Part 1 (Architecture & System Design)

- **High-level architecture diagram**
- **Frontend / API / Service / Data layers**
- **Caching + Security + Observability**
- **Scalability plan for 10k+ concurrent users + 500k+ articles**
- **AI suggested answers using customer context**
- **Trade-off analysis with at least 3 key architectural decisions**

Part 1 — Architecture & System Design

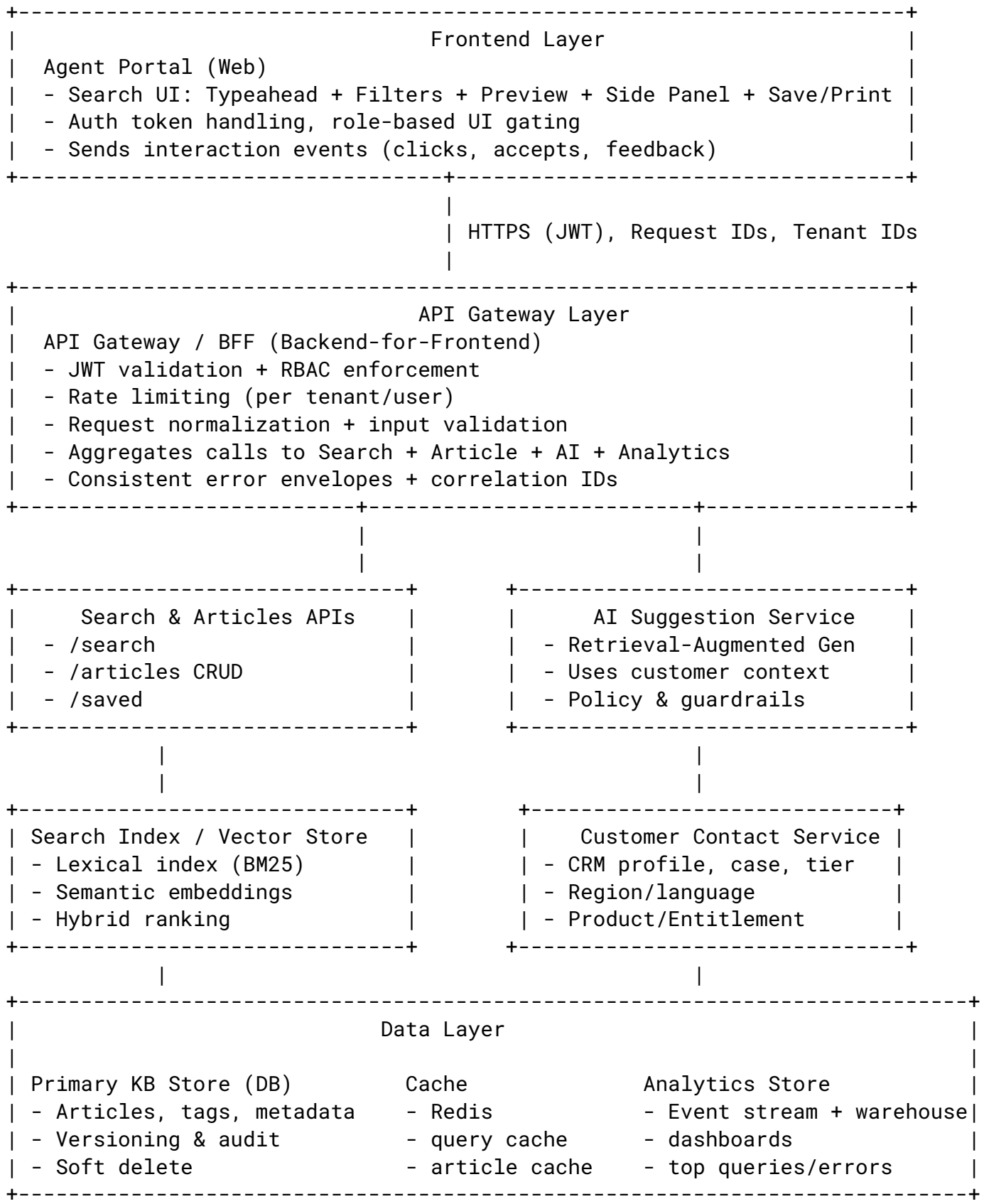
eGain Knowledge Search (AI-Powered) — System Design Proposal

Scenario

eGain needs a new **AI-powered knowledge search interface** for customer service agents. The system must:

- Search across **500,000+ knowledge articles** in near real-time
- Handle **10,000+ concurrent users** across multiple time zones
- Provide **AI-suggested answers** based on **customer context**
- Track **search analytics + agent interactions**
- Support **RBAC (role-based access control)**
- Integrate with **existing backend APIs**

High-Level Architecture (Layered)


Frontend Layer
Agent Portal (Web)
- Search UI: Typeahead + Filters + Preview + Side Panel + Save/Print
- Auth token handling, role-based UI gating
- Sends interaction events (clicks, accepts, feedback)
HTTPS (JWT), Request IDs, Tenant IDs
API Gateway Layer
API Gateway / BFF (Backend-for-Frontend)
- JWT validation + RBAC enforcement
- Rate limiting (per tenant/user)
- Request normalization + input validation
- Aggregates calls to Search + Article + AI + Analytics
- Consistent error envelopes + correlation IDs
Search & Articles APIs
- /search
- /articles CRUD
- /saved
AI Suggestion Service
- Retrieval-Augmented Gen
- Uses customer context
- Policy & guardrails
Search Index / Vector Store
- Lexical index (BM25)
- Semantic embeddings
- Hybrid ranking
Customer Contact Service
- CRM profile, case, tier
- Region/language
- Product/Entitlement
Data Layer
Primary KB Store (DB)
- Articles, tags, metadata
- Versioning & audit
- Soft delete
Cache
- Redis
- query cache
- article cache
Analytics Store
- Event stream + warehouse
- dashboards
- top queries/errors

Component Breakdown

1) Frontend Layer (Agent Portal)

Goals: fast search UX, predictable states, low-latency perception.

Key features:

- Typeahead suggestions (`/search/suggestions`)
- Filters (category/tags/date), sorting, pagination
- Result preview cards + side detail panel
- Save article, print, open in new tab
- Interaction tracking (search executed, opened, saved, agent accepted/rejected)

Technology choices:

- **React** (fast iteration, component model)
- **TypeScript** (safer UI state + API contracts)
- Optional later: speech input, image attachments, agent co-pilot panel
- Personalization: the end user personalize the UX

2) API / Service Layer (BFF + Domain Services)

BFF responsibilities

- JWT validation and RBAC enforcement
- Rate limiting, throttling (per-tenant/user, burst control, cost-based limits
- Request shaping (payload caps, pagination bounds)
- Routing + API governance (service dispatch, version routing, schema validation)
- Centralized security controls
- One consistent response format + error envelope
- Aggregation: search + article fetch + AI suggestion + analytics ingest

Domain services

- Search service (hybrid lexical + semantic)
- Articles service (CRUD + versioned retrieval)
- Saved service (per-user list)
- Analytics service (high-volume event ingestion)
- AI suggestion service (RAG, customer-context aware)

3) Data Layer

- **Knowledge store** (source of truth): relational DB or document DB
  - Supports versioning, soft-delete, tags, category, timestamps
- **Search index**: hybrid approach
  - Lexical index (BM25) for precision and exact matches
  - Vector store for semantic retrieval
  - Hybrid ranker merges both
- **Cache (Redis)**
  - Query cache for hot searches
  - Article cache for frequently opened articles
  - Suggestions cache (very high QPS)
- **Analytics store**
  - Event stream + warehouse/dashboard tables
  - Used for top queries, error rate, agent adoption metrics

API Design Principles

1. **Consistency**

- Standard headers: `X-Request-Id`, `X-Tenant-Id`
- Standard error envelope:

```
{ "error": { "code": "...", "message": "...", "requestId": "..." } }
```

2. **Versioning**

- `/api/v1` current stable
- `/api/v2` for breaking changes only
- Additive changes remain in v1

3. **Pagination**

- Page-based pagination for predictable UI and caching:

```
 "pagination": { "page": 1, "pageSize": 20 }
```

4. **Rate limiting**

- Per tenant + per user
- Separate budgets for:
  - suggestions (high QPS)
  - search (moderate)
  - analytics ingest (high volume batch)

- Return `429` with `Retry-After` and `X-RateLimit-*` headers

Scalability Approach (10k+ Concurrent Users)

Key strategies

- Stateless API services behind load balancers (horizontal scaling)
- Cache aggressively for hot queries/articles/suggestions
- Use hybrid search index optimized for reads
- Make analytics ingestion **async** with batching and idempotency
- Keep AI generation optional and decoupled from core search latency

Performance targets (example)

- Suggestions p95 < 150ms (cached)
- Search p95 < 600ms (hybrid, cached hot queries)
- Article fetch p95 < 250ms (cache first)
- AI suggestion p95 < 2500ms (async/streamed), not blocking search results
- Expensive CRM user profile data (cached)

Performance Optimization Strategies

- **Caching**
  - Redis for query + article + suggestions
  - Cache key includes tenant + query + filters + sort + page
- **Index optimization**
  - Precompute embeddings offline / incremental updates
  - Use hybrid ranking rather than “vector-only”
- **Backpressure**
  - Rate limit + queue analytics ingestion
  - Circuit breaker AI dependency (fallback to top KB hits)

Security Implementation

Authentication

- JWT bearer auth (`Authorization: Bearer <token>`)
- Signed tokens; short expiry; rotate secrets

Authorization (RBAC)

- Roles in JWT claims (viewer/editor/admin)
- Enforced at BFF + service

- “Least privilege” defaults

Data safety

- Tenant isolation (tenantId scoping in queries + cache keys)
- Policy agent to guard what tools, APIs can be called based on the user profile and scopes
- Audit logs for article edits/deletes
- Soft delete by default, hard delete restricted

Abuse prevention

- Rate limiting per tenant/user
- Payload size limits for analytics events
- Validation for all inputs (query, filters, ids)
- CSRF, Allowed Websites

Monitoring & Observability

What we measure

- Search latency (p50/p95/p99), suggestion latency, AI latency
- Error rates by endpoint + code (4xx vs 5xx)
- Top queries, zero-result queries
- Agent interaction funnel:
    - suggestions shown → clicked → accepted/rejected
    - answers generated → copied → feedback

Implementation

- Structured logs with requestId + tenantId + userId
- Metrics (Prometheus/OpenTelemetry style) + dashboards
- Traces across BFF → search → AI → analytics
- Alerting:
    - p95 latency regression
    - spike in 5xx
    - spike in zero-results (index or ingestion issue)

Trade-off Analysis (Key Architectural Decisions)

Trade-off 1: Performance vs Accuracy (Search + AI Responses)

Decision: Use a hybrid retrieval strategy combining:

- Traditional keyword / lexical search (BM25)
- Semantic vector search (embeddings)
- AI summarization layered on top

Trade off:

- Higher accuracy & relevance vs increased latency and cost

Why:

- Pure keyword search is fast but misses semantic intent.
- Pure vector search improves relevance but is slower and more expensive.
- A hybrid allows
    - Fast first-pass retrieval
    - Semantic reranking only when needed
    - AI answer generation scoped to top-N results

Mitigation:

- Cache popular queries and embeddings
    - **Default:** Treat retrieval as a product surface. Cache aggressively where it improves p95/p99 and cost.
    - **Tiered cache:** in-memory (fast), Redis (shared), and persisted vector store (source of truth).
- Apply AI summarization only for complex queries
    - **Default:** Don't summarize everything. Summarization is a *premium operation* (latency + cost + risk).
    - Summarize when: long context, multi-doc answers, conflicting sources, "compare/contrast," or user asks for "TL;DR."
- Use async/background generation for analytics and suggestions
    - **Default:** User-facing latency stays snappy; heavy work happens off the critical path.
- Switch LLM providers if required (budget / reliability)
    - **Default:** Provider-agnostic design. LLMs are dependencies, not destiny.
    - **Policy-based router:** route by task type (classification vs summarization vs generation), cost ceiling, and latency SLO.

Trade-off 2: Scalability vs. System Complexity

Decision: Adopt a layered, service-oriented architecture rather than a monolith.

Trade-off:

- **Operational complexity vs. horizontal scalability**

Why:

- Supports independent scaling of
    - Search ingestion
    - Query processing
    - Analytics tracking
    - AI inference
- Easier future evolution (new model, new agents)

Mitigation:

- Keep synchronous APIs thin
- Push heavy workflows to async pipelines (analytics, AI training/evals)
- Establish clear API contracts and observability from day one
- Platform onboard with the centralized security and logging

Trade-off 3: Security vs. Developer Velocity

Decision: Implement **role-based access control (RBAC)** and tenant isolation at the API layer.

Trade-off:

- Slower initial development vs. enterprise-grade security and compliance

Why:

- eGain customers are enterprise and regulated
- Security cannot be retrofitted safely later

Mitigation:

- Centralized auth middleware
- Policy-based access checks
- Shared libraries for consistent enforcement

Trade-off 4: Observability Depth vs. Runtime Overhead

Decision: Capture detailed search and agent interaction analytics

Trade-off :

- Increased telemetry overhead vs. actionable product insights

Why:

- AI Agent cannot be a blackbox, should be fully auditable
- Analytics powers for search tuning, AI quality improvements

Mitigation:

- Async event logging
- Sampling for high-volume events
- Separate hot path (search) from cold path (analytics)

Trade-off 5: AI Answers Synchronous vs Decoupled

Decision: decouple AI answer generation from core search results.

Trade-off:

- more orchestration (async job, streaming, or background generation).

Why: agents must always get fast results even if AI is slow/unavailable.

Mitigation:

- show KB results immediately;
- AI panel loads progressively;
- fallback to “top articles + highlights.”

Technology Stack Choices

- **Frontend:** React + TypeScript (fast UX iteration, safe state management)
- **BFF/API:** Node.js/Next.js API routes or dedicated service (Java/JVM-centric backend systems)
    - Large, long-lived Java services

    - Heavy emphasis on
        - Reliability
        - Backward compatibility
        - Governance
- **Cache:** Redis (low-latency shared cache, rate limit counters)
- **Search:** BM25 engine + vector DB (hybrid search quality)
- **Analytics:** event ingestion + warehouse tables (dashboards, funnels, top queries)
- **Observability:** OpenTelemetry + metrics + tracing (end-to-end visibility)

Summary

This architecture meets the requirements by:

- Delivering **fast, reliable search** at scale (500k+ articles, 10k+ concurrent agents)
- Supporting **secure, role-aware access** (JWT + RBAC + tenant isolation)
- Providing **AI suggestions grounded in customer context** (RAG + context service)
- Enabling **analytics + observability** as first-class features (events + dashboards + tracing)
- Maintaining **clear API design contracts** with versioning, pagination, and consistent errors