Privacy & Visibility Controls Backend

□ Table of Contents

        * Privacy Granularity vs Performance
        * Real-time vs Cached Permissions
        * SQL vs NoSQL for Relationship Data

□ Back to Top

Requirements Gathering

Functional Requirements

Core Privacy Control Functionality: - Enable users to set granular privacy settings for profile fields (birthday, education, photos, etc.) - Support multiple privacy levels: Public, Friends Only, Custom Groups, Only Me - Allow creation and management of custom privacy groups - Provide real-time privacy filtering for profile views and content access - Support bulk privacy updates and inheritance rules

Profile Visibility Management: - Control visibility of different profile sections based on viewer relationship - Enable conditional visibility (friends-of-friends, mutual connections) - Support time-based privacy settings (temporary visibility changes) - Provide privacy preview functionality for users to test their settings - Handle blocked user access restrictions

Relationship-based Access Control: - Enforce privacy based on friendship status and connection levels - Support custom friend lists and categorization - Handle pending friend requests and limited visibility states - Manage group membership and hierarchical access rights - Enable granular control over mutual friend visibility

Administrative Features: - Provide privacy audit trails and access logs - Support privacy policy enforcement and compliance - Enable bulk privacy administration for organizational accounts - Offer privacy analytics and usage insights

□ Back to Top

Non-Functional Requirements

Performance Requirements: - Support 1 billion user profiles with complex privacy settings - Handle 100 million profile views per hour with real-time privacy filtering - Permission check latency: $<$50ms (p99) - Privacy setting updates propagated within 1 second globally - System availability: 99.99% uptime with zero privacy leaks

Scalability Requirements: - Horizontally scalable to handle growing user base and relationships - Support for complex relationship graphs with millions of connections per user - Auto-scaling based on privacy check volume and geographic distribution - Linear performance scaling with increased privacy rule complexity

Security and Privacy: - Zero tolerance for privacy setting bypass or data leaks - End-to-end encryption for sensitive privacy configuration data - Audit logging for all privacy-related access and changes - GDPR and privacy regulation compliance built-in

Consistency Requirements: - Strong consistency for privacy setting updates - Eventual consistency acceptable for relationship graph updates (< 1 second) - Atomic privacy rule changes across multiple profile fields - Consistent privacy enforcement across all system components

▯ Back to Top

Traffic Estimation & Capacity Planning

User Activity Analysis

User Base Scale: - 1 billion registered users with active privacy settings - 500 million daily active users accessing profiles - Average 50 profile fields per user with individual privacy settings - 10 privacy groups per user on average

Privacy Setting Distribution: - Public settings: 30% of profile fields - Friends only: 50% of profile fields
- Custom groups: 15% of profile fields - Only me: 5% of profile fields

Relationship Complexity: - Average 200 friends per user - Average 5 custom privacy groups per user - Friend-of-friend connections: 20,000 per user average - Group memberships: Average 10 groups per user

▯ Back to Top

Permission Check Volume

Read Operations: - Profile views: 100 million per hour - Permission checks per view: Average 20 fields - Total permission checks: 2 billion per hour (555,000 per second) - Friend relationship lookups: 50 million per hour

Geographic Distribution: - North America: 35% of traffic - Europe: 25% of traffic - Asia-Pacific: 30% of traffic - Other regions: 10% of traffic

Peak Load Scenarios: - Holiday seasons: 3x normal traffic - Viral content events: 5x normal profile access - Privacy policy updates: 10x permission check volume

▯ Back to Top

Privacy Setting Updates

Write Operations: - Privacy setting updates: 1 million per hour - Bulk privacy changes: 100,000 per hour - Friend relationship changes: 5 million per hour - Group membership updates: 500,000 per hour

Update Patterns: - Individual field updates: 70% of changes - Bulk profile updates: 20% of changes - Import/migration operations: 10% of changes

Propagation Requirements: - Real-time updates: Privacy setting changes - Near real-time: Relationship changes (< 1 second) - Batch updates: Group membership bulk operations - Background processing: Privacy audit and analytics

□ Back to Top

Database Schema Design

User Profile Schema

Profile Fields Table: - User ID (Primary Key): Unique user identifier - Field Name: Profile field identifier (birthday, education, etc.) - Field Value: Actual profile data (encrypted for sensitive fields) - Privacy Level: Current privacy setting for this field - Custom Group ID: Reference to custom privacy group if applicable - Last Updated: Timestamp of last privacy or value change

Field Categories: - Basic Information: Name, profile picture, cover photo - Contact Information: Email, phone, address - Personal Details: Birthday, relationship status, hometown - Professional Information: Work history, education, skills - Preferences: Interests, favorite content, activities

Data Fragmentation Strategy: - Each profile field stored as separate record for granular privacy control - Partition by User ID for efficient retrieval - Secondary indexes on privacy levels for administrative queries - Encryption at rest for PII and sensitive data

□ Back to Top

Privacy Settings Schema

Privacy Rules Table: - Rule ID (Primary Key): Unique privacy rule identifier - User ID (Foreign Key): Owner of the privacy rule - Field Pattern: Regex or field names this rule applies to - Privacy Level: Public, Friends, Custom Group, Only Me - Group References: List of custom group IDs for custom privacy - Conditions: Additional conditions (time-based, location-based)

Custom Privacy Groups: - Group ID (Primary Key): Unique group identifier - User ID (Foreign Key): Group owner - Group Name: User-defined group name - Group Description: Optional group description - Member List: List of user IDs in this privacy group - Created Date: Group creation timestamp

Privacy Templates: - Template ID: Predefined privacy setting templates - Template Name: "Conservative", "Open", "Professional", etc. - Field Settings: Default privacy levels for each field type - User Adoption: Tracking of template usage for optimization

□ Back to Top

Relationship Graph Schema

Friendship Relations: - Relationship ID (Primary Key): Unique relationship identifier - User A ID: First user in the relationship - User B ID: Second user in the relationship - Relationship Type: Friend, Family, Colleague, Blocked, etc. - Status: Confirmed, Pending, Rejected - Created Date: When relationship was established - Mutual Friend Count: Cached count for efficiency

Connection Levels: - User ID (Composite Key Part 1): Source user - Target User ID (Composite Key Part 2): Target user - Connection Level: Direct (1), Friend-of-friend (2), Extended (3+) - Path Strength: Weighted strength of connection - Last Computed: When this connection level was calculated - Invalidation Flag: Marks stale data for recomputation

Adjacency List Optimization: - User ID (Primary Key): User identifier - Direct Friends: Serialized list of direct friend IDs - Friend Groups: Organized friend lists by categories - Blocked Users: List of blocked user IDs - Cached Metrics: Friend counts, mutual connections stats

□ Back to Top

System API Design

Privacy Management APIs

Privacy Setting Configuration: - Set field-level privacy settings with custom group support - Bulk privacy updates across multiple profile fields - Privacy template application and customization - Privacy rule validation and conflict resolution

Custom Group Management: - Create, update, and delete custom privacy groups - Add/remove members from privacy groups - Group sharing and collaboration features - Group-based permission inheritance

Privacy Testing and Preview: - Preview profile appearance for different viewer types - Privacy setting validation and impact analysis - Bulk privacy change preview before application - Privacy recommendation engine integration

□ Back to Top

Profile Access APIs

Privacy-Filtered Profile Retrieval: - Get user profile with privacy filtering applied - Batch profile retrieval with relationship context - Field-level access checking with detailed reasoning - Profile section access with conditional visibility

Relationship-Aware Data Access: - Friend list access with privacy filtering - Mutual connection discovery with privacy respect - Activity feed filtering based on privacy settings - Search result filtering with privacy consideration

Access Logging and Audit: - Profile access logging for privacy compliance - Privacy violation detection and alerting - Access pattern analysis for security monitoring - Audit trail generation for regulatory compliance

□ Back to Top

Relationship Management APIs

Friend Connection Management: - Send, accept, and reject friend requests - Friend categorization and custom list management - Relationship strength calculation and caching - Mutual friend discovery and recommendation

Connection Graph Queries: - Friend-of-friend path discovery with privacy filtering - Connection strength analysis and ranking - Network analysis for privacy recommendation - Relationship graph traversal with access control

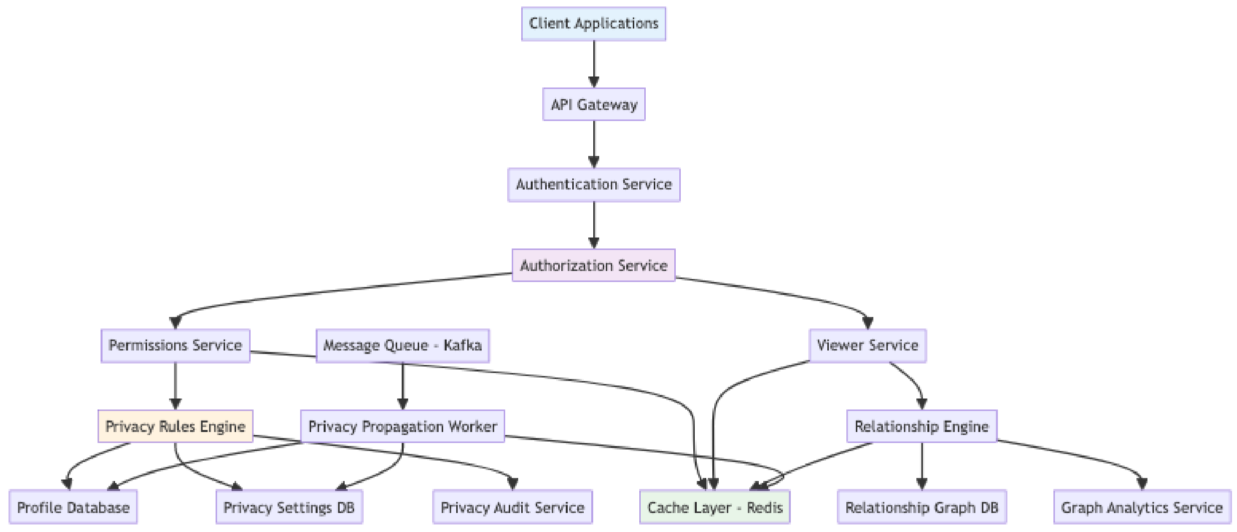
Bulk Relationship Operations: - Import friend lists from external platforms - Bulk friend categorization and privacy application - Relationship cleanup and inactive account handling - Privacy inheritance from relationship changes

□ Back to Top

High-Level Design (HLD)

System Architecture Overview

Microservices Privacy Architecture:



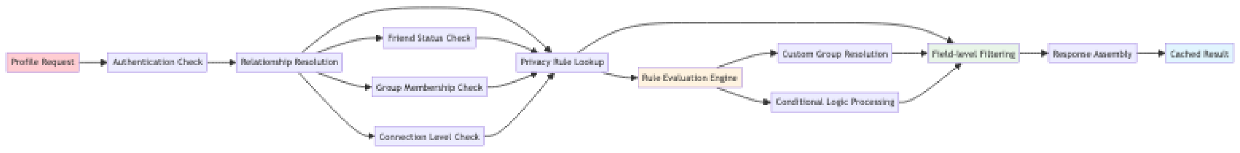
Core Components: - **Authentication Service**: User identity verification and session management - **Authorization Service**: High-level access control and permission orchestration - **Permissions Service**: Privacy rule evaluation and field-level access control -

Viewer Service: Profile viewing with relationship-aware filtering - **Relationship Engine**: Friend graph traversal and connection analysis - **Privacy Rules Engine**: Complex privacy logic and custom group resolution

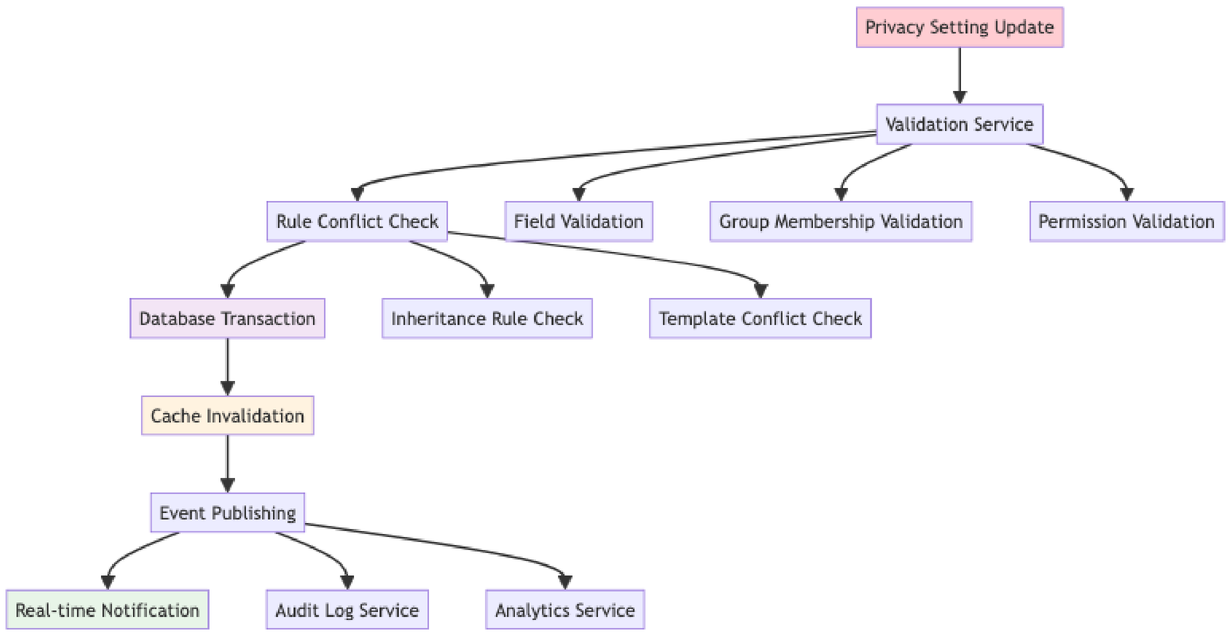
□ Back to Top

Privacy Control Data Flow

Profile Access with Privacy Filtering:



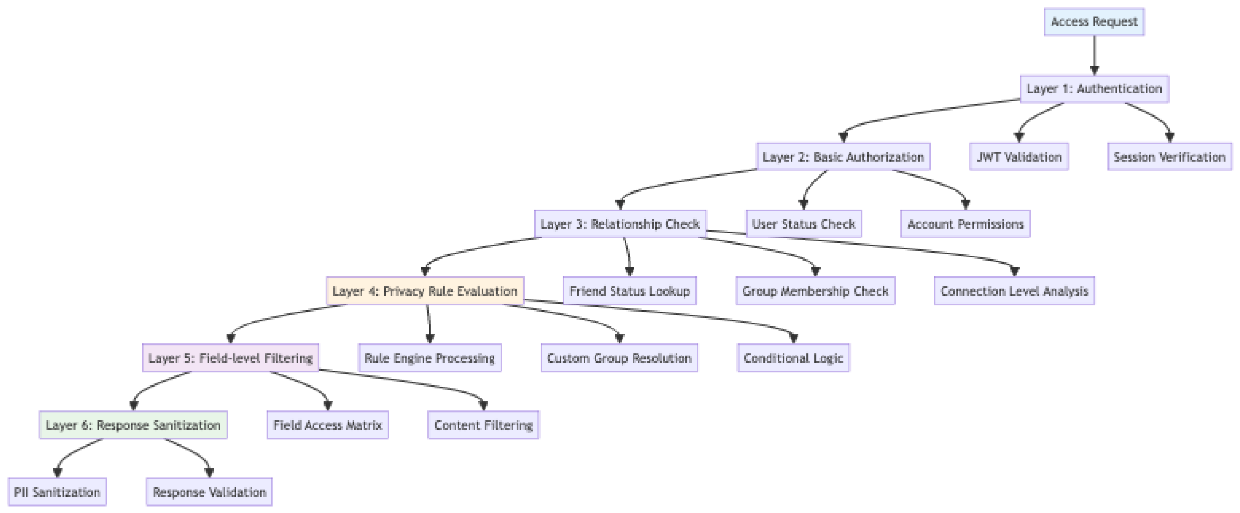
Privacy Setting Update Flow:



□ Back to Top

Authorization Pipeline

Multi-Layer Authorization Architecture:



◻ Back to Top

Low-Level Design (LLD)

Permissions Service

Privacy Rule Engine Design: - **Rule Parser**: Interprets complex privacy rules with conditions and inheritance - **Context Builder**: Assembles viewer context including relationships and group memberships - **Decision Engine**: Evaluates rules against context using configurable rule precedence - **Result Caching**: Intelligent caching of permission decisions with invalidation strategies

Custom Group Resolution: - **Group Membership Cache**: In-memory cache of user group memberships for fast lookup - **Hierarchical Groups**: Support for nested groups and inheritance relationships - **Dynamic Groups**: Groups based on computed criteria (mutual friends, location, etc.) - **Group Validation**: Ensures group membership consistency and prevents circular dependencies

Performance Optimization: - **Batch Processing**: Bulk permission evaluation for multiple fields or users - **Parallel Evaluation**: Concurrent processing of independent privacy rules - **Rule Compilation**: Pre-compiled rule structures for faster evaluation - **Memory Pooling**: Efficient memory management for high-frequency operations

◻ Back to Top

Viewer Service

Profile Filtering Engine: - **Field-level Filtering**: Granular control over individual profile field visibility - **Contextual Filtering**: Dynamic filtering based on viewer relationship and context - **Bulk Profile Processing**: Efficient filtering of multiple profiles in single request - **Progressive Disclosure**: Staged revelation of information based on interaction level

Relationship Context Assembly: - **Connection Graph Traversal**: Efficient graph algorithms for relationship discovery - **Relationship Strength Calculation**: Weighted relationship scoring for nuanced privacy - **Mutual Connection Analysis**: Fast mutual friend discovery and intersection operations - **Social Graph Caching**: Strategic caching of relationship data for performance

Response Optimization: - **Selective Field Loading**: Load only fields that pass privacy checks - **Response Compression**: Efficient serialization of filtered profile data - **Streaming Responses**: Progressive loading for large profile datasets - **Error Handling**: Graceful degradation when privacy checks fail

□ Back to Top

Relationship Resolution Engine

Graph Traversal Optimization: - **Adjacency List Caching**: Memory-optimized representation of user connections - **Path Finding Algorithms**: BFS/DFS optimization for friend-of-friend discovery - **Graph Partitioning**: Distributed graph storage for scalability - **Connection Strength Metrics**: Real-time calculation of relationship weights

Relationship State Management: - **State Synchronization**: Consistent relationship state across distributed services - **Event-Driven Updates**: Real-time relationship change propagation - **Conflict Resolution**: Handling simultaneous relationship state changes - **Garbage Collection**: Cleanup of stale relationship data and cached connections

Scalability Architecture: - **Sharded Graph Storage**: Distributed relationship data across multiple nodes - **Replication Strategy**: Multi-region relationship data replication - **Load Balancing**: Intelligent routing of relationship queries - **Hot Spot Mitigation**: Handling popular users with massive connection counts

□ Back to Top

Core Algorithms

1. Privacy Resolution Algorithm

Multi-Stage Privacy Decision Tree: - Evaluate user authentication and basic access permissions - Resolve viewer-target relationship status and connection level - Look up applicable privacy rules based on field and relationship context - Process custom group memberships and hierarchical permissions - Apply conditional logic (time-based, location-based, interaction-based rules) - Generate final access decision with detailed reasoning for audit

Rule Precedence and Conflict Resolution: - Explicit deny rules override all allow rules (security-first approach) - User-specific rules override group-based or template rules -

More restrictive settings take precedence in conflicts - Recent rule changes override older conflicting rules - Administrative override capabilities for compliance scenarios

Optimization Strategies: - Short-circuit evaluation for common deny scenarios - Rule compilation and caching for frequently accessed patterns - Batch evaluation for multiple fields with shared context - Probabilistic early termination for complex rule sets

□ Back to Top

2. Friend-of-Friend Visibility Algorithm

Multi-Hop Connection Discovery: - Build adjacency lists for each user with direct connections - Implement bidirectional BFS for efficient path discovery - Cache intermediate results for common connection patterns - Apply privacy filtering at each hop to respect friend visibility settings - Limit search depth to prevent performance degradation

Connection Strength Calculation: - Weight edges based on interaction frequency and recency - Consider mutual friend counts and shared group memberships - Apply decay functions for inactive or weak connections - Normalize scores across different user activity levels - Update strengths asynchronously to maintain performance

Fan-out Optimization: - Pre-compute friend-of-friend lists for active users - Use probabilistic data structures for large-scale approximations - Implement incremental updates when friendship networks change - Balance accuracy vs. performance based on use case requirements - Provide fallback to real-time computation for cache misses

□ Back to Top

3. Custom Group Access Algorithm

Dynamic Group Membership Resolution: - Support static membership lists with explicit user inclusion - Implement computed groups based on relationship criteria - Handle nested groups with inheritance and override rules - Manage temporal group memberships with expiration dates - Provide group template systems for common access patterns

Group-based Permission Inheritance: - Resolve group hierarchies with proper precedence ordering - Handle circular dependency detection and prevention - Implement permission aggregation across multiple group memberships - Support group-specific overrides for individual members - Maintain audit trails for group-based access decisions

Scalability and Performance: - Cache group membership data with smart invalidation - Implement lazy loading for large groups with thousands of members - Use bloom filters for fast negative membership checks - Batch group resolution for multiple access checks - Optimize storage for sparse group membership matrices

□ Back to Top

4. Batch Permission Update Algorithm

Atomic Privacy Rule Changes: - Group related privacy changes into atomic transactions - Implement two-phase commit for distributed privacy updates - Provide rollback capabilities for failed batch operations - Ensure consistency across multiple database partitions - Handle partial failures with appropriate error recovery

Propagation and Cache Invalidation: - Identify all affected cached data from privacy rule changes - Implement intelligent cache invalidation strategies - Use message queues for asynchronous propagation - Provide progress tracking for long-running batch operations - Ensure global consistency with eventual propagation guarantees

Performance Optimization: - Batch similar privacy changes for efficient database operations - Implement priority queues for urgent privacy updates - Use parallel processing for independent privacy rule changes - Optimize database queries with proper indexing strategies - Provide real-time progress feedback for user experience

▯ Back to Top

5. Privacy Inheritance Algorithm

Template-based Privacy Configuration: - Provide predefined privacy templates for common use cases - Allow customization of templates while maintaining base structure - Implement template versioning for updates and rollbacks - Support organization-wide templates for corporate accounts - Enable smart recommendations based on user behavior patterns

Field-level Inheritance Rules: - Support inheritance from profile sections to individual fields - Implement override capabilities for specific field requirements - Handle inheritance conflicts with clear precedence rules - Provide bulk inheritance application with selective overrides - Maintain inheritance history for audit and troubleshooting

Dynamic Inheritance Updates: - Automatically apply template updates to derived privacy settings - Allow users to opt-out of automatic inheritance updates - Implement cascading updates with impact analysis - Provide preview capabilities before applying inheritance changes - Handle inheritance conflicts with user notification and choice

▯ Back to Top

Performance Optimizations

Caching Strategy

Multi-Level Caching Architecture: - **L1 Cache**: Application-level caching for hot privacy rules and relationships - **L2 Cache**: Distributed cache (Redis) for cross-service privacy data sharing - **L3 Cache**: Database query result caching for complex relationship queries - **L4 Cache**: CDN caching for public profile data and static privacy templates

Intelligent Cache Management: - **Smart Invalidation**: Selective cache invalidation based on privacy change impact - **Predictive Warming**: Pre-populate cache with likely-accessed privacy data - **Hierarchical Expiration**: Different TTL values based on data volatility - **Cache Coherency**: Maintain consistency across distributed cache layers

Performance Metrics: - Cache hit ratios > 95% for privacy rule lookups - Sub-10ms cache response times for critical privacy decisions - Automatic cache sizing based on usage patterns - Real-time cache performance monitoring and alerting

▯ Back to Top

Pre-computation Optimization

Friend-of-Friend Pre-computation: - **Batch Processing**: Nightly computation of friend-of-friend relationships - **Incremental Updates**: Real-time updates for new friend connections - **Materialized Views**: Pre-computed privacy-filtered friend lists - **Connection Strength**: Pre-calculated relationship weights and scores

Privacy Rule Compilation: - **Rule Optimization**: Compile complex privacy rules into efficient decision trees - **Pattern Recognition**: Identify common privacy patterns for optimization - **Index Generation**: Create specialized indexes for frequent privacy queries - **Result Memoization**: Cache privacy decisions for repeated access patterns

Graph Analytics: - **Community Detection**: Identify user clusters for optimized privacy grouping - **Influence Scoring**: Calculate user influence for privacy recommendation - **Anomaly Detection**: Identify unusual privacy access patterns - **Trend Analysis**: Track privacy setting changes for recommendation improvement

▯ Back to Top

Database Query Optimization

Partition Strategy: - **User-based Partitioning**: Partition privacy data by user ID for locality - **Temporal Partitioning**: Separate current and historical privacy data - **Relationship Sharding**: Distribute relationship graph across multiple shards - **Hot-Cold Data Separation**: Optimize storage for frequently vs. rarely accessed data

Index Optimization: - **Composite Indexes**: Multi-field indexes for complex privacy queries - **Partial Indexes**: Indexes on subset of data based on common query patterns - **Covering Indexes**: Include all needed fields to avoid table lookups - **Adaptive Indexing**: Dynamic index creation based on query patterns

Query Performance: - **Query Plan Optimization**: Analyze and optimize expensive privacy queries - **Parallel Execution**: Concurrent processing of independent privacy checks - **Connection Pooling**: Efficient database connection management - **Read Replicas**: Distribute read queries across multiple database replicas

▯ Back to Top

Security Considerations

Backend Authorization

Defense in Depth: - **Multiple Authorization Layers**: Authentication, authorization, privacy, and field-level checks - **Principle of Least Privilege**: Grant minimum necessary access for each request - **Zero Trust Architecture**: Verify every access request regardless of source - **Continuous Validation**: Re-validate permissions for long-running sessions

Authorization Enforcement: - **Server-side Filtering**: All privacy filtering performed on backend to prevent bypass - **API Gateway Controls**: Centralized authorization enforcement at entry points - **Service Mesh Security**: Inter-service communication with mutual TLS and authorization - **Database-level Security**: Row-level security and column encryption for sensitive data

Audit and Monitoring: - **Access Logging**: Comprehensive logging of all privacy-related access attempts - **Anomaly Detection**: Machine learning-based detection of unusual access patterns - **Real-time Alerting**: Immediate alerts for potential privacy violations - **Compliance Reporting**: Automated reports for regulatory compliance requirements

□ Back to Top

Data Leak Prevention

Frontend Security: - **Data Minimization**: Send only approved data to frontend applications - **Response Sanitization**: Remove sensitive metadata from API responses - **Client-side Validation**: Prevent UI manipulation from bypassing privacy controls - **Session Management**: Secure session handling with automatic expiration

API Security: - **Rate Limiting**: Prevent privacy probing through automated requests - **Request Validation**: Strict validation of all privacy-related API requests - **Error Message Security**: Avoid leaking privacy information through error responses - **API Versioning**: Maintain security across different API versions

Data Protection: - **Encryption at Rest**: Encrypt sensitive privacy data in databases - **Encryption in Transit**: TLS encryption for all privacy-related communications - **Key Management**: Secure key storage and rotation for encryption systems - **Data Anonymization**: Remove or pseudonymize personal identifiers where possible

□ Back to Top

Testing Strategy

Privacy Rule Testing

Comprehensive Test Coverage: - **Unit Tests**: Individual privacy rule evaluation with edge cases - **Integration Tests**: End-to-end privacy filtering across multiple services - **Regression Tests**: Ensure privacy rule changes don't break existing functionality - **Performance Tests**: Validate privacy rule evaluation performance under load

Privacy Scenario Testing: - **Relationship Testing**: Test all combinations of friendship and relationship states - **Group Membership Testing**: Validate custom group access across different scenarios - **Inheritance Testing**: Ensure proper privacy rule inheritance and override behavior - **Edge Case Testing**: Handle unusual relationship configurations and privacy settings

Compliance Testing: - **Regulatory Testing**: Validate compliance with GDPR, CCPA, and other privacy regulations - **Policy Testing**: Ensure privacy policies are correctly implemented and enforced - **Audit Testing**: Verify audit trail completeness and accuracy - **Security Testing**: Penetration testing for privacy bypass vulnerabilities

▯ Back to Top

Performance Testing

Load Testing: - **Privacy Check Volume**: Test system under peak privacy evaluation loads - **Concurrent Users**: Validate performance with millions of simultaneous users - **Database Performance**: Test privacy database queries under heavy load - **Cache Performance**: Validate cache effectiveness under various load patterns

Stress Testing: - **Resource Exhaustion**: Test system behavior when resources are fully utilized - **Cascade Failures**: Validate graceful degradation when components fail - **Recovery Testing**: Test system recovery after privacy service outages - **Data Consistency**: Ensure privacy consistency during high-stress scenarios

Scalability Testing: - **Horizontal Scaling**: Validate privacy system scaling across multiple nodes - **Database Scaling**: Test privacy database scaling strategies - **Cache Scaling**: Validate distributed cache scaling for privacy data - **Geographic Distribution**: Test privacy consistency across global deployments

▯ Back to Top

Trade-offs and Considerations

Privacy Granularity vs Performance

Granularity Benefits: - Enhanced user control over personal information sharing - Compliance with strict privacy regulations and user expectations - Competitive advantage through superior privacy features - Reduced privacy-related support requests through clear controls

Performance Impact: - Increased complexity in privacy rule evaluation and caching - Higher database storage requirements for detailed privacy settings - More complex cache invalidation strategies - Potential latency increase for profile access operations

Optimization Strategies: - Intelligent defaults that cover majority of use cases - Performance-aware privacy rule design and evaluation - Strategic pre-computation of common privacy scenarios - Tiered privacy levels balancing granularity with performance

▯ Back to Top

Real-time vs Cached Permissions

Real-time Benefits: - Immediate privacy setting updates without propagation delays - Guaranteed consistency for privacy-critical operations - Accurate permission evaluation for edge cases - Complete audit trail for real-time access decisions

Caching Advantages: - Significantly improved response times for profile access - Reduced database load and improved overall system scalability - Better user experience through faster page loads - Cost savings through reduced computational requirements

Hybrid Approach: - Real-time evaluation for privacy-critical operations - Cached evaluation for performance-critical read operations - Smart cache invalidation based on privacy change impact - Fallback to real-time when cache inconsistency is detected

▯ Back to Top

SQL vs NoSQL for Relationship Data

SQL Database Benefits: - ACID transactions for consistent relationship and privacy data - Complex JOIN operations for relationship graph queries - Mature indexing and query optimization capabilities - Strong consistency guarantees for critical privacy operations

NoSQL Advantages: - Horizontal scaling for massive relationship graphs - Flexible schema for evolving privacy and relationship models - Better performance for simple relationship lookups - Natural fit for graph-like relationship data structures

Hybrid Architecture: - SQL for transactional privacy settings and user data - Graph databases (Neo4j) for complex relationship traversal - NoSQL (DynamoDB) for high-volume relationship caching - Event streaming (Kafka) for maintaining consistency across storage systems

Technology Selection: - PostgreSQL for privacy settings with JSONB for flexible rules - Neo4j for complex relationship graph analysis and traversal - Redis for high-performance caching of privacy decisions - Cassandra for time-series privacy audit logs and analytics

▯ Back to Top