Low-Level Design (LLD) - SIA Service

Comprehensive Implementation Specification

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1.1 FastAPI Application Structure

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│   ├── chat.router        (/chat)
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└── Middleware
    └── Traceloop (OpenTelemetry)
```

1.2 Module Organization

```
siaservice/
├── routers/              # API route handlers
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├── domain/soar/          # Domain models (Case, PlaybookTask, etc.)
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├── parsers/             # Output parsers
├── noise_reduction/     # FPR pipeline
└── common.py            # Shared utilities
```

---

2. Domain Models

2.1 Case Model

```
class Case(BaseModel):
    """
    Represents a security incident/case
    """
    deployment_id: str      # Deployment identifier
    tenant_id: str          # Tenant identifier
    case_id: str           # Unique case identifier
    case_detail: str       # Detailed case description
    iocs: str              # Indicators of Compromise
    findings: Optional[List[Finding]] = None

    def to_dict(self) -> dict
    @model_validator(mode='before')
    def check_non_empty_fields(cls, values)
```

Validation Rules: - All fields except `findings` are required - No empty strings allowed for required fields - Automatic validation via Pydantic

2.2 PlaybookTask Model

```
class PlaybookTask(BaseModel):
    """
    Represents an executed task within a playbook
    """
    deployment_id: str
    tenant_id: str
    case_id: str
    playbook_run_id: str
    task_details: dict      # Full task execution details

    def to_dict(self) -> dict
    @model_validator(mode='before')
    def check_non_empty_fields(cls, values)
```

Usage: - Captures historical task executions - Used for similarity search and context retrieval - Indexed in vector database

2.3 Finding Model

```
class Finding(BaseModel):
    """
    Individual finding from case analysis
    """
    source: str        # Source system or tool
    finding: str       # Description of the finding
```

---

3. Database Schema

3.1 Core Tables

cases

```
CREATE TABLE cases (
    id UUID PRIMARY KEY DEFAULT uuid_generate_v4(),
    case_id VARCHAR(256) NOT NULL,
    deployment_id VARCHAR(256) NOT NULL,
    tenant_id VARCHAR(256) NOT NULL,
    iocs VARCHAR(1000),
    status VARCHAR(256),
    analyst_id INTEGER,
    text JSON NOT NULL,
    timeline_analysis JSON,
    playbook_recommendation JSON,
    analyst_recommendation JSON,
    investigation_report JSON,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

CREATE INDEX idx_cases_case_id ON cases(case_id);
CREATE INDEX idx_cases_deployment_id ON cases(deployment_id);
CREATE INDEX idx_cases_tenant_id ON cases(tenant_id);
CREATE INDEX idx_cases_iocs ON cases(iocs);
CREATE INDEX idx_cases_status ON cases(status);
```

case_summary

```
CREATE TABLE case_summary (
    id SERIAL PRIMARY KEY,
    case_id UUID REFERENCES cases(id) ON DELETE CASCADE,
    summary JSON NOT NULL,
    version INTEGER DEFAULT 1,
    conclusion VARCHAR(256) DEFAULT 'unknown',
    risk_score FLOAT DEFAULT 0.0,
    embedding VECTOR(1536),  -- pgvector type
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

CREATE INDEX idx_case_summary_conclusion ON case_summary(conclusion);
CREATE INDEX idx_case_summary_risk_score ON case_summary(risk_score);
CREATE INDEX embedding_case_summary_idx ON case_summary
    USING hnsw (embedding vector_l2_ops)
    WITH (m = 16, ef_construction = 64);
```

playbook_tasks

```
CREATE TABLE playbook_tasks (
    id UUID PRIMARY KEY DEFAULT uuid_generate_v4(),
    case_id VARCHAR(256) NOT NULL,
    deployment_id VARCHAR(256) NOT NULL,
    tenant_id VARCHAR(256) NOT NULL,
    text JSON NOT NULL,
    embedding VECTOR(1536),
    text_summary VARCHAR(4096) NOT NULL,
    risk_score FLOAT DEFAULT 0.0,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

CREATE INDEX idx_playbook_tasks_case_id ON playbook_tasks(case_id);
CREATE INDEX idx_playbook_tasks_risk_score ON playbook_tasks(risk_score);
CREATE INDEX embedding_hnsw_index ON playbook_tasks
    USING hnsw (embedding vector_l2_ops)
    WITH (m = 16, ef_construction = 64);
```

task_classification

```
CREATE TABLE task_classification (
    id SERIAL PRIMARY KEY,
    playbook_task_id UUID REFERENCES playbook_tasks(id) ON DELETE CASCADE,
    version INTEGER DEFAULT 1,
    lookup BOOLEAN NOT NULL,
    action BOOLEAN NOT NULL,
    decision BOOLEAN NOT NULL,
    playbook_name VARCHAR(256) NOT NULL,
    task_name VARCHAR(256) NOT NULL,
    case_id VARCHAR(256) NOT NULL,
    task_id VARCHAR(256) NOT NULL,
    playbook_id VARCHAR(256) NOT NULL,
    summary VARCHAR(1024),
    target JSON,
    source JSON,
    iocs JSON,
    result VARCHAR(1024),
    malicious BOOLEAN,
    malicious_reason VARCHAR(1024),
    timestamp BIGINT NOT NULL,
    embedding VECTOR(1536),
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);
```

3.2 Chat & Thread Tables

chathistory

```
CREATE TABLE chathistory (
    id UUID PRIMARY KEY DEFAULT uuid_generate_v4(),
    user VARCHAR NOT NULL,
    user_id INTEGER,
    created_ts TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_ts TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    message TEXT NOT NULL,
    deployment_id VARCHAR NOT NULL,
    tenant_id VARCHAR NOT NULL,
    thread_id UUID REFERENCES threads(thread_id) ON DELETE CASCADE,
    topic VARCHAR,
    entity VARCHAR NOT NULL,
    message_type VARCHAR NOT NULL
);

CREATE INDEX idx_chathistory_deployment_id ON chathistory(deployment_id);
CREATE INDEX idx_chathistory_tenant_id ON chathistory(tenant_id);
```

threads

```
CREATE TABLE threads (
    thread_id UUID PRIMARY KEY DEFAULT uuid_generate_v4(),
    name VARCHAR(1024),
    deployment_id VARCHAR NOT NULL,
    tenant_id VARCHAR NOT NULL,
    case_id VARCHAR(256),
    user_id INTEGER,
    entity VARCHAR(256),
    created_ts TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_ts TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);
```

3.3 Definition Tables

playbook_definitions

```
CREATE TABLE playbook_definitions (
    id SERIAL PRIMARY KEY,
    deployment_id VARCHAR(256) NOT NULL,
    tenant_id VARCHAR(256) NOT NULL,
    playbook_id INTEGER NOT NULL,
    description TEXT NOT NULL,
    name VARCHAR(255) NOT NULL,
    categoryname VARCHAR(255),
    summary JSON NOT NULL,
    embedding VECTOR(1536),
    eliminate_threat VARCHAR(256) DEFAULT 'No',
    restore_systems VARCHAR(256) DEFAULT 'No',
    enhance_measures VARCHAR(256) DEFAULT 'No',
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

CREATE INDEX idx_playbook_deployment_id ON playbook_definitions(deployment_id);
CREATE INDEX idx_playbook_eliminate_threat ON playbook_definitions(eliminate_threat);
```

task_definitions

```
CREATE TABLE task_definitions (
    id SERIAL PRIMARY KEY,
    deployment_id VARCHAR(256) NOT NULL,
    tenant_id VARCHAR(256) NOT NULL,
    task_id INTEGER NOT NULL,
    task_type VARCHAR(255) NOT NULL,
    integration_id INTEGER,
    name VARCHAR(255),
    summary JSON,
    role VARCHAR(255),
    embedding VECTOR(1536),
    task_tag VARCHAR(255) NOT NULL,
    created_ts TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_ts TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

CREATE INDEX idx_task_definitions_task_type ON task_definitions(task_type);
CREATE INDEX idx_task_definitions_task_tag ON task_definitions(task_tag);
```

3.4 Noise Reduction Tables

case_suspicious_analysis

```
CREATE TABLE case_suspicious_analysis (
    id SERIAL PRIMARY KEY,
    case_id UUID REFERENCES cases(id) ON DELETE CASCADE UNIQUE,
    deployment_id VARCHAR(256) NOT NULL,
    tenant_id VARCHAR(256) NOT NULL,
    is_novel BOOLEAN NOT NULL,
    cluster_id VARCHAR(256) NOT NULL,
    suspicious_score FLOAT,
    suspicious_reason VARCHAR(512),
    enriched_case JSON,
    is_fp BOOLEAN,
    created_at TIMESTAMP WITH TIME ZONE DEFAULT NOW(),
    updated_at TIMESTAMP WITH TIME ZONE DEFAULT NOW()
);

CREATE INDEX ix_case_suspicious_analysis_deployment_tenant_case
    ON case_suspicious_analysis(deployment_id, tenant_id, case_id);
```

event_streams & events

```
CREATE TABLE event_streams (
    stream_id UUID PRIMARY KEY DEFAULT uuid_generate_v4(),
    name VARCHAR,
    window_length INTEGER NOT NULL,
    created_at TIMESTAMP DEFAULT NOW()
);

CREATE TABLE events (
    id UUID PRIMARY KEY DEFAULT uuid_generate_v4(),
    stream_id UUID REFERENCES event_streams(stream_id),
    event_id VARCHAR NOT NULL,
    content JSON NOT NULL,
    tags JSON,
    embedding VECTOR(384),  -- MiniLM-L6-v2
    created_at TIMESTAMP DEFAULT NOW()
);
```

---

4. API Design

4.1 Case Analysis Endpoints

POST /case/analysis

Request:

```
{
  "case": {
    "deployment_id": "prod-001",
    "tenant_id": "customer-123",
    "case_id": "CASE-2024-001",
    "case_detail": "Suspicious IP 211.226.165.33 detected...",
    "iocs": "211.226.165.33, malicious-domain.com",
    "findings": [
      {
        "source": "VirusTotal",
        "finding": "High community score of 96/100"
      }
    ]
  }
}
```

Response:

```
{
  "task_id": "e09f6929-f562-4428-a155-0f3ccf74a1b1"
}
```

GET /case/analysis/{task_id}

Response:

```
{
  "task_id": "e09f6929-f562-4428-a155-0f3ccf74a1b1",
  "task_status": "SUCCESS",
  "task_result": {
    "result": {
      "executive_summary": "...",
      "conclusion": {
        "status": "malicious",
        "reason": "...",
        "score": 10
      },
      "findings": [...],
      "recommendations": [...]
    }
  }
}
```

4.2 Chat Endpoints

POST /chat/completions

Request:

```
{
  "model": "gpt-4",
  "messages": [
    {"role": "system", "content": "You are a security analyst assistant"},
    {"role": "user", "content": "Analyze this case..."}
  ],
  "stream": true
}
```

Response (Streaming):

```
data: {"chunk": "Based on the analysis..."}
data: {"chunk": " the IP address..."}
data: {"chunk": " is malicious."}
```

POST /chat/thread

Request:

```
{
  "deployment_id": "prod-001",
  "tenant_id": "customer-123",
  "user_id": 1,
  "case_id": "CASE-2024-001",
  "entity": "case",
  "name": "Investigation Thread"
}
```

4.3 Indexing Endpoints

POST /indexing/case/playbook/task

Request:

```
{
  "tasks": [
    {
      "deployment_id": "prod-001",
      "tenant_id": "customer-123",
      "case_id": "CASE-2024-001",
      "playbook_run_id": "playbook-run-123",
      "task_details": {
        "task_id": "task-456",
        "name": "Check IP Reputation",
        "result": "Malicious",
        ...
      }
    }
  ]
}
```

5. Service Layer

5.1 CaseAnalysisService

```
class OpenAICaseAnalysisService:
    """
    Main service for case analysis using LLM
    """

    def __init__(self, playbook_task_repo: PlaybookTaskRepo,
                 model_name: str = "llama3.1:8b"):
        self.model = LLMWrapper()
        self.parser = SelfRepairJsonOutputParser()
        self.templates_factory = AnalysisTemplatesFactory()
        self.case2template = Case2UserTemplateConverter()
        self._case_analysis = CaseAnalysis(...)

    @retry((NoneResultException), tries=3, delay=2, backoff=2)
    def run(self, case: Case) -> Tuple[dict, bool]:
        """
        Execute case analysis with retry logic

        Returns:
            Tuple[dict, bool]: (result, is_cached)
        """
        result, existing = self._case_analysis.run(case)
        if result is None:
            raise NoneResultException()
        return result, existing
```

5.2 CaseAnalysis Engine

```
class CaseAnalysis:
    """
    Core analysis logic with RAG (Retrieval-Augmented Generation)
    """

    def run(self, case: Case) -> Tuple[dict, bool]:
        # 1. Check cache (Redis)
        hash_value = generate_hash_value(case)
        cached_result = get_redis_value(hash_value)
        if cached_result:
            return cached_result, True

        # 2. Retrieve relevant context (Vector search)
        question = "Find all threat intel lookup tasks..."
        playbook_tasks = self.playbook_task_repo.search_by_case(
            question, case.deployment_id, case.tenant_id,
            case.case_id, limit=50
        )

        # 3. Build prompt
        contexts = [task.text_summary for task in playbook_tasks]
        system_template = self.templates_factory.get_by_case(case)
        user_template = self.case2template.convert(case, contexts)

        # 4. Generate with LLM
        prompt = ChatPromptTemplate.from_messages([
            ("system", system_template),
            ("user", user_template)
        ])
        chain = prompt | self.model | self.parser
        result = chain.invoke({})

        # 5. Store in cache
        store_redis_value(hash_value, result)

        return result, False
```

5.3 ChatBotAgent

```
class ChatBotAgent:
    """
    Handles interactive chat with RAG context
    """

    async def stream(self, db: Session, deployment_id: str,
                     tenant_id: str, case_id: str, user_id: int,
                     user_name: str, thread_id: str,
                     prompt: str) -> AsyncGenerator[str, None]:
        """
        Stream LLM response with context retrieval
        """
        # 1. Retrieve chat history
        history = ChatHistory(...)
        messages = history.get_latest_chat_history(thread_id, 5, user_id)

        # 2. Search relevant context
        playbook_repo = PlaybookTaskRepo(db, embedding_client)
        contexts = playbook_repo.search_by_case(
            prompt, deployment_id, tenant_id, case_id, limit=10
        )

        # 3. Build RAG prompt
        context_str = "\n".join([c.text_summary for c in contexts])
        full_prompt = f"Context: {context_str}\n\nUser: {prompt}"

        # 4. Stream response
        llm = LLMWrapper(streaming=True)
        async for chunk in llm.astream(full_prompt):
            yield chunk.content

        # 5. Store in history
        history.store_chat_history({
            "thread_id": thread_id,
            "user": user_name,
            "message": prompt,
            "response": accumulated_response
        })
```

6. Repository Pattern

6.1 PlaybookTaskRepo

```
class PlaybookTaskRepo:
    """
    Repository for playbook task CRUD and vector search
    """

    def __init__(self, session: Session, embedding: AIEmbedding):
        self.session = session
        self.embedding = embedding

    def add_task(self, task: PlaybookTask) -> PlaybookTaskModel:
        """Create new task with embedding"""
        text_summary = self._generate_summary(task.task_details)
        embedding_vector = self.embedding.embed_text(text_summary)

        db_task = PlaybookTaskModel(
            case_id=task.case_id,
            deployment_id=task.deployment_id,
            tenant_id=task.tenant_id,
            text=task.task_details,
            text_summary=text_summary,
            embedding=embedding_vector
        )
        self.session.add(db_task)
        self.session.commit()
        return db_task

    def search_by_case(self, query: str, deployment_id: str,
                       tenant_id: str, case_id: str,
                       limit: int = 10) -> List[PlaybookTaskModel]:
        """Vector similarity search"""
        query_embedding = self.embedding.embed_text(query)

        results = self.session.query(PlaybookTaskModel).filter(
            PlaybookTaskModel.deployment_id == deployment_id,
            PlaybookTaskModel.tenant_id == tenant_id,
            PlaybookTaskModel.case_id == case_id
        ).order_by(
            PlaybookTaskModel.embedding.l2_distance(query_embedding)
        ).limit(limit).all()

        return results
```

6.2 CaseRepo

```
class CaseRepo:
    """
    Repository for case management
    """

    def create_case(self, case: Case) -> CaseModel:
        """Create new case record"""
        db_case = CaseModel(
            case_id=case.case_id,
            deployment_id=case.deployment_id,
            tenant_id=case.tenant_id,
            iocs=case.iocs,
            text={"case_detail": case.case_detail}
        )
        self.session.add(db_case)
        self.session.commit()
        return db_case

    def add_summary(self, case_uuid: UUID, summary: dict,
                    conclusion: str, risk_score: float) -> CaseSummary:
        """Add AI-generated summary"""
        embedding = self.embedding.embed_text(
            json.dumps(summary)
        )

        db_summary = CaseSummary(
            case_id=case_uuid,
            summary=summary,
            conclusion=conclusion,
            risk_score=risk_score,
            embedding=embedding,
            version=1
        )
        self.session.add(db_summary)
        self.session.commit()
        return db_summary
```

6.3 ChatHistory Repo

```
class ChatHistory:
    """
    Repository for chat thread and message management
    """

    def add_thread(self, data: dict) -> dict:
        """Create new chat thread"""
        thread = Threads(
            deployment_id=data["deployment_id"],
            tenant_id=data["tenant_id"],
            case_id=data.get("case_id", ""),
            user_id=data["user_id"],
            entity=data.get("entity", "case"),
            name=data.get("name", f"Thread {datetime.now()}")
        )
        self.session.add(thread)
        self.session.commit()
        return {"thread_id": str(thread.thread_id)}

    def store_chat_history(self, data: dict) -> dict:
        """Store chat message"""
        chat = ChatHistoryModel(
            thread_id=UUID(data["thread_id"]),
            user=data["user"],
            user_id=data.get("user_id"),
            message=data["message"],
            deployment_id=data["deployment_id"],
            tenant_id=data["tenant_id"],
            entity=data.get("entity", "case"),
            message_type=data.get("message_type", "text")
        )
        self.session.add(chat)
        self.session.commit()
        return {"id": str(chat.id)}

    def get_chat_history(self, thread_id: str, skip: int,
                         limit: int, user_id: int) -> List[dict]:
        """Retrieve paginated chat history"""
        results = self.session.query(ChatHistoryModel).filter(
            ChatHistoryModel.thread_id == UUID(thread_id)
        ).order_by(
            ChatHistoryModel.created_ts.desc()
        ).offset(skip).limit(limit).all()

        return [self._to_dict(r) for r in results]
```

7. LLM Integration

7.1 LLMWrapper

```
class LLMWrapper(Runnable):
    """
    Unified LLM interface supporting multiple backends
    """

    def __init__(self, model: str = os.getenv('MODEL_NAME'),
                 backend: str = os.getenv('LLM_BACKEND'),
                 temperature: float = 0.0,
                 streaming: bool = False):
        self.backend = backend
        self.model = model
        self.temperature = temperature
        self.streaming = streaming

        if backend == "OPENAI":
            self.llm = ChatOpenAI(
                model=model,
                temperature=temperature,
                streaming=streaming
            )
        else:  # On-premise (Ollama)
            self.llm = ChatOllama(
                model=model,
                base_url=os.getenv("ONPREM_MODEL_BASE_URL"),
                temperature=temperature,
                streaming=streaming
            )

    def invoke(self, prompt: Union[str, List[BaseMessage]],
               *args, **kwargs) -> Any:
        """Synchronous invocation"""
        messages = self._prepare_messages(prompt)
        response = self.llm.invoke(messages, *args, **kwargs)
        if self.structured_parser:
            return self.structured_parser.parse(response.content)
        return response

    async def astream(self, prompt: Union[str, List[BaseMessage]],
                      *args, **kwargs) -> AsyncGenerator[Any, None]:
        """Asynchronous streaming"""
        messages = self._prepare_messages(prompt)
        async for chunk in self.llm.astream(messages, *args, **kwargs):
            if self.structured_parser:
                yield self.structured_parser.parse(chunk)
            else:
                yield chunk

    def with_structured_output(self, output_class: Type[Any]):
        """Enable structured output parsing"""
        self.structured_parser = PydanticOutputParser(
            pydantic_object=output_class
        )
        return self
```

7.2 AIEmbedding

```
class AIEmbedding:
    """
    Embedding generation with multiple backends
    """

    def __init__(self):
        self.backend = os.getenv("EMBEDDING_BACKEND", "OPENAI")
        self.model = os.getenv("EMBEDDING_MODEL_NAME")

        if self.backend == "OPENAI":
            self.client = OpenAI()
        else:
            self.base_url = os.getenv("ONPREM_EMBEDDING_URL")

    def embed_text(self, text: str) -> List[float]:
        """Generate embedding vector"""
        if self.backend == "OPENAI":
            response = self.client.embeddings.create(
                model=self.model,
                input=text
            )
            return response.data[0].embedding
        else:
            # On-premise embedding
            response = requests.post(
                f"{self.base_url}/embed",
                json={"text": text}
            )
            return response.json()["embedding"]

    def embed_batch(self, texts: List[str]) -> List[List[float]]:
        """Batch embedding generation"""
        return [self.embed_text(text) for text in texts]
```

8. Message Processing

8.1 Kafka Consumer (Indexer)

```
class KafkaConsumer_PgvIndexer:
    """
    Consumes indexing messages and stores in PostgreSQL
    """

    def __init__(self, uri: str, embedding: AIEmbedding,
                 upstream_kafka_producer: FpProcessingProducer):
        self.uri = uri
        self.embedding = embedding
        self.upstream_producer = upstream_kafka_producer

    def subscribe_and_index(self, topic: str):
        """Main processing loop"""
        consumer = KafkaConsumer(
            topic,
            bootstrap_servers=[self.uri],
            value_deserializer=lambda m: json.loads(m.decode('utf-8')),
            auto_offset_reset='earliest'
        )

        for message in consumer:
            tasks = message.value
            for task_dict in tasks:
                self._process_task(task_dict)

    def _process_task(self, task_dict: dict):
        """Process individual task"""
        task = PlaybookTask(**task_dict)

        # Generate embedding
        text_summary = self._summarize_task(task.task_details)
        embedding = self.embedding.embed_text(text_summary)

        # Store in database
        db = get_session_for_tenant(task.tenant_id)
        try:
            repo = PlaybookTaskRepo(db, self.embedding)
            db_task = repo.add_task(task)

            # Forward to FPR processing
            self.upstream_producer.publish({
                "task_id": str(db_task.id),
                "case_id": task.case_id,
                "tenant_id": task.tenant_id,
                "deployment_id": task.deployment_id
            })
        finally:
            db.close()
```

8.2 Celery Worker

```
@celery.task(name="create_case_analysis_task")
def create_case_analysis_task(case_dict: dict):
    """
    Background task for case analysis
    """
    case = Case(**case_dict)
    logger.info(f"Processing case {case.case_id}")

    # Get database session for tenant
    with db_session(case.tenant_id) as session:
        # Initialize services
        playbook_task_repo = PlaybookTaskRepo(
            session=session,
            embedding=embedding_client
        )
        case_service = OpenAICaseAnalysisService(
            playbook_task_repo=playbook_task_repo
        )

        # Run analysis
        result, existing = case_service.run(case)

        # Store result
        case_repo = CaseRepo(session)
        case_repo.add_summary(
            case.case_id,
            result,
            result["conclusion"]["status"],
            result["conclusion"]["score"]
        )

        # Trigger risk scoring (async)
        if not existing:
            set_risk.delay(
                case.deployment_id,
                case.tenant_id,
                case.case_id,
                case.case_detail,
                case.iocs,
                result
            )

        return {"result": result}
```

9. Analysis Pipeline

9.1 Template Factory

```
class AnalysisTemplatesFactory:
    """
    Provides analysis prompt templates
    """

    def get_by_case(self, case: Case) -> str:
        """
        Returns system prompt based on case type
        """
        return """
You are an expert security analyst. Your task is to analyze
security cases and provide:

1. Executive Summary: Brief overview of the incident
2. Findings: Detailed findings from each source
3. Conclusion: Assessment (malicious/benign/suspicious) with score
4. Recommendations: Actionable remediation steps

Use the provided context from historical tasks to inform your analysis.
Output must be valid JSON following this structure:
{
  "executive_summary": "...",
  "findings": [...],
  "conclusion": {"status": "...", "reason": "...", "score": 0-10},
  "recommendations": [...]
}
"""
```

9.2 Output Parser

```
class SelfRepairJsonOutputParser(JsonOutputParser):
    """
    JSON parser with self-repair capability
    """

    def parse(self, text: str) -> dict:
        """
        Parse LLM output with error recovery
        """
        try:
            # Try standard JSON parsing
            return json.loads(text)
        except json.JSONDecodeError as e:
            logger.warning(f"JSON parse error: {e}")

            # Try to repair JSON
            from json_repair import repair_json
            try:
                repaired = repair_json(text)
                return json.loads(repaired)
            except Exception as e2:
                logger.error(f"JSON repair failed: {e2}")

                # Last resort: extract JSON from markdown
                import re
                json_match = re.search(
                    r'```json\s*(\{.*?\})\s*```',
                    text,
                    re.DOTALL
                )
                if json_match:
                    return json.loads(json_match.group(1))

                raise ValueError("Unable to parse JSON response")
```

9.3 Risk Scoring

```
def analyze_risk_and_recommendation(session: Session,
                                    deployment_id: str,
                                    tenant_id: str,
                                    case_id: str,
                                    case_detail: str,
                                    iocs: str,
                                    summary: dict,
                                    is_novel: bool,
                                    cluster_id: str,
                                    case_uuid: str):
    """
    Calculate risk score and generate recommendations
    """
    # 1. Extract features
    conclusion = summary.get("conclusion", {})
    base_score = conclusion.get("score", 5)
    status = conclusion.get("status", "unknown")

    # 2. Adjust score based on factors
    risk_score = base_score

    if status == "malicious":
        risk_score = min(risk_score + 2, 10)
    elif status == "suspicious":
        risk_score = min(risk_score + 1, 10)

    if is_novel:
        risk_score = min(risk_score + 1, 10)

    if len(iocs) > 100:  # Multiple IOCs
        risk_score = min(risk_score + 0.5, 10)

    # 3. Generate recommendations
    recommendations = []
    if risk_score >= 8:
        recommendations.append({
            "priority": "critical",
            "action": "Immediate investigation required"
        })
    elif risk_score >= 6:
        recommendations.append({
            "priority": "high",
            "action": "Review within 4 hours"
        })

    # 4. Store in database
    case_repo = CaseRepo(session)
    case_repo.update_risk_score(case_uuid, risk_score)
    case_repo.add_recommendations(case_uuid, recommendations)
```

10. False Positive Reduction

10.1 FPR Worker

```
class CaseFPReductionWorker:
    """
    Main worker for false positive reduction
    """

    def __init__(self, config: FPReductionConfig):
        self.config = config
        self.nds_client = NDSClient()
        self.embedding_client = AIEmbedding()
        self.batch_buffer = defaultdict(list)

    def start_fpr_case_processor(self):
        """Process enriched cases"""
        consumer = KafkaConsumer(
            self.config.processing_topic,
            bootstrap_servers=[self.config.kafka_broker],
            value_deserializer=lambda m: json.loads(m.decode('utf-8')),
            group_id=self.config.processing_group_id
        )

        for msg in consumer:
            case = msg.value
            tenant_id = case.get("tenant_id")

            # Buffer cases by tenant
            self.batch_buffer[tenant_id].append(case)

            # Process when batch is full
            if len(self.batch_buffer[tenant_id]) >= self.config.batch_size:
                self.process_tenant_batch(
                    case["deployment_id"],
                    tenant_id,
                    self.batch_buffer[tenant_id]
                )
                self.batch_buffer[tenant_id] = []

    def process_tenant_batch(self, deployment_id: str,
                             tenant_id: str,
                             cases: List[dict]):
        """Process batch of cases"""
        db = get_session_for_tenant(tenant_id)
        try:
            for case in cases:
                # 1. Build features
                features = FeatureBuilderModuleV2.build(case)

                # 2. Check novelty
                novelty_result = self.nds_client.check_novelty(
                    deployment_id,
                    tenant_id,
                    case,
                    self.config.nds_window_length
                )

                # 3. Score suspiciousness
                score, reason = SuspiciousScoringModule.score(
                    case,
                    features,
                    novelty_result
                )

                # 4. Classify as FP or legit
                is_fp = self._classify_fp(score, novelty_result)

                # 5. Store results
                upsert_case_suspicious_analysis(
                    db,
                    case["case_id"],
                    deployment_id,
                    tenant_id,
                    novelty_result["is_novel"],
                    novelty_result["cluster_id"],
                    score,
                    reason,
                    is_fp
                )
```

```
                # 6. Update case status
                if is_fp:
                    set_case_as_noise(
                        db,
                        deployment_id,
                        tenant_id,
                        case["case_id"]
                    )
        finally:
            db.close()

    def _classify_fp(self, score: float, novelty: dict) -> bool:
        """Determine if case is false positive"""
        if not novelty["is_novel"] and score < 3.0:
            return True
        if score < 1.0:
            return True
        return False
```

10.2 Feature Builder

```
class FeatureBuilderModuleV2:
    """
    Extract ML features from case data
    """

    @staticmethod
    def build(case: dict) -> dict:
        """
        Build feature vector
        """
        features = {
            # IOC features
            "num_iocs": len(case.get("iocs", "").split(",")),
            "has_ip": bool(re.search(r'\d+\.\d+\.\d+\.\d+', case.get("iocs", ""))),
            "has_domain": bool(re.search(r'[a-z0-9-]+\.[a-z]{2,}', case.get("iocs", ""))),
            "has_hash": bool(re.search(r'[a-f0-9]{32,64}', case.get("iocs", ""))),

            # Case features
            "case_length": len(case.get("case_detail", "")),
            "num_findings": len(case.get("findings", [])),

            # Temporal features
            "hour_of_day": datetime.now().hour,
            "day_of_week": datetime.now().weekday(),

            # Text features
            "contains_malicious": "malicious" in case.get("case_detail", "").lower(),
            "contains_suspicious": "suspicious" in case.get("case_detail", "").lower(),
        }

        return features
```

10.3 Novelty Detection Client

```
class NDSClient:
    """
    Client for Novelty Detection Service
    """

    def __init__(self):
        self.base_url = os.getenv("NDS_API_URL")

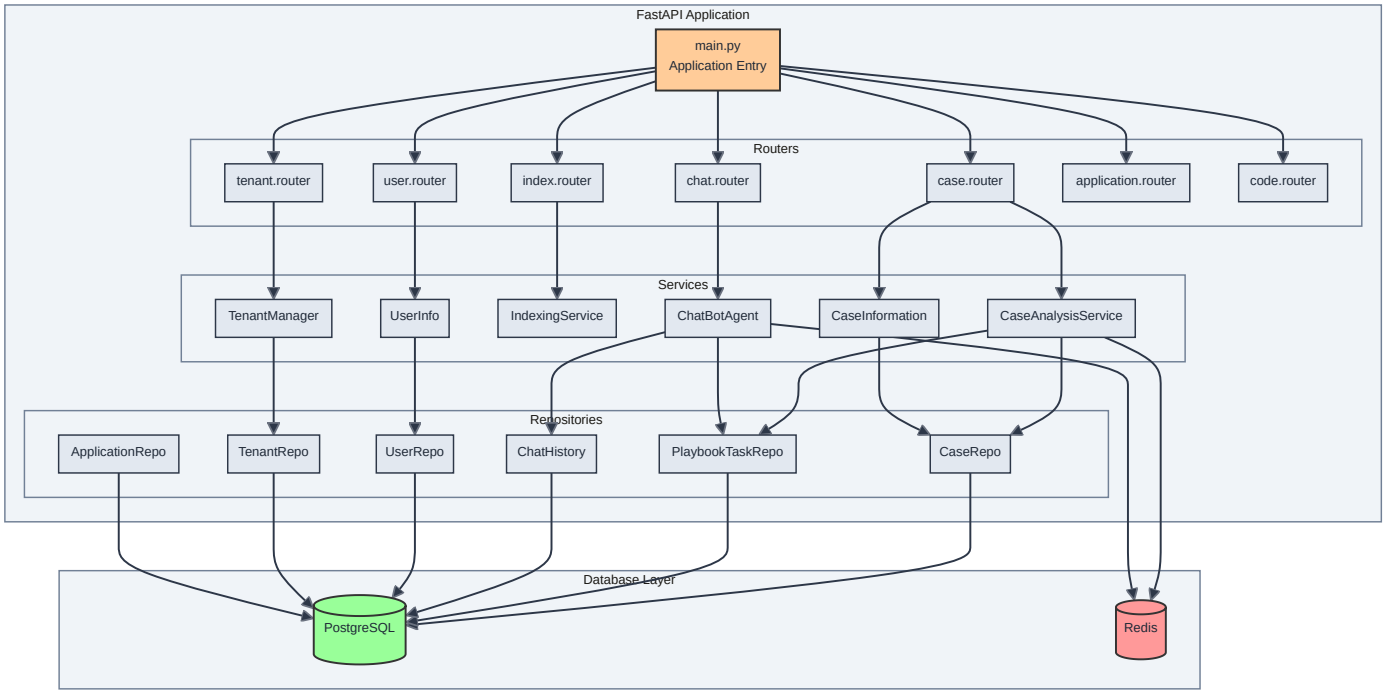
    def check_novelty(self, deployment_id: str, tenant_id: str,
                      case: dict, window_length: int) -> dict:
        """
        Check if case is novel
        """
        # Generate embedding for case
        embedding = self._generate_embedding(case)

        # Call NDS API
        response = requests.post(
            f"{self.base_url}/api/v1/novelty/check",
            json={
                "stream_id": f"{deployment_id}_{tenant_id}",
                "event_id": case["case_id"],
                "content": case,
                "embedding": embedding,
                "window_length": window_length
            }
        )

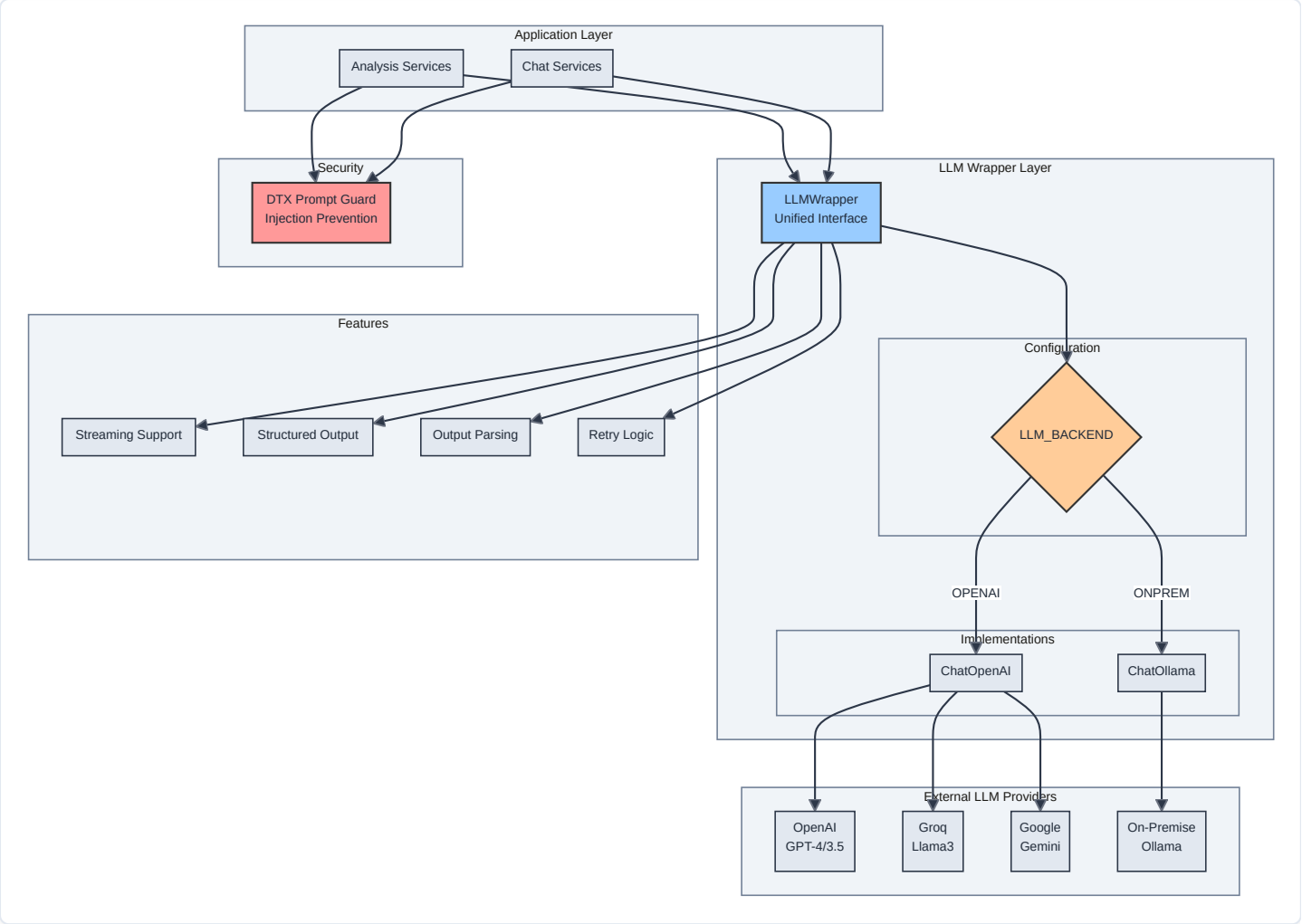
        result = response.json()
        return {
            "is_novel": result["is_novel"],
            "similarity_score": result["similarity_score"],
            "similar_cases": result.get("similar_event_ids", []),
            "cluster_id": result.get("cluster_id", "")
        }
```

11. Implementation Diagrams

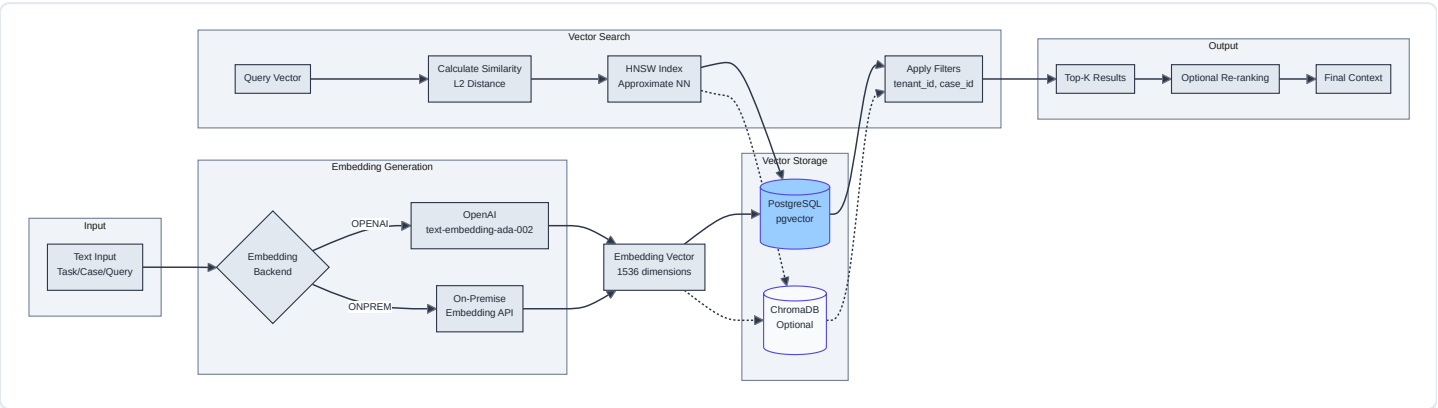
11.1 Component Interaction Diagram



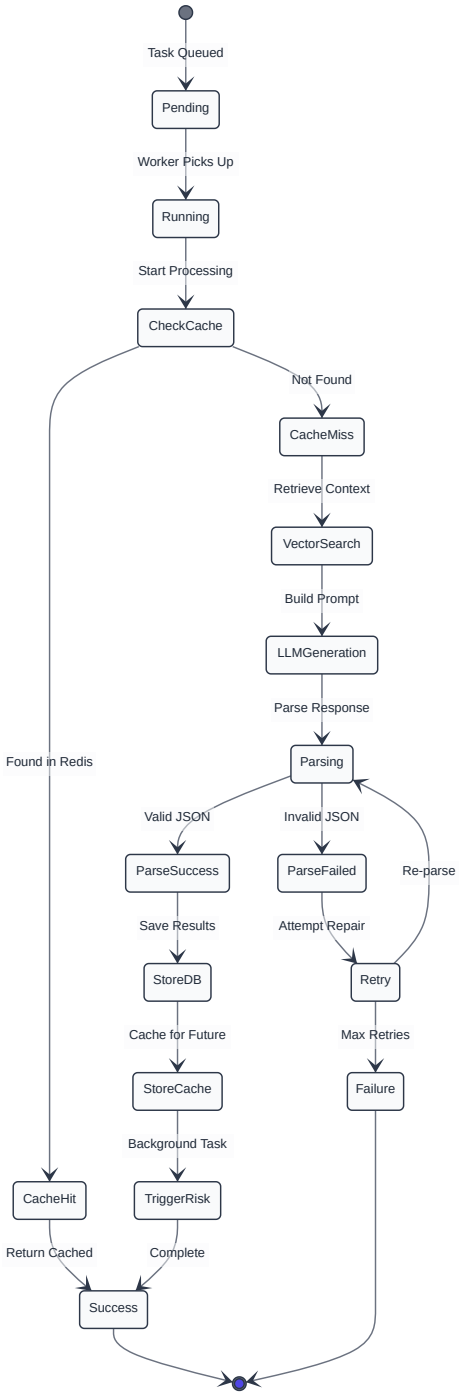
11.2 LLM Integration Architecture



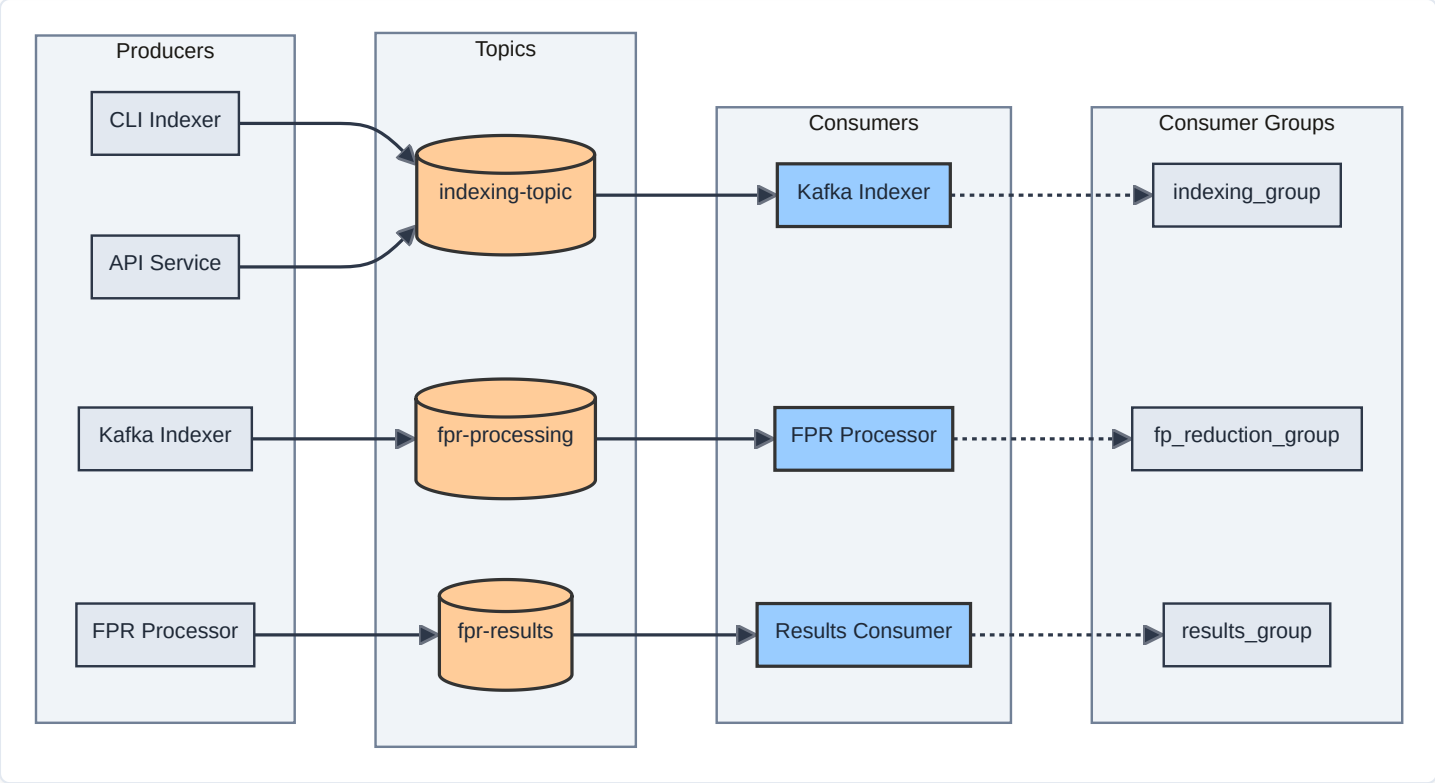
11.3 Vector Search Implementation



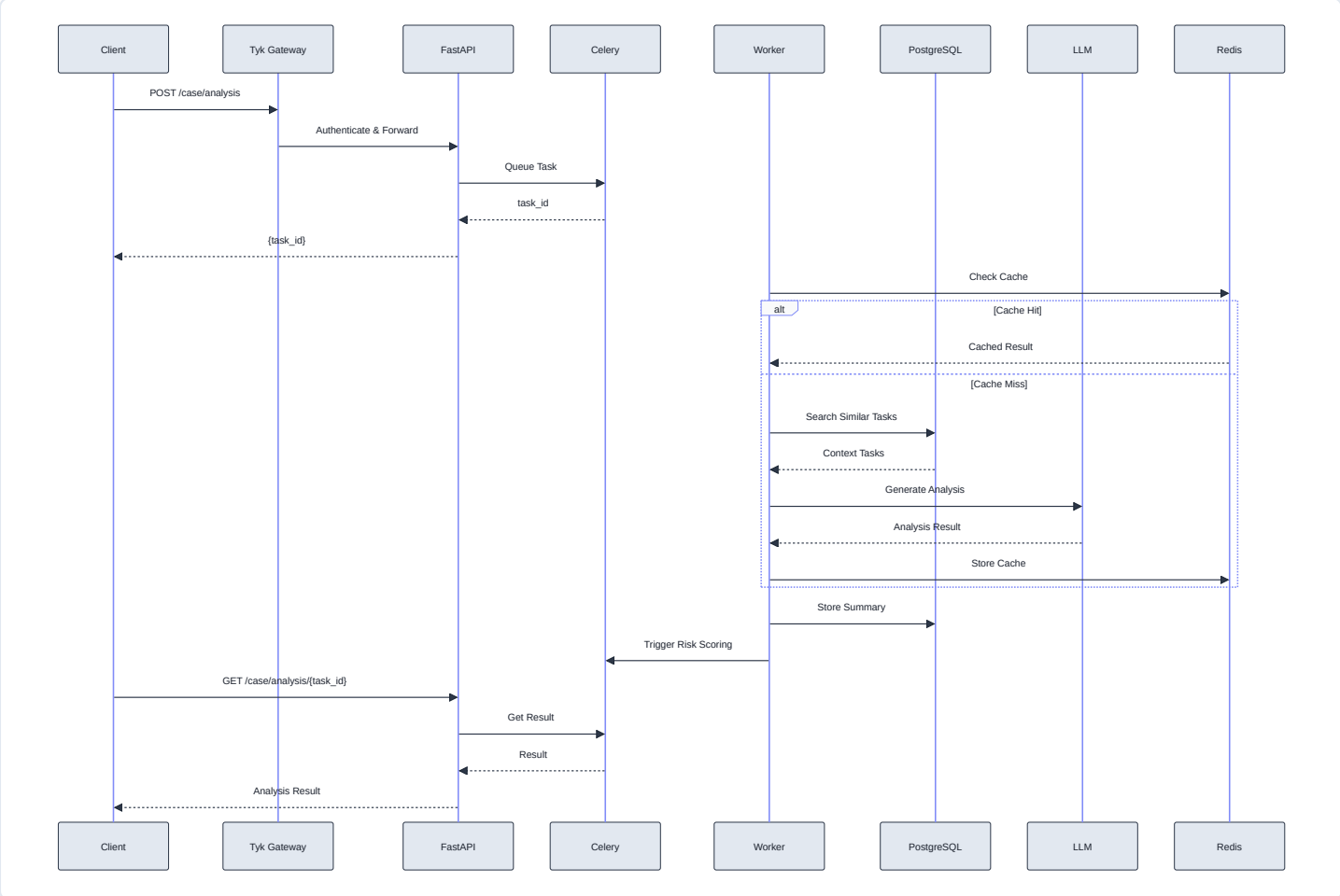
11.4 Celery Task State Machine


Task Queued
Pending
Worker Picks Up
Running
Start Processing
CheckCache
Found in Redis
Not Found
CacheMiss
Retrieve Context
VectorSearch
Build Prompt
LLMGeneration
Parse Response
Parsing
Valid JSON
Invalid JSON
ParseSuccess
ParseFailed
Re-parse
Save Results
Attempt Repair
StoreDB
Retry
Cache for Future
Max Retries
StoreCache
Failure
Background Task
CacheHit
TriggerRisk
Return Cached
Complete
Success

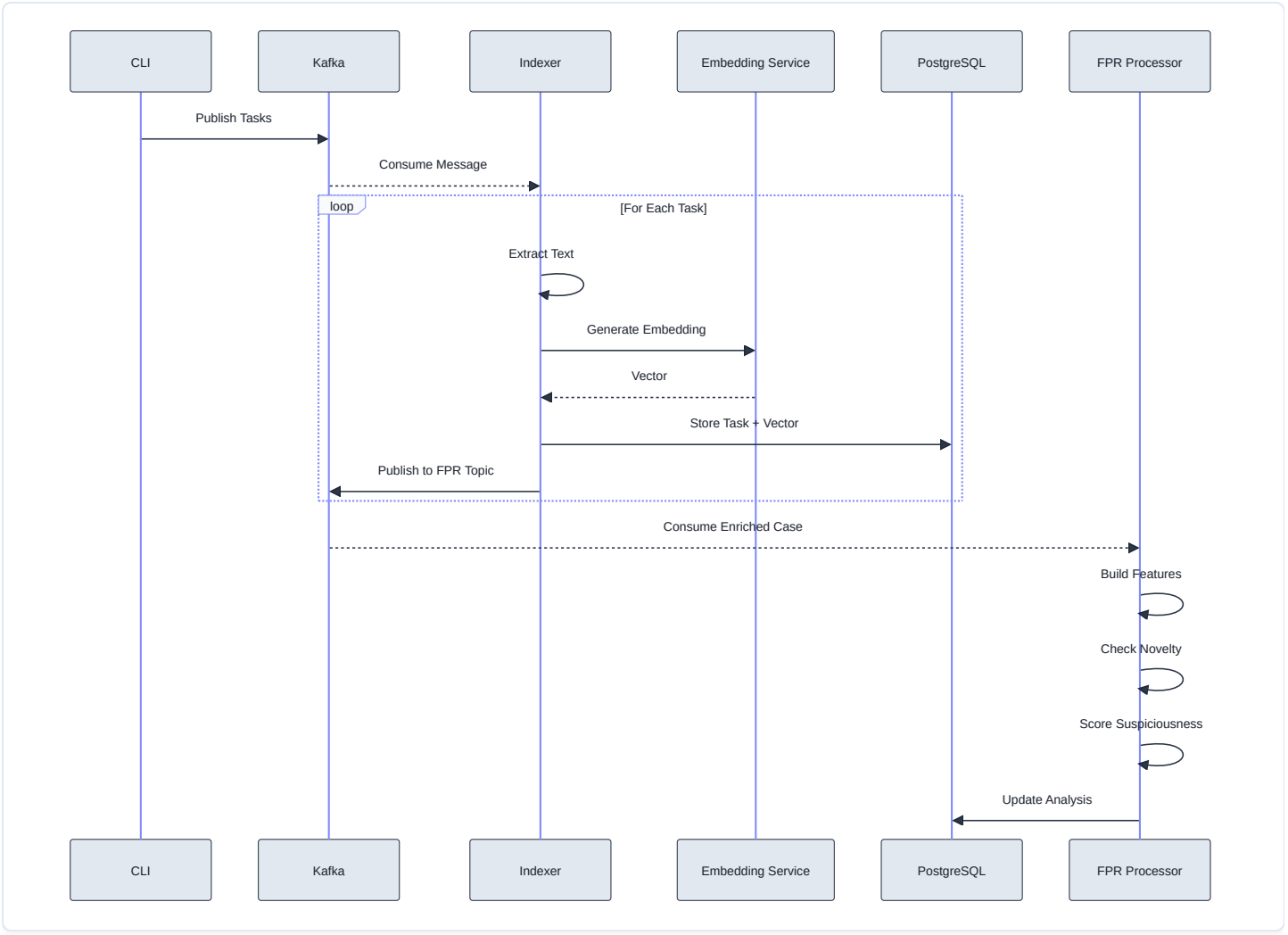
11.5 Kafka Topic Flow



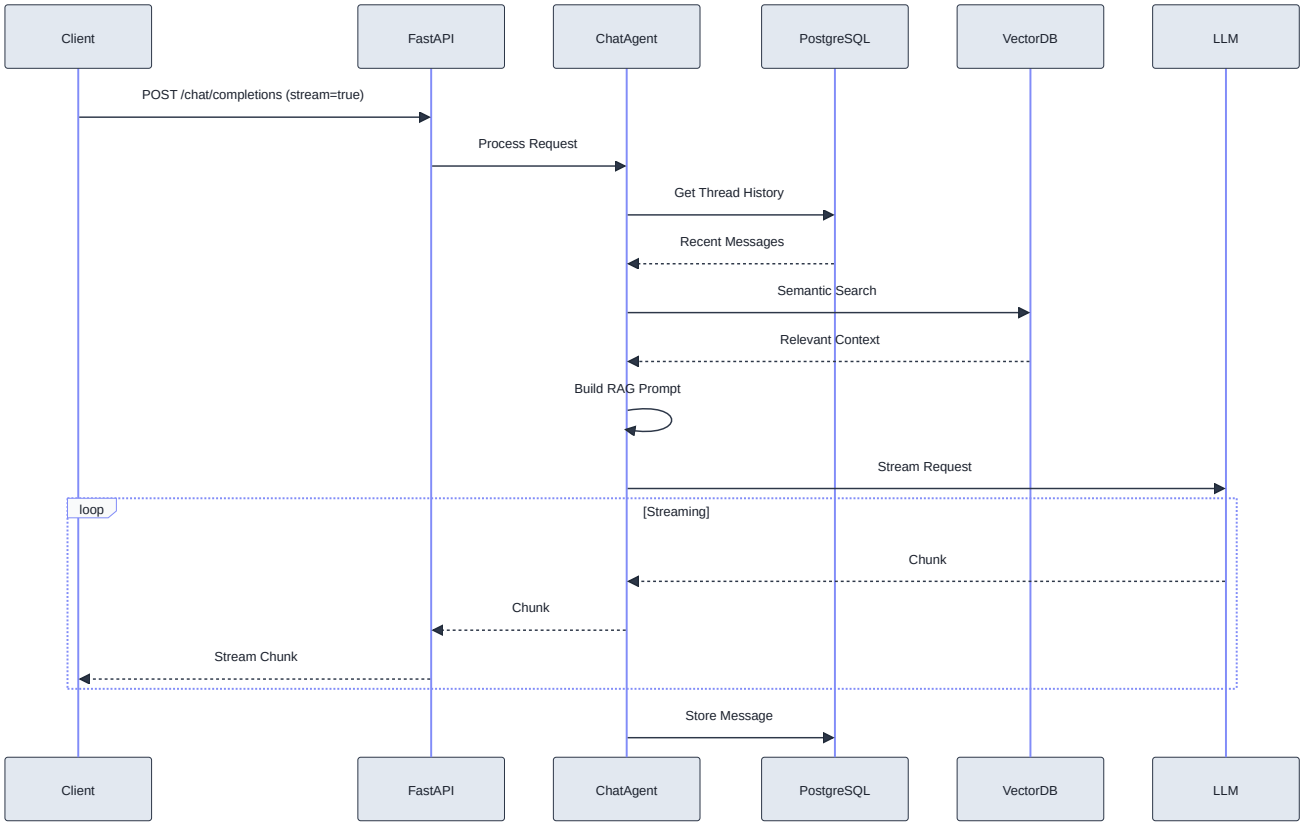
11.6 Sequence Diagram: Case Analysis Flow



11.2 Task Indexing Flow



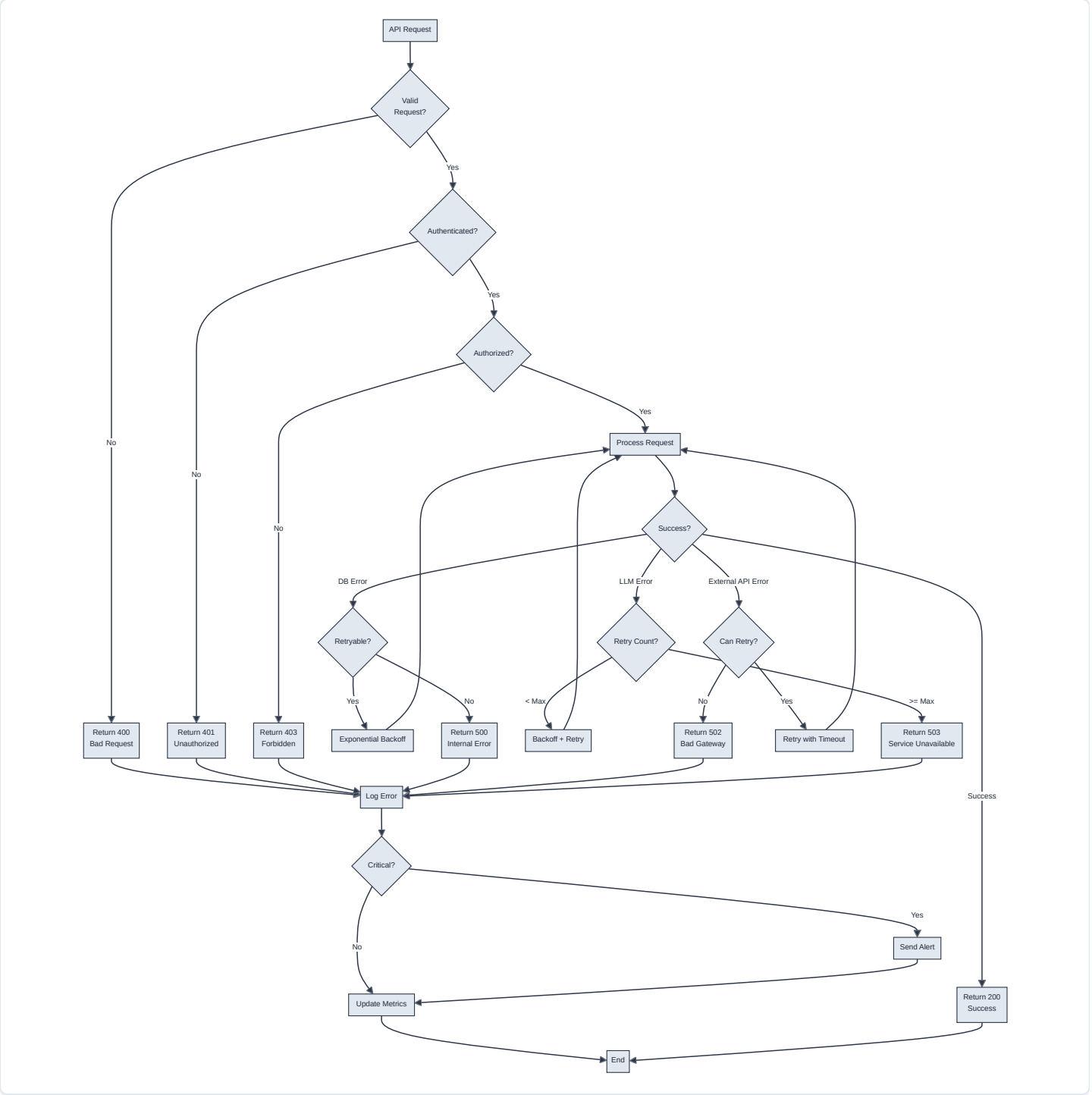
11.3 Chat Flow with RAG



11.4 Repository Pattern Class Diagram

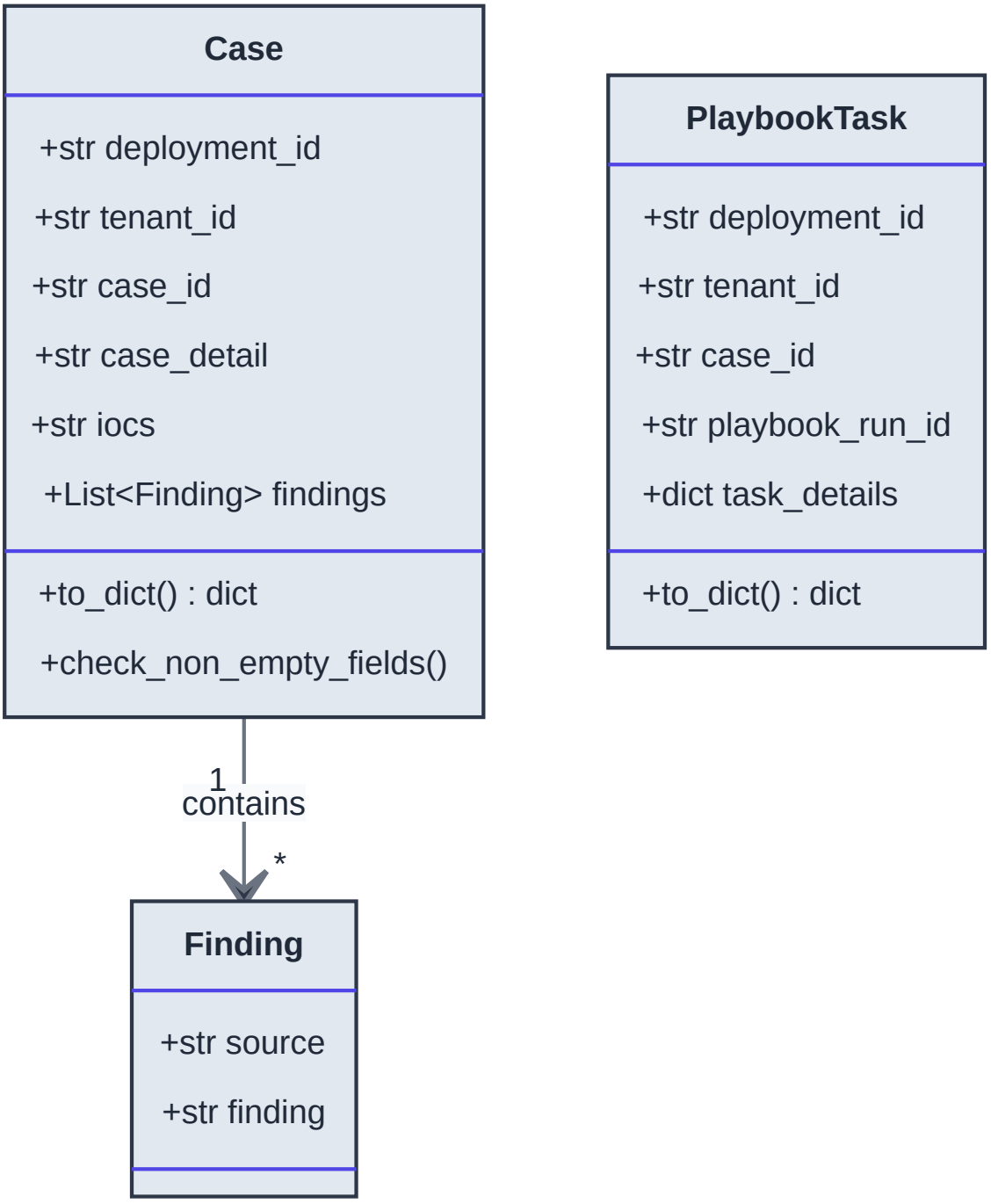
11.5 Tenant Onboarding Workflow

11.6 Error Handling Flow

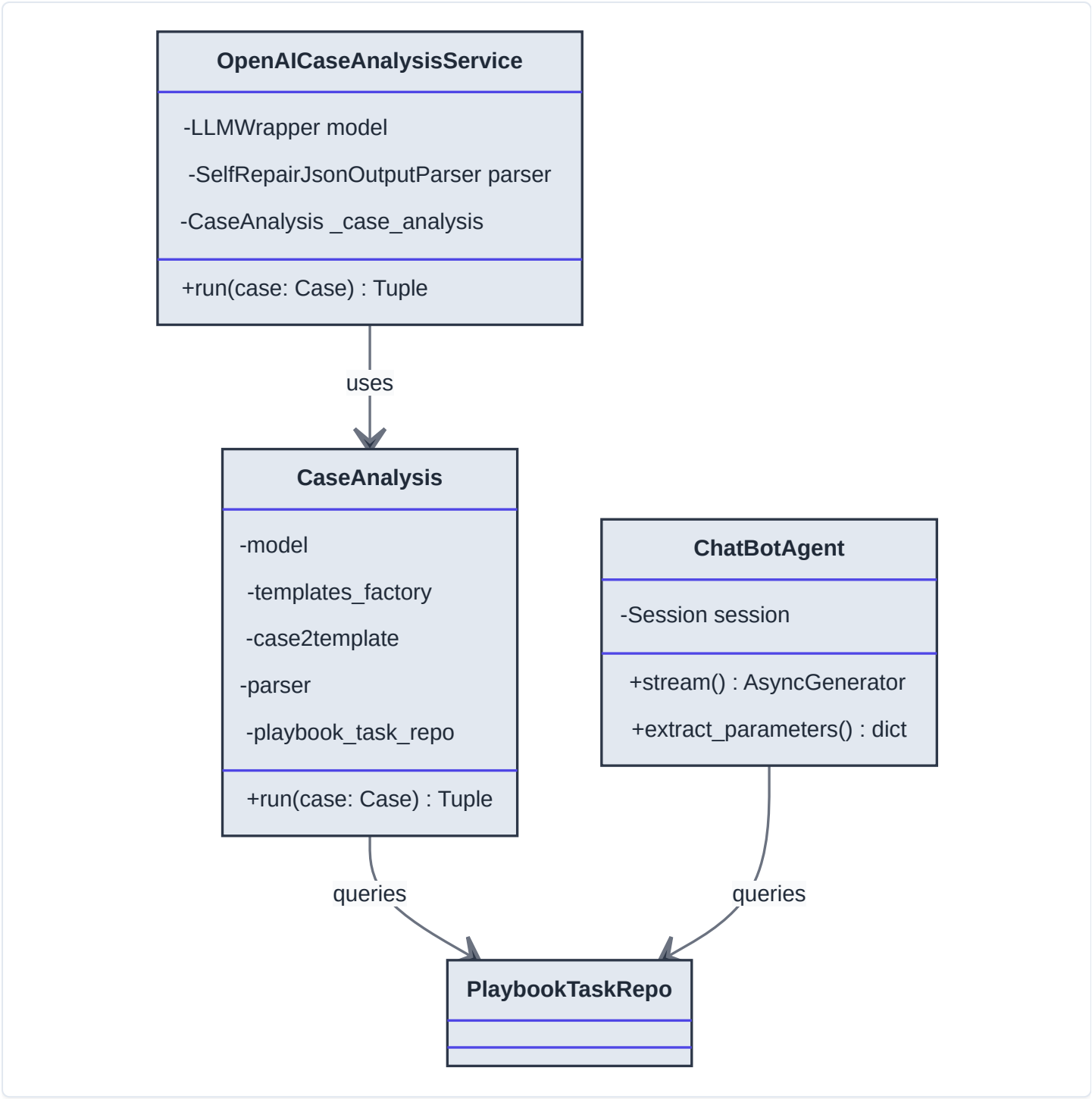


12. Class Diagrams

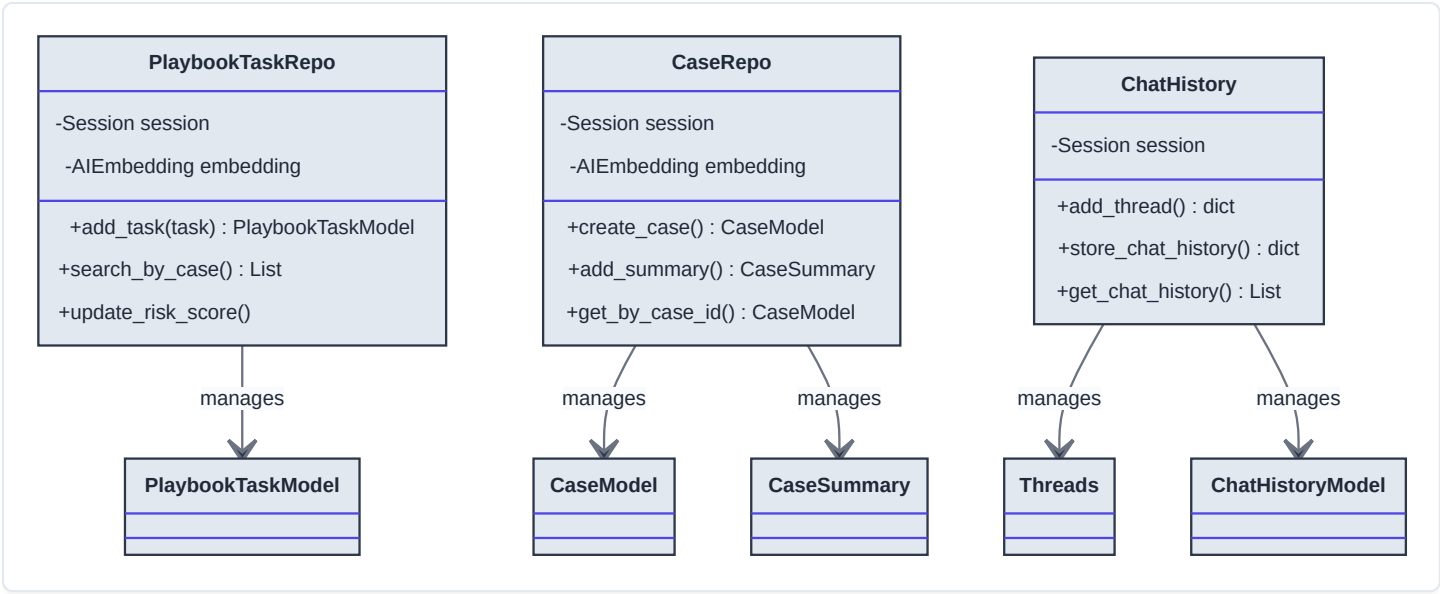
12.1 Domain Model



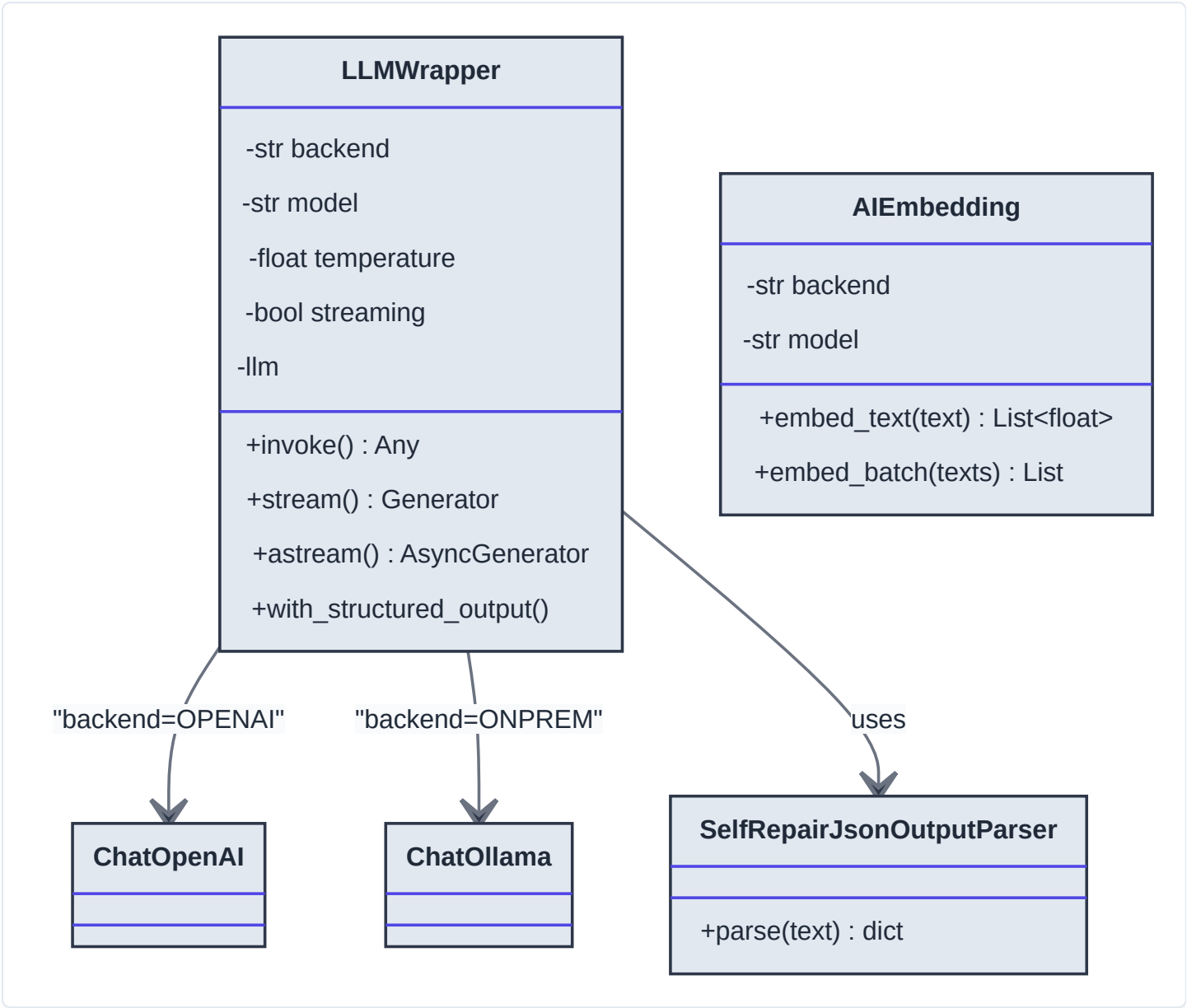
12.2 Service Layer



12.3 Repository Layer



12.4 LLM Integration



13. Key Design Patterns

13.1 Repository Pattern

- **Purpose**: Abstract data access logic
- **Implementation**: Separate repository classes for each entity
- **Benefits**: Testability, decoupling, consistency

13.2 Dependency Injection

- **Purpose**: Manage dependencies cleanly
- **Implementation**: FastAPI Depends(), constructor injection
- **Benefits**: Testability, flexibility, loose coupling

13.3 Strategy Pattern

- **Purpose**: Switch LLM backends dynamically
- **Implementation**: LLMWrapper with backend selection
- **Benefits**: Flexibility, extensibility

13.4 Observer Pattern

- **Purpose**: Event-driven processing
- **Implementation**: Kafka pub/sub
- **Benefits**: Scalability, decoupling

13.5 Factory Pattern

- **Purpose**: Create objects based on type
- **Implementation**: AnalysisTemplatesFactory
- **Benefits**: Centralized creation logic

---

14. Error Handling

14.1 Exception Hierarchy

```
class SiaException(Exception):
    """Base exception"""
    pass

class InvalidInputException(SiaException):
    """Invalid user input"""
    pass

class NoneResultException(SiaException):
    """LLM returned None"""
    pass

class DatabaseException(SiaException):
    """Database operation failed"""
    pass
```

14.2 Retry Logic

```
@retry((NoneResultException), tries=3, delay=2, backoff=2)
def run_analysis(case: Case):
    """Retry on specific exceptions"""
    result = analyze(case)
    if result is None:
        raise NoneResultException()
    return result
```

---

15. Performance Optimizations

15.1 Caching Strategy

- **Redis**: LLM response caching
- **Hash-based keys**: Deterministic cache hits
- **TTL**: Configurable expiration

15.2 Vector Search Optimization

- **HNSW Index**: Fast approximate nearest neighbor
- **Batch Processing**: Group operations
- **Selective Filtering**: Reduce search space

15.3 Connection Pooling

- **SQLAlchemy**: Automatic connection pooling
- **Redis**: Connection pool configuration
- **Kafka**: Reusable consumers

---

15. Testing Strategy

15.1 Unit Testing

```
# tests/apis/test_case_service.py
import pytest
from siaservice.apis.services.cases import OpenAICaseAnalysisService
from siaservice.domain.soar.cases import Case

@pytest.fixture
def mock_playbook_repo(mocker):
    repo = mocker.Mock()
    repo.search_by_case.return_value = []
    return repo

@pytest.fixture
def case_service(mock_playbook_repo):
    return OpenAICaseAnalysisService(
        playbook_task_repo=mock_playbook_repo
    )

def test_case_analysis_success(case_service):
    case = Case(
        deployment_id="test",
        tenant_id="test",
        case_id="CASE-001",
        case_detail="Test case",
        iocs="192.168.1.1"
    )

    result, is_cached = case_service.run(case)

    assert result is not None
    assert "executive_summary" in result
    assert "conclusion" in result
    assert isinstance(is_cached, bool)
```

15.2 Integration Testing

```
# tests/integration/test_case_flow.py
import pytest
from fastapi.testclient import TestClient
from main import app

@pytest.fixture
def client():
    return TestClient(app)

def test_case_analysis_flow(client):
    # Submit case
    response = client.post(
        "/case/analysis",
        json={
            "case": {
                "deployment_id": "test",
                "tenant_id": "test",
                "case_id": "CASE-001",
                "case_detail": "Test",
                "iocs": "192.168.1.1"
            }
        }
    )
    assert response.status_code == 201
    task_id = response.json()["task_id"]

    # Poll for result
    result_response = client.get(f"/case/analysis/{task_id}")
    assert result_response.status_code == 200
```

15.3 Performance Testing

```
# tests/performance/test_vector_search.py
import time
import pytest
from siaservice.repositories.playbook_tasks_repo import PlaybookTaskRepo

def test_vector_search_performance(db_session, embedding_client):
    repo = PlaybookTaskRepo(db_session, embedding_client)

    start = time.time()
    results = repo.search_by_case(
        "malicious IP",
        "test-dep",
        "test-tenant",
        "CASE-001",
        limit=100
    )
    duration = time.time() - start

    assert duration < 1.0  # Sub-second search
    assert len(results) > 0
```

16. Code Examples

16.1 Adding a New API Endpoint

```
# siaservice/routers/example.py
from fastapi import APIRouter, Depends
from sqlalchemy.orm import Session
from siaservice.db.pgv.db import get_db_for_tenant
from siaservice.apis.services.base.models import ExamplePayload
from siaservice.common import get_logger

logger = get_logger(__name__)
router = APIRouter(prefix="/example", tags=["Example"])

@router.post("/process", status_code=201)
def process_example(
    payload: ExamplePayload,
    db: Session = Depends(get_db_for_tenant)
):
    logger.info(f"Processing example: {payload.id}")

    # Business logic here
    result = {"status": "success"}

    return result
```

16.2 Creating a New Repository

```
# siaservice/repositories/example_repo.py
from sqlalchemy.orm import Session
from siaservice.db.pgv.models import ExampleModel
from siaservice.db.embed.embedding import AIEmbedding
from typing import List, Optional

class ExampleRepo:
    def __init__(self, session: Session, embedding: AIEmbedding):
        self.session = session
        self.embedding = embedding

    def create(self, data: dict) -> ExampleModel:
        """Create new record"""
        # Generate embedding if needed
        text = data.get("description", "")
        embedding_vector = self.embedding.embed_text(text)

        model = ExampleModel(
            **data,
            embedding=embedding_vector
        )

        self.session.add(model)
        self.session.commit()
        self.session.refresh(model)

        return model

    def search_similar(
        self,
        query: str,
        tenant_id: str,
        limit: int = 10
    ) -> List[ExampleModel]:
        """Vector similarity search"""
        query_vector = self.embedding.embed_text(query)

        results = self.session.query(ExampleModel).filter(
            ExampleModel.tenant_id == tenant_id
        ).order_by(
            ExampleModel.embedding.l2_distance(query_vector)
        ).limit(limit).all()

        return results
```

16.3 Adding a New Celery Task

```
# worker.py - Add new task
from celery import Celery
from siaservice.db.pgv.db import db_session
from siaservice.common import get_logger

logger = get_logger(__name__)
celery = Celery(__name__)

@celery.task(name="process_example_task")
def process_example_task(data: dict):
    """
    Background task for processing examples
    """
    tenant_id = data["tenant_id"]
    logger.info(f"Processing example for tenant: {tenant_id}")

    with db_session(tenant_id) as session:
        # Your logic here
        result = perform_processing(session, data)

        return {"result": result}

def perform_processing(session, data):
    # Implementation
    return {"status": "completed"}
```

16.4 Adding a New LLM Prompt Template

```
# siaservice/analysis/templates.py
class AnalysisTemplatesFactory:
    def get_example_template(self) -> str:
        """
        Returns prompt template for example analysis
        """
        return """
You are an expert security analyst. Analyze the following data:

Context:
{context}

Data to analyze:
{data}

Provide your analysis in JSON format:
{{
  "summary": "...",
  "findings": [...],
  "recommendations": [...]
}}
"""

    def get_by_type(self, analysis_type: str) -> str:
        """Get template by type"""
        templates = {
            "case": self.get_by_case,
            "example": self.get_example_template,
        }

        return templates.get(analysis_type, self.get_default)()
```

16.5 Database Migration Example

```
# migrations/versions/xxxxx_add_example_table.py
"""Add example table

Revision ID: xxxxx
Revises: yyyyy
Create Date: 2025-11-11 16:00:00.000000

"""
from alembic import op
import sqlalchemy as sa
from pgvector.sqlalchemy import Vector

# revision identifiers
revision = 'xxxxx'
down_revision = 'yyyyy'
branch_labels = None
depends_on = None

def upgrade():
    op.create_table(
        'examples',
        sa.Column('id', sa.UUID(), nullable=False),
        sa.Column('tenant_id', sa.String(256), nullable=False),
        sa.Column('name', sa.String(255), nullable=False),
        sa.Column('description', sa.Text(), nullable=True),
        sa.Column('embedding', Vector(1536), nullable=True),
        sa.Column('created_at', sa.DateTime(timezone=True),
                  server_default=sa.text('now()'), nullable=False),
        sa.PrimaryKeyConstraint('id')
    )

    op.create_index(
        'ix_examples_tenant_id',
        'examples',
        ['tenant_id']
    )

    op.create_index(
        'ix_examples_embedding',
        'examples',
        ['embedding'],
        postgresql_using='hnsw',
        postgresql_with={'m': 16, 'ef_construction': 64},
        postgresql_ops={'embedding': 'vector_l2_ops'}
    )

def downgrade():
    op.drop_index('ix_examples_embedding', table_name='examples')
    op.drop_index('ix_examples_tenant_id', table_name='examples')
    op.drop_table('examples')
```

16.6 Adding Environment Configuration

```
# .env additions
# Example Service Configuration
EXAMPLE_API_KEY=your_api_key_here
EXAMPLE_BASE_URL=https://api.example.com
EXAMPLE_TIMEOUT=30
EXAMPLE_MAX_RETRIES=3
```

```
# siaservice/services/example_client.py
import os
import requests
from typing import Dict, Any
from siaservice.common import get_logger

logger = get_logger(__name__)

class ExampleClient:
    def __init__(self):
        self.api_key = os.getenv("EXAMPLE_API_KEY")
        self.base_url = os.getenv("EXAMPLE_BASE_URL")
        self.timeout = int(os.getenv("EXAMPLE_TIMEOUT", 30))
        self.max_retries = int(os.getenv("EXAMPLE_MAX_RETRIES", 3))

    def call_api(self, endpoint: str, data: Dict[str, Any]) -> Dict[str, Any]:
        """Make API call with retry logic"""
        url = f"{self.base_url}/{endpoint}"
        headers = {"Authorization": f"Bearer {self.api_key}"}

        for attempt in range(self.max_retries):
            try:
                response = requests.post(
                    url,
                    json=data,
                    headers=headers,
                    timeout=self.timeout
                )
                response.raise_for_status()
                return response.json()

            except requests.RequestException as e:
                logger.warning(f"API call failed (attempt {attempt + 1}): {e}")
                if attempt == self.max_retries - 1:
                    raise

        return {}
```

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