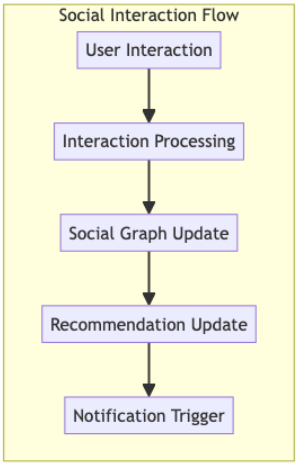
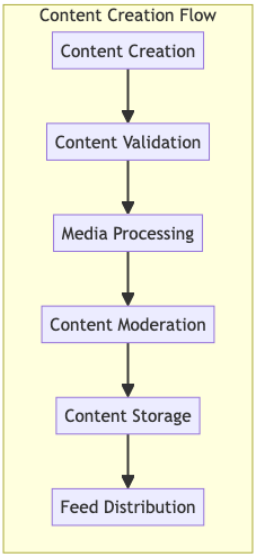

Feed Generation Flow
Feed Request
User Preferences
Content Ranking
Personalized Feed
Feed Caching
Feed Delivery


Social Interaction Flow
User Interaction
Interaction Processing
Social Graph Update
Recommendation Update
Notification Trigger


Content Creation Flow
Content Creation
Content Validation
Media Processing
Content Moderation
Content Storage
Feed Distribution

Low-Level Design (LLD)

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Feed Generation Algorithm

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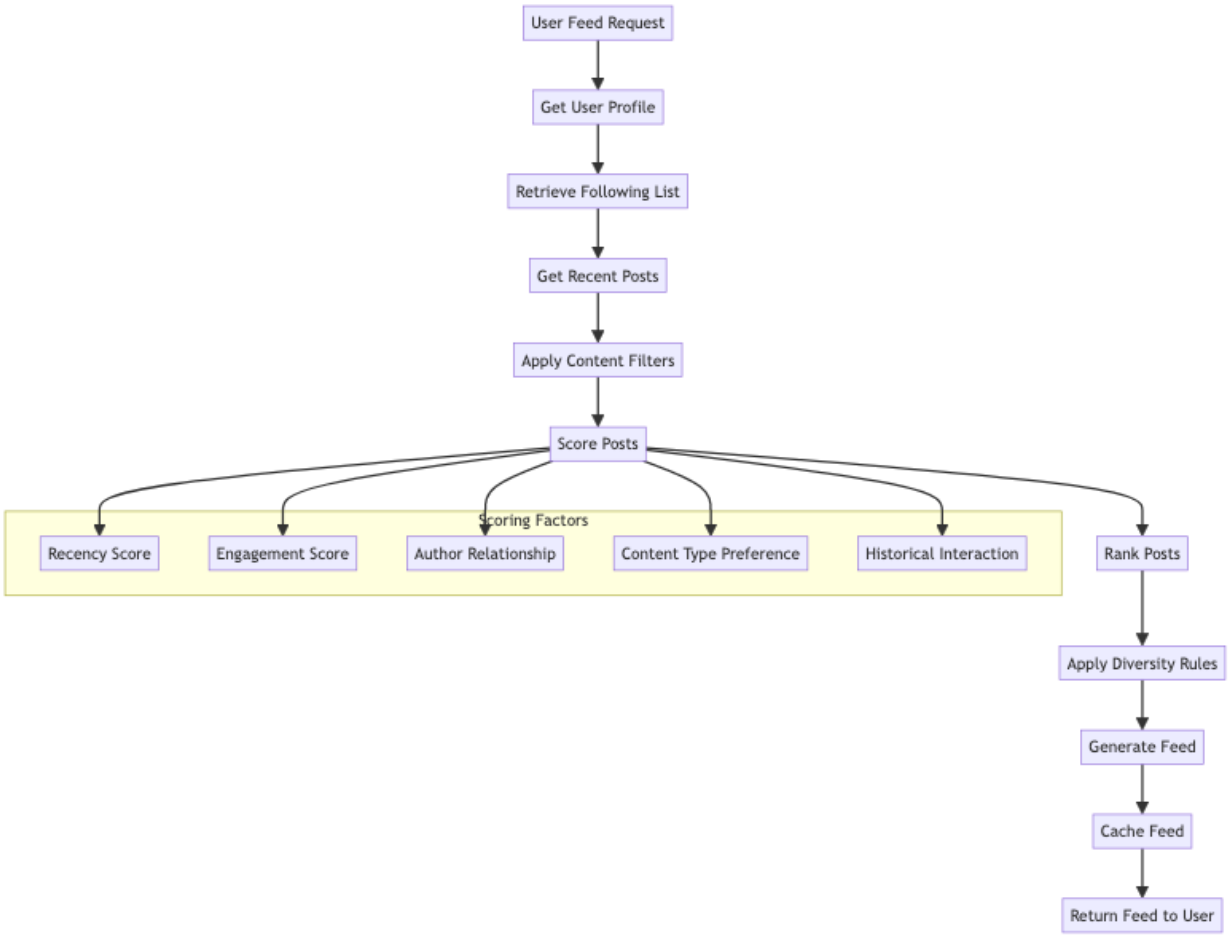

Social Graph Management

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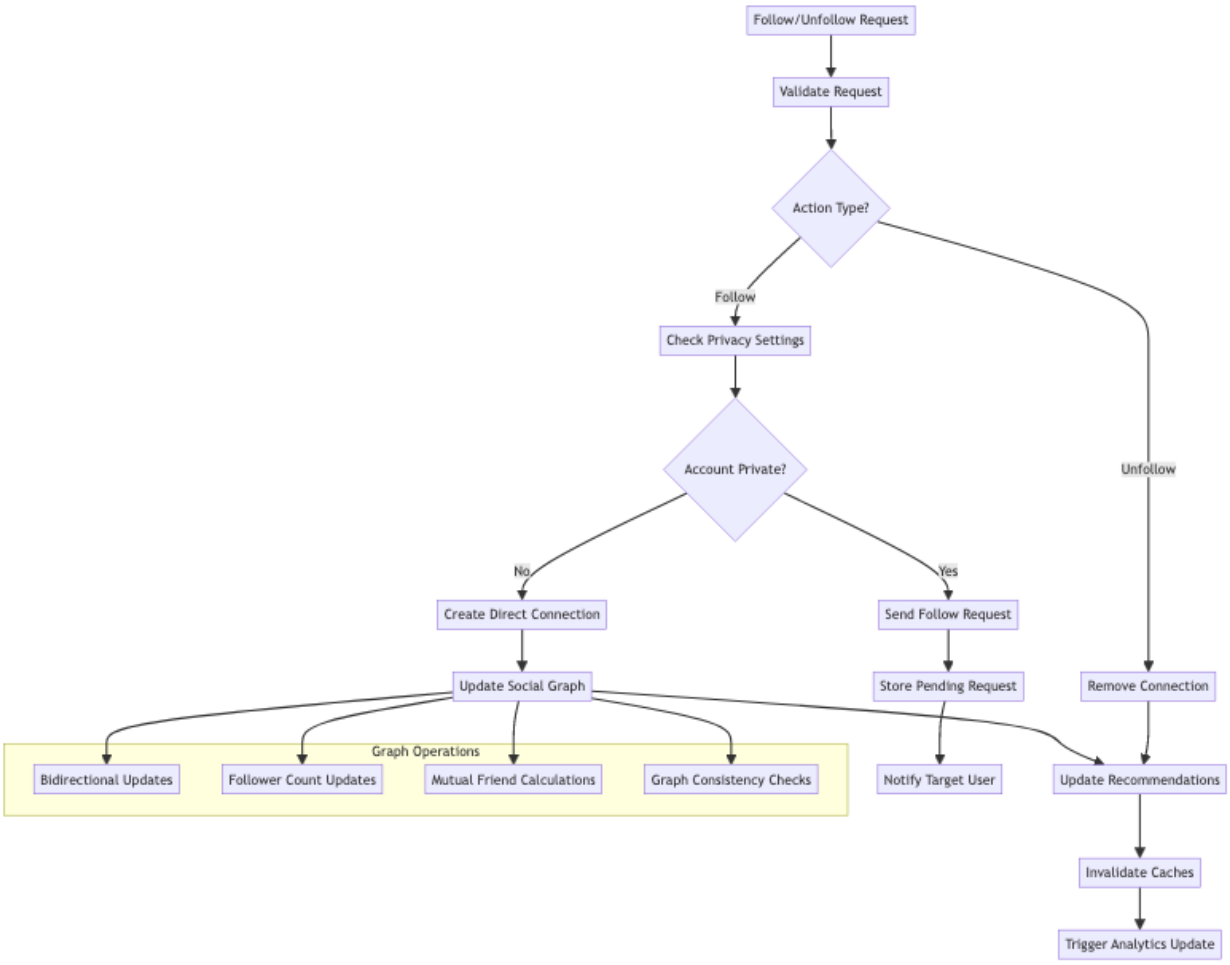

Content Moderation Pipeline

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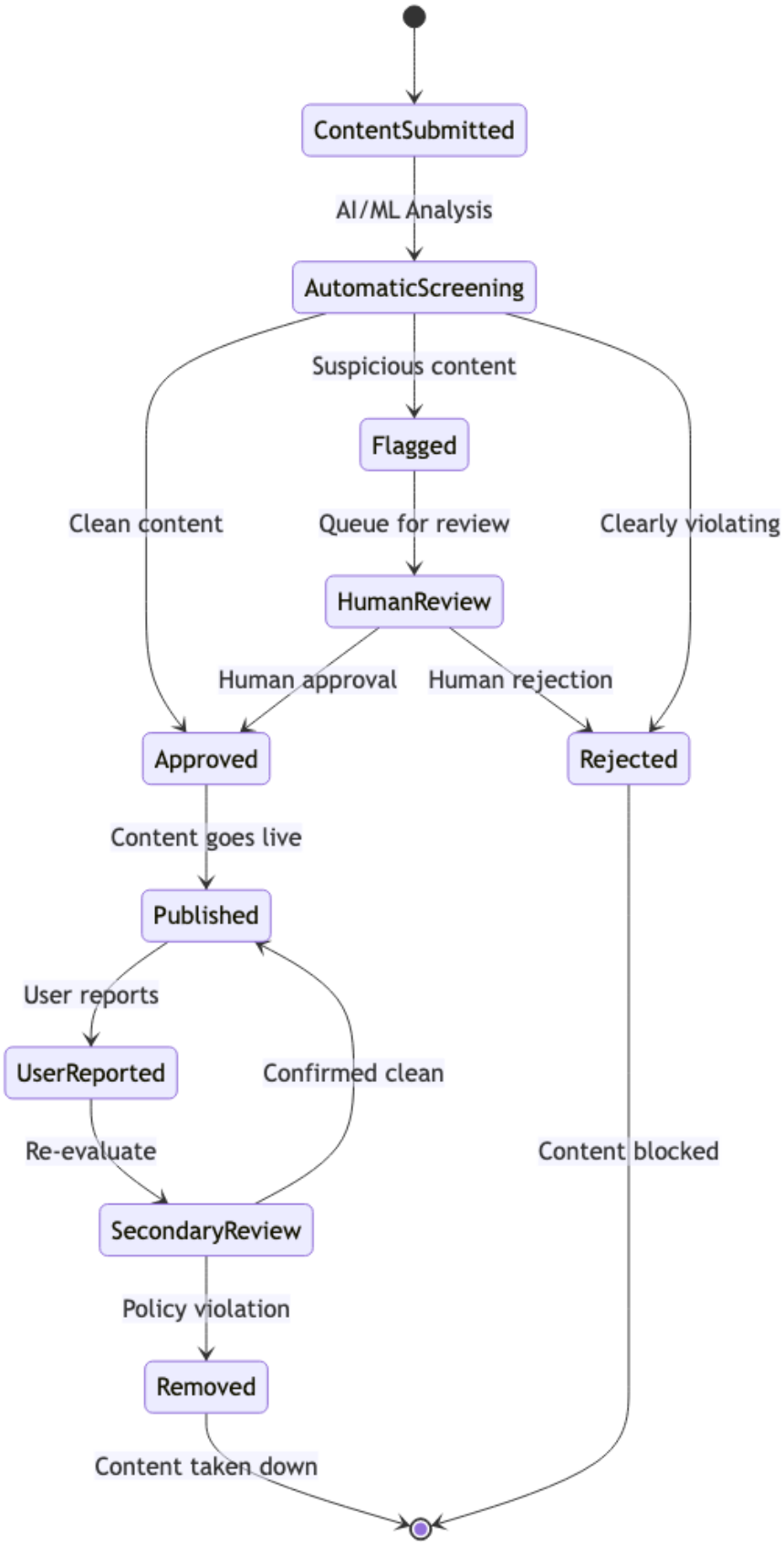
ContentSubmitted
AI/ML Analysis
AutomaticScreening
Suspicious content
Flagged
Clean content
Queue for review
Clearly violating
HumanReview
Human approval
Human rejection
Approved
Rejected
Content goes live
Published
User reports
UserReported
Confirmed clean
Re-evaluate
Content blocked
SecondaryReview
Policy violation
Removed
Content taken down

Core Algorithms

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---

1. Personalized Feed Generation Algorithm

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Purpose: Generate personalized content feeds that maximize user engagement while ensuring content diversity and freshness.

Multi-Signal Ranking Algorithm:

```
FeedGenerationConfig = {
  rankingSignals: {
    recency: { weight: 0.25, decayFactor: 0.1 },
    engagement: { weight: 0.3, timeWindow: 86400000 },
    relationship: { weight: 0.2, connectionStrength: true },
    contentType: { weight: 0.15, userPreferences: true },
    diversity: { weight: 0.1, categorySpread: true }
  },

  feedGeneration: {
    maxPostsPerFeed: 50,
    maxPostsPerAuthor: 3,
    freshnessThreshold: 604800000,  # 7 days
    minEngagementThreshold: 0.01
  },

  caching: {
    precomputedFeedSize: 200,
    cacheRefreshInterval: 300000,   # 5 minutes
    personalizedCacheTTL: 1800000   # 30 minutes
  }
}

class PersonalizedFeedGenerator:
  constructor(config):
    this.config = config
    this.socialGraph = new SocialGraphService()
    this.contentRanker = new ContentRankingService()
    this.userPreferences = new UserPreferenceService()
    this.engagementPredictor = new EngagementPredictor()
```

```
function generateFeed(userId, feedSize = 20, lastSeenPostId = null):
  startTime = Date.now()

  # Check for cached feed first
  cachedFeed = this.getCachedFeed(userId, lastSeenPostId)
  if cachedFeed and cachedFeed.length >= feedSize:
    return this.prepareFeedResponse(cachedFeed.slice(0, feedSize), startTime)

  # Get user's social context
  userContext = this.buildUserContext(userId)

  # Collect candidate posts
  candidatePosts = this.collectCandidatePosts(userContext)

  # Score and rank posts
  rankedPosts = this.scoreAndRankPosts(candidatePosts, userContext)

  # Apply diversity and business rules
  diversifiedFeed = this.applyDiversificationRules(rankedPosts, userContext)

  # Cache the generated feed
  this.cacheFeed(userId, diversifiedFeed)

  return this.prepareFeedResponse(diversifiedFeed.slice(0, feedSize), startTime)

function buildUserContext(userId):
  return {
    userId: userId,
    following: this.socialGraph.getFollowing(userId),
    preferences: this.userPreferences.getUserPreferences(userId),
    recentInteractions: this.getRecentInteractions(userId),
    demographics: this.getUserDemographics(userId),
    deviceContext: this.getDeviceContext(userId),
    timeContext: {
      currentTime: Date.now(),
      timezone: this.getUserTimezone(userId),
      timeOfDay: this.getTimeOfDay(userId)
    }
  }

function collectCandidatePosts(userContext):
  candidates = []

  # Posts from followed users
```

```
  followingPosts = this.getPostsFromFollowing(userContext.following, userContext.timeC
  candidates.push(...followingPosts)

  # Trending posts
  trendingPosts = this.getTrendingPosts(userContext.preferences.interests)
  candidates.push(...trendingPosts)

  # Recommended posts based on social graph
  recommendedPosts = this.getRecommendedPosts(userContext)
  candidates.push(...recommendedPosts)

  # Sponsored/promoted content
  promotedPosts = this.getPromotedPosts(userContext)
  candidates.push(...promotedPosts)

  # Remove duplicates and posts user has already seen
  uniqueCandidates = this.deduplicateAndFilter(candidates, userContext.userId)

  return uniqueCandidates

function scoreAndRankPosts(posts, userContext):
  scoredPosts = posts.map(post => ({
    ...post,
    score: this.calculatePostScore(post, userContext),
    signals: this.extractRankingSignals(post, userContext)
  }))

  # Sort by score (descending)
  return scoredPosts.sort((a, b) => b.score - a.score)

function calculatePostScore(post, userContext):
  score = 0

  # Recency score
  recencyScore = this.calculateRecencyScore(post.createdAt, userContext.timeContext.cu
  score += recencyScore * this.config.rankingSignals.recency.weight

  # Engagement score
  engagementScore = this.calculateEngagementScore(post)
  score += engagementScore * this.config.rankingSignals.engagement.weight

  # Relationship score
  relationshipScore = this.calculateRelationshipScore(post.authorId, userContext)
  score += relationshipScore * this.config.rankingSignals.relationship.weight
```

```
  # Content type preference score
  contentTypeScore = this.calculateContentTypeScore(post, userContext.preferences)
  score += contentTypeScore * this.config.rankingSignals.contentType.weight

  # Predicted engagement score
  predictedEngagement = this.engagementPredictor.predict(post, userContext)
  score += predictedEngagement * 0.2

  return Math.max(0, Math.min(1, score)) # Clamp between 0 and 1

function calculateRecencyScore(postTime, currentTime):
  ageInHours = (currentTime - postTime) / 3600000
  decayFactor = this.config.rankingSignals.recency.decayFactor

  # Exponential decay based on age
  return Math.exp(-decayFactor * ageInHours)

function calculateEngagementScore(post):
  timeWindow = this.config.rankingSignals.engagement.timeWindow
  recentEngagements = this.getRecentEngagements(post.id, timeWindow)

  # Weighted engagement calculation
  engagementScore = (
    recentEngagements.likes * 1.0 +
    recentEngagements.comments * 3.0 +
    recentEngagements.shares * 5.0 +
    recentEngagements.saves * 4.0
  )

  # Normalize by post age and follower count
  postAgeHours = (Date.now() - post.createdAt) / 3600000
  normalizedScore = engagementScore / (postAgeHours + 1) / (post.authorFollowerCount +

  return Math.min(1, normalizedScore * 100) # Scale and cap at 1

function applyDiversificationRules(rankedPosts, userContext):
  diversifiedFeed = []
  authorCounts = new Map()
  categoryDistribution = new Map()

  for post in rankedPosts:
    # Check author diversity constraint
    authorCount = authorCounts.get(post.authorId) || 0
    if authorCount >= this.config.feedGeneration.maxPostsPerAuthor:
      continue
```

```
      # Check category diversity
      if this.shouldSkipForDiversity(post, categoryDistribution, diversifiedFeed.length)
        continue

      # Add post to feed
      diversifiedFeed.push(post)
      authorCounts.set(post.authorId, authorCount + 1)
      this.updateCategoryDistribution(post, categoryDistribution)

      # Stop when we have enough posts
      if diversifiedFeed.length >= this.config.feedGeneration.maxPostsPerFeed:
        break

    return diversifiedFeed
```

2. Social Graph Management Algorithm

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Purpose: Efficiently manage follower/following relationships, friend connections, and social graph traversal operations.

Distributed Social Graph Storage:

```
SocialGraphConfig = {
  graphStorage: 'adjacency_list',       # 'adjacency_list', 'edge_list', 'matrix'
  shardingStrategy: 'user_id_hash',     # 'user_id_hash', 'geographic', 'random'
  replicationFactor: 3,

  relationshipTypes: {
    follow: { bidirectional: false, requiresApproval: false },
    friend: { bidirectional: true, requiresApproval: true },
    block: { bidirectional: false, cascading: true }
  },

  graphTraversal: {
    maxDepth: 3,                        # Maximum traversal depth
    maxResultsPerQuery: 1000,
    timeoutMs: 5000
  }
}

class SocialGraphManager:
  constructor(config):
```

```
  this.config = config
  this.graphStore = new DistributedGraphStore(config)
  this.relationshipValidator = new RelationshipValidator()
  this.graphAnalytics = new GraphAnalytics()
  this.cacheManager = new GraphCacheManager()

function createRelationship(fromUserId, toUserId, relationshipType):
  # Validate relationship request
  validation = this.relationshipValidator.validate(fromUserId, toUserId, relationshipT
  if not validation.valid:
    return { success: false, errors: validation.errors }

  # Check if relationship already exists
  existingRelationship = this.getRelationship(fromUserId, toUserId)
  if existingRelationship:
    return this.updateExistingRelationship(existingRelationship, relationshipType)

  # Create new relationship
  relationship = {
    fromUserId: fromUserId,
    toUserId: toUserId,
    type: relationshipType,
    createdAt: Date.now(),
    status: this.getInitialStatus(relationshipType),
    metadata: this.extractRelationshipMetadata(fromUserId, toUserId)
  }

  # Store relationship
  result = this.graphStore.addEdge(relationship)

  if result.success:
    # Update derived data
    this.updateUserCounts(fromUserId, toUserId, relationshipType, 'add')
    this.invalidateRelevantCaches(fromUserId, toUserId)
    this.triggerGraphAnalyticsUpdate(relationship)

    # Send notifications if required
    if this.shouldNotifyRelationshipCreation(relationshipType):
      this.sendRelationshipNotification(relationship)

  return result

function getFollowing(userId, limit = 100, cursor = null):
  cacheKey = `following:${userId}:${limit}:${cursor}`
  cached = this.cacheManager.get(cacheKey)
```

```
  if cached:
    return cached

  # Query graph store
  following = this.graphStore.getOutgoingEdges(userId, {
    edgeType: 'follow',
    limit: limit,
    cursor: cursor,
    includeMetadata: true
  })

  # Enrich with user data
  enrichedFollowing = this.enrichWithUserData(following)

  # Cache result
  this.cacheManager.set(cacheKey, enrichedFollowing, 300000) # 5 minutes

  return enrichedFollowing

function getFollowers(userId, limit = 100, cursor = null):
  cacheKey = `followers:${userId}:${limit}:${cursor}`
  cached = this.cacheManager.get(cacheKey)

  if cached:
    return cached

  # Query graph store
  followers = this.graphStore.getIncomingEdges(userId, {
    edgeType: 'follow',
    limit: limit,
    cursor: cursor,
    includeMetadata: true
  })

  # Enrich with user data
  enrichedFollowers = this.enrichWithUserData(followers)

  # Cache result
  this.cacheManager.set(cacheKey, enrichedFollowers, 300000) # 5 minutes

  return enrichedFollowers

function findMutualConnections(userId1, userId2):
  # Get followers for both users
```

```
  user1Followers = this.getFollowerIds(userId1)
  user2Followers = this.getFollowerIds(userId2)

  # Find intersection
  mutualFollowers = user1Followers.filter(id => user2Followers.includes(id))

  # Get following for both users
  user1Following = this.getFollowingIds(userId1)
  user2Following = this.getFollowingIds(userId2)

  # Find intersection
  mutualFollowing = user1Following.filter(id => user2Following.includes(id))

  return {
    mutualFollowers: mutualFollowers,
    mutualFollowing: mutualFollowing,
    connectionStrength: this.calculateConnectionStrength(userId1, userId2, mutualFollo
  }

function recommendConnections(userId, limit = 10):
  # Get user's current network
  currentNetwork = this.getUserNetwork(userId)

  # Generate candidates using multiple strategies
  candidates = new Map()

  # Friends of friends
  friendsOfFriends = this.getFriendsOfFriends(userId, currentNetwork)
  this.addCandidates(candidates, friendsOfFriends, 'friends_of_friends')

  # Similar interests
  similarInterests = this.findUsersBySimilarInterests(userId)
  this.addCandidates(candidates, similarInterests, 'similar_interests')

  # Geographic proximity
  nearbyUsers = this.findNearbyUsers(userId)
  this.addCandidates(candidates, nearbyUsers, 'geographic_proximity')

  # Professional connections
  professionalConnections = this.findProfessionalConnections(userId)
  this.addCandidates(candidates, professionalConnections, 'professional')

  # Score and rank candidates
  scoredCandidates = this.scoreCandidates(candidates, userId, currentNetwork)
```

```
    return scoredCandidates
      .sort((a, b) => b.score - a.score)
      .slice(0, limit)

  function calculateConnectionStrength(userId1, userId2, mutualFollowers, mutualFollowin
    # Base score from mutual connections
    mutualScore = (mutualFollowers.length + mutualFollowing.length) / 100 # Normalize

    # Interaction frequency score
    interactionScore = this.getInteractionFrequency(userId1, userId2) / 10 # Normalize

    # Common interests score
    commonInterestsScore = this.getCommonInterestsScore(userId1, userId2)

    # Temporal factors (how long they've been connected)
    relationshipAge = this.getRelationshipAge(userId1, userId2)
    ageScore = Math.min(relationshipAge / (365 * 24 * 60 * 60 * 1000), 1) # Normalize to

    # Weighted combination
    connectionStrength = (
      mutualScore * 0.3 +
      interactionScore * 0.4 +
      commonInterestsScore * 0.2 +
      ageScore * 0.1
    )

    return Math.min(1, connectionStrength)
```

3. Content Discovery and Trending Algorithm

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Purpose: Identify trending content, viral posts, and emerging topics using real-time engagement analysis and machine learning.

Real-time Trending Detection:

```
TrendingConfig = {
  trendingTimeWindows: [
    { name: 'real_time', duration: 900000 },      # 15 minutes
    { name: 'short_term', duration: 3600000 },    # 1 hour
    { name: 'medium_term', duration: 14400000 },  # 4 hours
    { name: 'daily', duration: 86400000 }         # 24 hours
  ],
```

```
  engagementWeights: {
    likes: 1.0,
    comments: 3.0,
    shares: 5.0,
    saves: 4.0,
    clicks: 0.5
  },

  viralityThresholds: {
    minimumEngagements: 10,
    growthRateThreshold: 2.0,    # 100% growth rate
    velocityThreshold: 0.1,      # Engagements per minute
    reachThreshold: 1000         # Minimum unique users reached
  }
}

class TrendingContentDetector:
  constructor(config):
    this.config = config
    this.engagementTracker = new EngagementTracker()
    this.viralityAnalyzer = new ViralityAnalyzer()
    this.topicExtractor = new TopicExtractor()
    this.trendingCache = new TrendingCache()

  function detectTrendingContent(timeWindow = 'short_term'):
    windowConfig = this.config.trendingTimeWindows.find(w => w.name === timeWindow)
    if not windowConfig:
      throw new Error(`Invalid time window: ${timeWindow}`)

    currentTime = Date.now()
    windowStart = currentTime - windowConfig.duration

    # Get content with significant engagement in time window
    candidateContent = this.getCandidateContent(windowStart, currentTime)

    # Calculate trending scores
    scoredContent = candidateContent.map(content => ({
      ...content,
      trendingScore: this.calculateTrendingScore(content, windowConfig),
      viralityMetrics: this.calculateViralityMetrics(content, windowConfig)
    }))

    # Filter by minimum thresholds
    trendingContent = scoredContent.filter(content =>
      this.meetsTrendingThresholds(content, windowConfig)
```

```
  )

  # Sort by trending score
  rankedTrending = trendingContent
    .sort((a, b) => b.trendingScore - a.trendingScore)
    .slice(0, 100) # Top 100 trending items

  # Update trending cache
  this.trendingCache.set(timeWindow, rankedTrending)

  return rankedTrending

function calculateTrendingScore(content, windowConfig):
  # Base engagement score
  engagementScore = this.calculateEngagementScore(content)

  # Velocity score (engagement rate over time)
  velocityScore = this.calculateVelocityScore(content, windowConfig)

  # Growth rate score (acceleration of engagement)
  growthScore = this.calculateGrowthScore(content, windowConfig)

  # Reach score (unique users engaged)
  reachScore = this.calculateReachScore(content)

  # Diversity score (engagement from different user segments)
  diversityScore = this.calculateDiversityScore(content)

  # Recency boost (newer content gets slight boost)
  recencyBoost = this.calculateRecencyBoost(content, windowConfig)

  # Weighted combination
  trendingScore = (
    engagementScore * 0.3 +
    velocityScore * 0.25 +
    growthScore * 0.2 +
    reachScore * 0.15 +
    diversityScore * 0.1
  ) * recencyBoost

  return trendingScore

function calculateEngagementScore(content):
  totalEngagement = 0
```

```
  for [engagementType, count] in Object.entries(content.engagements):
    weight = this.config.engagementWeights[engagementType] || 1.0
    totalEngagement += count * weight

  # Normalize by content age and author follower count
  contentAgeHours = (Date.now() - content.createdAt) / 3600000
  normalizedScore = totalEngagement / (contentAgeHours + 1) / Math.log(content.authorF

  return Math.min(1, normalizedScore / 100) # Scale and cap

function calculateVelocityScore(content, windowConfig):
  # Get engagement timeline
  engagementTimeline = this.getEngagementTimeline(content.id, windowConfig.duration)

  if engagementTimeline.length === 0:
    return 0

  # Calculate engagement velocity (engagements per minute)
  totalEngagements = engagementTimeline.reduce((sum, point) => sum + point.count, 0)
  timeSpanMinutes = windowConfig.duration / 60000
  velocity = totalEngagements / timeSpanMinutes

  # Normalize velocity score
  return Math.min(1, velocity / this.config.viralityThresholds.velocityThreshold)

function calculateGrowthScore(content, windowConfig):
  # Split window into two halves
  halfWindow = windowConfig.duration / 2
  currentTime = Date.now()

  # Get engagement for first half vs second half
  firstHalfEngagement = this.getEngagementCount(content.id, currentTime - windowConfig
  secondHalfEngagement = this.getEngagementCount(content.id, currentTime - halfWindow,

  # Calculate growth rate
  if firstHalfEngagement === 0:
    return secondHalfEngagement > 0 ? 1 : 0

  growthRate = (secondHalfEngagement - firstHalfEngagement) / firstHalfEngagement

  # Normalize growth score
  return Math.min(1, growthRate / this.config.viralityThresholds.growthRateThreshold)

function detectEmergingTopics(timeWindow = 'real_time'):
  # Get recent content
```

```
recentContent = this.getRecentContent(timeWindow)

# Extract topics from content
contentTopics = recentContent.map(content => ({
  contentId: content.id,
  topics: this.topicExtractor.extract(content.text),
  engagements: content.engagements,
  createdAt: content.createdAt
}))

# Aggregate topic mentions and engagement
topicAggregation = new Map()

for contentTopic in contentTopics:
  for topic in contentTopic.topics:
    if not topicAggregation.has(topic.text):
      topicAggregation.set(topic.text, {
        topicText: topic.text,
        mentions: 0,
        totalEngagement: 0,
        firstMention: contentTopic.createdAt,
        lastMention: contentTopic.createdAt,
        contentIds: []
      })

    topicData = topicAggregation.get(topic.text)
    topicData.mentions++
    topicData.totalEngagement += this.calculateTotalEngagement(contentTopic.engageme
    topicData.lastMention = Math.max(topicData.lastMention, contentTopic.createdAt)
    topicData.firstMention = Math.min(topicData.firstMention, contentTopic.createdAt
    topicData.contentIds.push(contentTopic.contentId)

# Score topics for emerging potential
emergingTopics = Array.from(topicAggregation.values()).map(topic => ({
  ...topic,
  emergingScore: this.calculateEmergingScore(topic, timeWindow),
  velocity: this.calculateTopicVelocity(topic),
  reach: this.calculateTopicReach(topic)
}))

# Filter and rank emerging topics
significantTopics = emergingTopics
  .filter(topic => topic.mentions >= 3 and topic.emergingScore > 0.3)
  .sort((a, b) => b.emergingScore - a.emergingScore)
  .slice(0, 20)
```

```
    return significantTopics

  function calculateEmergingScore(topic, timeWindow):
    windowDuration = this.config.trendingTimeWindows.find(w => w.name === timeWindow).du

    # Mention frequency score
    mentionFrequency = topic.mentions / (windowDuration / 3600000) # Mentions per hour

    # Engagement score
    avgEngagementPerMention = topic.totalEngagement / topic.mentions

    # Recency score (newer topics get higher scores)
    recencyScore = Math.max(0, 1 - (Date.now() - topic.lastMention) / windowDuration)

    # Growth score (how quickly topic is spreading)
    timeSpread = topic.lastMention - topic.firstMention
    growthScore = timeSpread > 0 ? topic.mentions / (timeSpread / 60000) : topic.mention

    # Weighted combination
    emergingScore = (
      Math.min(1, mentionFrequency / 10) * 0.3 +         # Normalize by 10 mentions/hour
      Math.min(1, avgEngagementPerMention / 100) * 0.25 + # Normalize by 100 engagements
      recencyScore * 0.25 +
      Math.min(1, growthScore / 5) * 0.2                  # Normalize by 5 mentions/minu
    )

    return emergingScore
```

4. Content Moderation Algorithm

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Purpose: Automatically detect and moderate inappropriate content using machine learning, community guidelines, and human review workflows.

Multi-Modal Content Moderation:

```
ModerationConfig = {
  automatedChecks: {
    textAnalysis: {
      enabled: true,
      profanityDetection: true,
      toxicityThreshold: 0.7,
      spamDetection: true,
```

```
      languageDetection: true
    },
    imageAnalysis: {
      enabled: true,
      nudityDetection: true,
      violenceDetection: true,
      logoDetection: true,
      faceDetection: true
    },
    videoAnalysis: {
      enabled: true,
      keyFrameAnalysis: true,
      audioAnalysis: true,
      durationLimits: true
    }
  },

  moderationActions: {
    autoApprove: { threshold: 0.1 },
    flagForReview: { threshold: 0.5 },
    autoReject: { threshold: 0.9 },
    shadowBan: { threshold: 0.8 }
  },

  humanReview: {
    enabled: true,
    queuePrioritization: 'risk_score',
    reviewerAssignment: 'round_robin',
    escalationThreshold: 0.95
  }
}

class ContentModerationEngine:
  constructor(config):
    this.config = config
    this.textAnalyzer = new TextModerationAnalyzer()
    this.imageAnalyzer = new ImageModerationAnalyzer()
    this.videoAnalyzer = new VideoModerationAnalyzer()
    this.mlModerationModel = new MLModerationModel()
    this.humanReviewQueue = new HumanReviewQueue()

  function moderateContent(content, authorId):
    moderationResult = {
      contentId: content.id,
      authorId: authorId,
```

```
    submittedAt: Date.now(),
    moderationScores: {},
    overallRiskScore: 0,
    action: 'pending',
    reasoning: [],
    humanReviewRequired: false
  }

  # Perform automated analysis
  if content.text and this.config.automatedChecks.textAnalysis.enabled:
    textScore = this.analyzeTextContent(content.text)
    moderationResult.moderationScores.text = textScore
    moderationResult.reasoning.push(...textScore.violations)

  if content.images and this.config.automatedChecks.imageAnalysis.enabled:
    imageScores = content.images.map(image => this.analyzeImageContent(image))
    moderationResult.moderationScores.images = imageScores
    imageScores.forEach(score => moderationResult.reasoning.push(...score.violations))

  if content.video and this.config.automatedChecks.videoAnalysis.enabled:
    videoScore = this.analyzeVideoContent(content.video)
    moderationResult.moderationScores.video = videoScore
    moderationResult.reasoning.push(...videoScore.violations)

  # Calculate overall risk score
  moderationResult.overallRiskScore = this.calculateOverallRiskScore(moderationResult.

  # Determine moderation action
  moderationResult.action = this.determineModerationAction(moderationResult.overallRis

  # Check if human review is needed
  if this.requiresHumanReview(moderationResult):
    moderationResult.humanReviewRequired = true
    this.queueForHumanReview(moderationResult)

  return moderationResult

function analyzeTextContent(text):
  analysisResult = {
    toxicityScore: 0,
    spamScore: 0,
    profanityScore: 0,
    overallScore: 0,
    violations: [],
    detectedLanguage: null
```

```
}

# Detect language
analysisResult.detectedLanguage = this.textAnalyzer.detectLanguage(text)

# Toxicity analysis
if this.config.automatedChecks.textAnalysis.toxicityThreshold:
  toxicityResult = this.textAnalyzer.analyzeToxicity(text)
  analysisResult.toxicityScore = toxicityResult.score

  if toxicityResult.score > this.config.automatedChecks.textAnalysis.toxicityThresho
    analysisResult.violations.push({
      type: 'toxicity',
      severity: toxicityResult.score,
      details: toxicityResult.categories
    })

# Profanity detection
if this.config.automatedChecks.textAnalysis.profanityDetection:
  profanityResult = this.textAnalyzer.detectProfanity(text)
  analysisResult.profanityScore = profanityResult.score

  if profanityResult.detected:
    analysisResult.violations.push({
      type: 'profanity',
      severity: profanityResult.score,
      details: profanityResult.words
    })

# Spam detection
if this.config.automatedChecks.textAnalysis.spamDetection:
  spamResult = this.textAnalyzer.detectSpam(text)
  analysisResult.spamScore = spamResult.score

  if spamResult.isSpam:
    analysisResult.violations.push({
      type: 'spam',
      severity: spamResult.score,
      details: spamResult.indicators
    })

# Calculate overall text score
analysisResult.overallScore = Math.max(
  analysisResult.toxicityScore,
  analysisResult.spamScore,
```

```
    analysisResult.profanityScore
  )

  return analysisResult

function analyzeImageContent(imageData):
  analysisResult = {
    nudityScore: 0,
    violenceScore: 0,
    inappropriateScore: 0,
    overallScore: 0,
    violations: [],
    detectedObjects: []
  }

  # Nudity detection
  nudityResult = this.imageAnalyzer.detectNudity(imageData)
  analysisResult.nudityScore = nudityResult.score

  if nudityResult.detected:
    analysisResult.violations.push({
      type: 'nudity',
      severity: nudityResult.score,
      details: nudityResult.regions
    })

  # Violence detection
  violenceResult = this.imageAnalyzer.detectViolence(imageData)
  analysisResult.violenceScore = violenceResult.score

  if violenceResult.detected:
    analysisResult.violations.push({
      type: 'violence',
      severity: violenceResult.score,
      details: violenceResult.indicators
    })

  # Object detection for context
  objectsResult = this.imageAnalyzer.detectObjects(imageData)
  analysisResult.detectedObjects = objectsResult.objects

  # Check for inappropriate objects/scenes
  inappropriateObjects = this.checkInappropriateObjects(objectsResult.objects)
  if inappropriateObjects.length > 0:
    analysisResult.inappropriateScore = 0.8
```

```
    analysisResult.violations.push({
      type: 'inappropriate_content',
      severity: 0.8,
      details: inappropriateObjects
    })

  # Calculate overall image score
  analysisResult.overallScore = Math.max(
    analysisResult.nudityScore,
    analysisResult.violenceScore,
    analysisResult.inappropriateScore
  )

  return analysisResult

function determineModerationAction(riskScore):
  if riskScore <= this.config.moderationActions.autoApprove.threshold:
    return 'approved'
  else if riskScore <= this.config.moderationActions.flagForReview.threshold:
    return 'flagged_for_review'
  else if riskScore <= this.config.moderationActions.autoReject.threshold:
    return 'rejected'
  else:
    return 'auto_rejected'

function queueForHumanReview(moderationResult):
  reviewTask = {
    taskId: generateTaskId(),
    contentId: moderationResult.contentId,
    authorId: moderationResult.authorId,
    priority: this.calculateReviewPriority(moderationResult),
    moderationResult: moderationResult,
    queuedAt: Date.now(),
    assignedReviewer: null,
    status: 'pending'
  }

  this.humanReviewQueue.enqueue(reviewTask, reviewTask.priority)

  return reviewTask.taskId

function calculateReviewPriority(moderationResult):
  # Higher risk score = higher priority
  riskPriority = moderationResult.overallRiskScore * 100
```

```
    # Viral content gets higher priority
    engagementBoost = Math.log(moderationResult.engagementCount + 1) * 10

    # Author reputation affects priority
    authorReputationBoost = this.getAuthorReputationBoost(moderationResult.authorId)

    return Math.min(1000, riskPriority + engagementBoost + authorReputationBoost)
```

5. Real-time Notification System

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Purpose: Deliver personalized, timely notifications across multiple channels while respecting user preferences and avoiding notification fatigue.

Intelligent Notification Delivery:

```
NotificationConfig = {
  channels: {
    push: { enabled: true, priority: 'high', deliveryTimeout: 30000 },
    email: { enabled: true, priority: 'medium', deliveryTimeout: 300000 },
    inApp: { enabled: true, priority: 'low', deliveryTimeout: 0 },
    sms: { enabled: false, priority: 'critical', deliveryTimeout: 10000 }
  },

  notificationTypes: {
    like: { priority: 'low', frequency: 'batched', cooldown: 3600000 },
    comment: { priority: 'medium', frequency: 'immediate', cooldown: 0 },
    follow: { priority: 'medium', frequency: 'immediate', cooldown: 300000 },
    mention: { priority: 'high', frequency: 'immediate', cooldown: 0 },
    message: { priority: 'high', frequency: 'immediate', cooldown: 0 }
  },

  intelligentDelivery: {
    enabled: true,
    userActivityTracking: true,
    timezonalDelivery: true,
    frequencyCapping: true
  }
}

class IntelligentNotificationSystem:
  constructor(config):
    this.config = config
    this.notificationQueue = new PriorityNotificationQueue()
```

```
  this.userPreferenceManager = new UserPreferenceManager()
  this.deliveryOptimizer = new DeliveryOptimizer()
  this.channelManagers = this.initializeChannelManagers()

function sendNotification(notification, recipients):
  # Process each recipient individually
  deliveryResults = []

  for recipient in recipients:
    recipientResult = this.processRecipientNotification(notification, recipient)
    deliveryResults.push(recipientResult)

  return {
    notificationId: notification.id,
    totalRecipients: recipients.length,
    deliveryResults: deliveryResults,
    overallSuccess: deliveryResults.every(r => r.success)
  }

function processRecipientNotification(notification, recipientId):
  # Get user preferences
  userPreferences = this.userPreferenceManager.getPreferences(recipientId)

  # Check if user wants this type of notification
  if not this.shouldDeliverNotification(notification, userPreferences):
    return { success: true, reason: 'user_preference_filtered', recipientId: recipient

  # Apply frequency capping
  if this.isFrequencyCapped(notification, recipientId):
    return { success: true, reason: 'frequency_capped', recipientId: recipientId }

  # Determine optimal delivery channels
  optimalChannels = this.selectOptimalChannels(notification, recipientId, userPreferen

  # Schedule delivery
  deliveryPlan = this.createDeliveryPlan(notification, recipientId, optimalChannels)

  # Execute delivery
  return this.executeDeliveryPlan(deliveryPlan)

function selectOptimalChannels(notification, recipientId, userPreferences):
  # Get user's active channels
  activeChannels = this.getActiveChannels(recipientId)

  # Filter by user preferences
```

```
  preferredChannels = activeChannels.filter(channel =>
    userPreferences.channels[channel]?.enabled !== false
  )

  # Select channels based on notification priority and type
  notificationConfig = this.config.notificationTypes[notification.type]
  selectedChannels = []

  # Always include in-app notifications
  if preferredChannels.includes('inApp'):
    selectedChannels.push('inApp')

  # Add push notifications for medium+ priority
  if notificationConfig.priority in ['medium', 'high', 'critical'] and preferredChanne
    # Check user's current activity status
    userActivity = this.getUserActivityStatus(recipientId)

    if not userActivity.isActiveInApp:
      selectedChannels.push('push')

  # Add email for batched notifications or high priority
  if (notificationConfig.frequency === 'batched' or notificationConfig.priority === 'h
    selectedChannels.push('email')

  # Add SMS for critical notifications only
  if notificationConfig.priority === 'critical' and preferredChannels.includes('sms'):
    selectedChannels.push('sms')

  return selectedChannels

function createDeliveryPlan(notification, recipientId, channels):
  userTimezone = this.getUserTimezone(recipientId)
  optimalDeliveryTime = this.calculateOptimalDeliveryTime(notification, recipientId, u

  deliveryTasks = channels.map(channel => ({
    notificationId: notification.id,
    recipientId: recipientId,
    channel: channel,
    scheduledTime: optimalDeliveryTime,
    priority: this.calculateDeliveryPriority(notification, channel),
    payload: this.createChannelPayload(notification, channel, recipientId),
    retryPolicy: this.getRetryPolicy(channel)
  }))

  return {
```

```
    recipientId: recipientId,
    deliveryTasks: deliveryTasks,
    createdAt: Date.now()
  }

function calculateOptimalDeliveryTime(notification, recipientId, userTimezone):
  notificationConfig = this.config.notificationTypes[notification.type]

  # Immediate delivery for high priority notifications
  if notificationConfig.frequency === 'immediate':
    return Date.now()

  # For batched notifications, find optimal time
  if notificationConfig.frequency === 'batched':
    return this.findOptimalBatchTime(recipientId, userTimezone)

  # For scheduled notifications, respect user's active hours
  if this.config.intelligentDelivery.timezonalDelivery:
    return this.findNextActiveHour(recipientId, userTimezone)

  return Date.now()

function findOptimalBatchTime(recipientId, userTimezone):
  # Get user's engagement patterns
  engagementData = this.getUserEngagementPattern(recipientId)

  # Find the next high-engagement time window
  currentHour = new Date().getHours()
  optimalHours = engagementData.peakHours || [9, 18] # Default to 9 AM and 6 PM

  # Find next optimal hour
  nextOptimalHour = optimalHours.find(hour => hour > currentHour) || optimalHours[0]

  # Calculate delivery time
  nextDelivery = new Date()
  nextDelivery.setHours(nextOptimalHour, 0, 0, 0)

  # If next optimal hour is tomorrow, adjust date
  if nextOptimalHour <= currentHour:
    nextDelivery.setDate(nextDelivery.getDate() + 1)

  return nextDelivery.getTime()

function executeDeliveryPlan(deliveryPlan):
  deliveryResults = []
```

```
  for task in deliveryPlan.deliveryTasks:
    try:
      # Check if delivery should be delayed
      if task.scheduledTime > Date.now():
        this.scheduleDelayedDelivery(task)
        deliveryResults.push({
          channel: task.channel,
          status: 'scheduled',
          scheduledTime: task.scheduledTime
        })
      else:
        # Deliver immediately
        result = this.deliverToChannel(task)
        deliveryResults.push(result)

    catch error:
      deliveryResults.push({
        channel: task.channel,
        status: 'failed',
        error: error.message
      })

  return {
    success: deliveryResults.some(r => r.status === 'delivered' or r.status === 'sched
    recipientId: deliveryPlan.recipientId,
    channelResults: deliveryResults
  }

function deliverToChannel(deliveryTask):
  channelManager = this.channelManagers[deliveryTask.channel]

  if not channelManager:
    throw new Error(`Channel manager not found: ${deliveryTask.channel}`)

  # Record delivery attempt
  this.recordDeliveryAttempt(deliveryTask)

  # Execute delivery
  deliveryResult = channelManager.deliver(deliveryTask.payload, deliveryTask.recipient

  # Update delivery status
  this.updateDeliveryStatus(deliveryTask, deliveryResult)

  return {
```

```
      channel: deliveryTask.channel,
      status: deliveryResult.success ? 'delivered' : 'failed',
      deliveredAt: Date.now(),
      messageId: deliveryResult.messageId,
      error: deliveryResult.error
    }

  function isFrequencyCapped(notification, recipientId):
    notificationConfig = this.config.notificationTypes[notification.type]

    if notificationConfig.cooldown === 0:
      return false # No frequency capping

    # Check recent notifications of the same type
    recentNotifications = this.getRecentNotifications(
      recipientId,
      notification.type,
      notificationConfig.cooldown
    )

    return recentNotifications.length > 0
```

Performance Optimizations

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Feed Generation Optimization

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Precomputed Feed Strategy:

```
FeedOptimization = {
  precomputation: {
    enabled: true,
    batchSize: 1000,
    updateFrequency: 300000  # 5 minutes
  },

  caching: {
    userFeeds: { ttl: 1800000, size: 100000 },    # 30 minutes, 100K users
    trendingContent: { ttl: 900000, size: 1000 },  # 15 minutes, 1K items
```

```
    socialGraphData: { ttl: 3600000, size: 50000 } # 1 hour, 50K relationships
  }
}
```

Database Optimization

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Social Graph Storage Strategy: - Graph database for relationships (Neo4j/Amazon Neptune) - Time-series database for engagement metrics - Document database for posts and user profiles - Search index for content discovery

Security Considerations

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Social Media Security Framework

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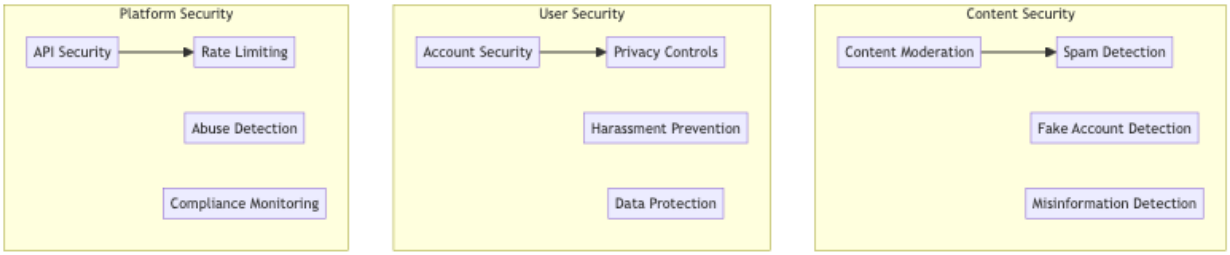

Testing Strategy

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Load Testing

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High Traffic Scenarios: - Viral content propagation testing - Feed generation performance - Real-time interaction handling - Database query optimization

Social Features Testing

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User Behavior Simulation: - Follow/unfollow patterns - Content engagement patterns - Trending content emergence - Network effect validation

Trade-offs and Considerations

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Engagement vs Well-being

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- **Algorithmic feeds**: Engagement vs mental health
- **Notification frequency**: User retention vs notification fatigue
- **Content recommendation**: Relevance vs filter bubbles
- **Social validation**: Engagement metrics vs psychological impact

Privacy vs Personalization

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- **Data collection**: Personalization quality vs privacy
- **Social graph mining**: Feature enhancement vs user privacy
- **Behavioral tracking**: Recommendation accuracy vs data protection
- **Cross-platform integration**: Convenience vs data sharing

Scalability vs Consistency

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- **Real-time feeds**: Immediate updates vs system performance
- **Global content**: Worldwide reach vs regulatory compliance
- **Social graph updates**: Consistency vs availability
- **Content moderation**: Accuracy vs processing speed

This social media backend system provides a comprehensive foundation for large-scale social networking with features like personalized feeds, social graph management, content discovery, moderation, and intelligent notifications while maintaining high performance, security, and user experience standards.