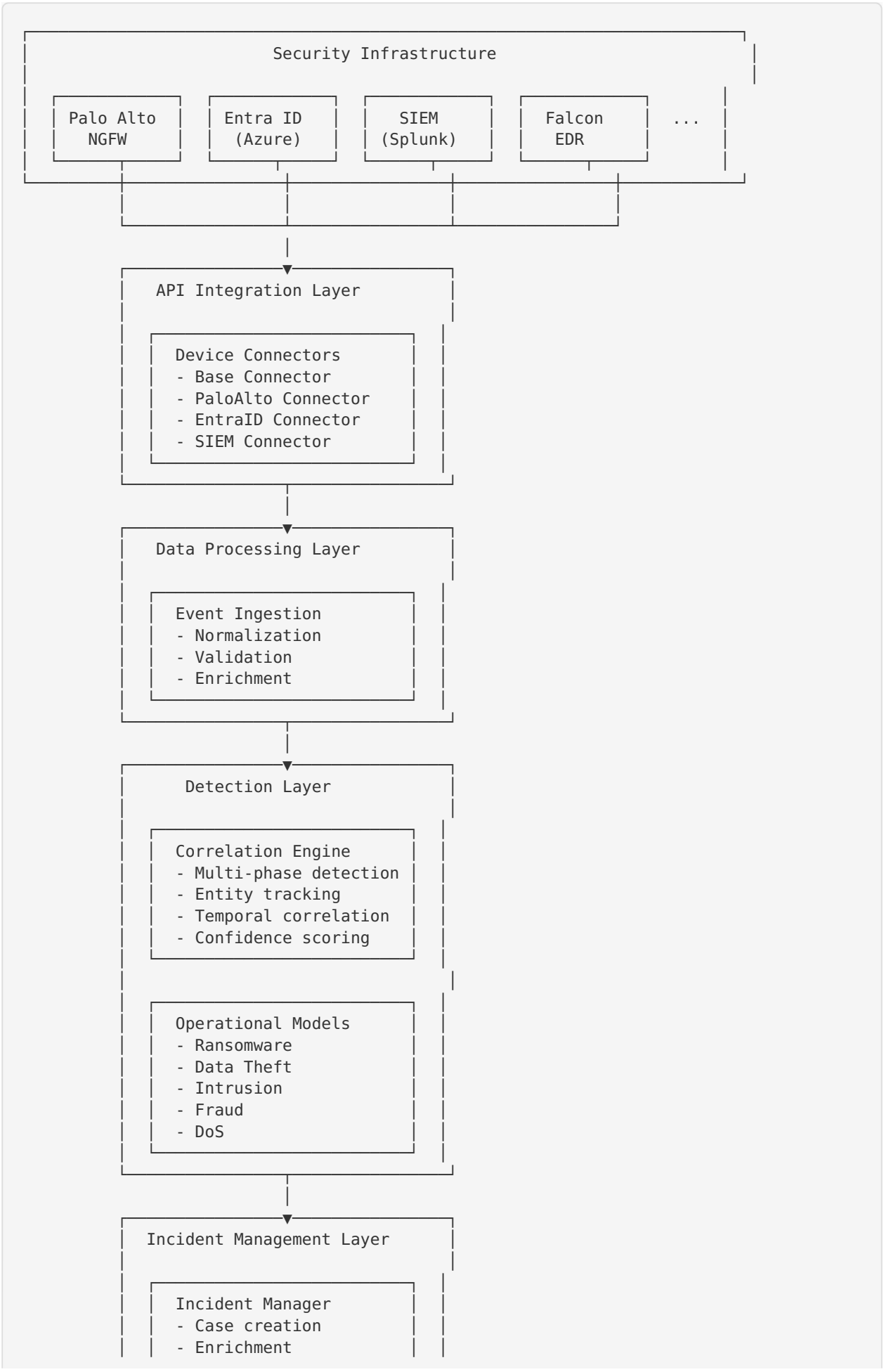
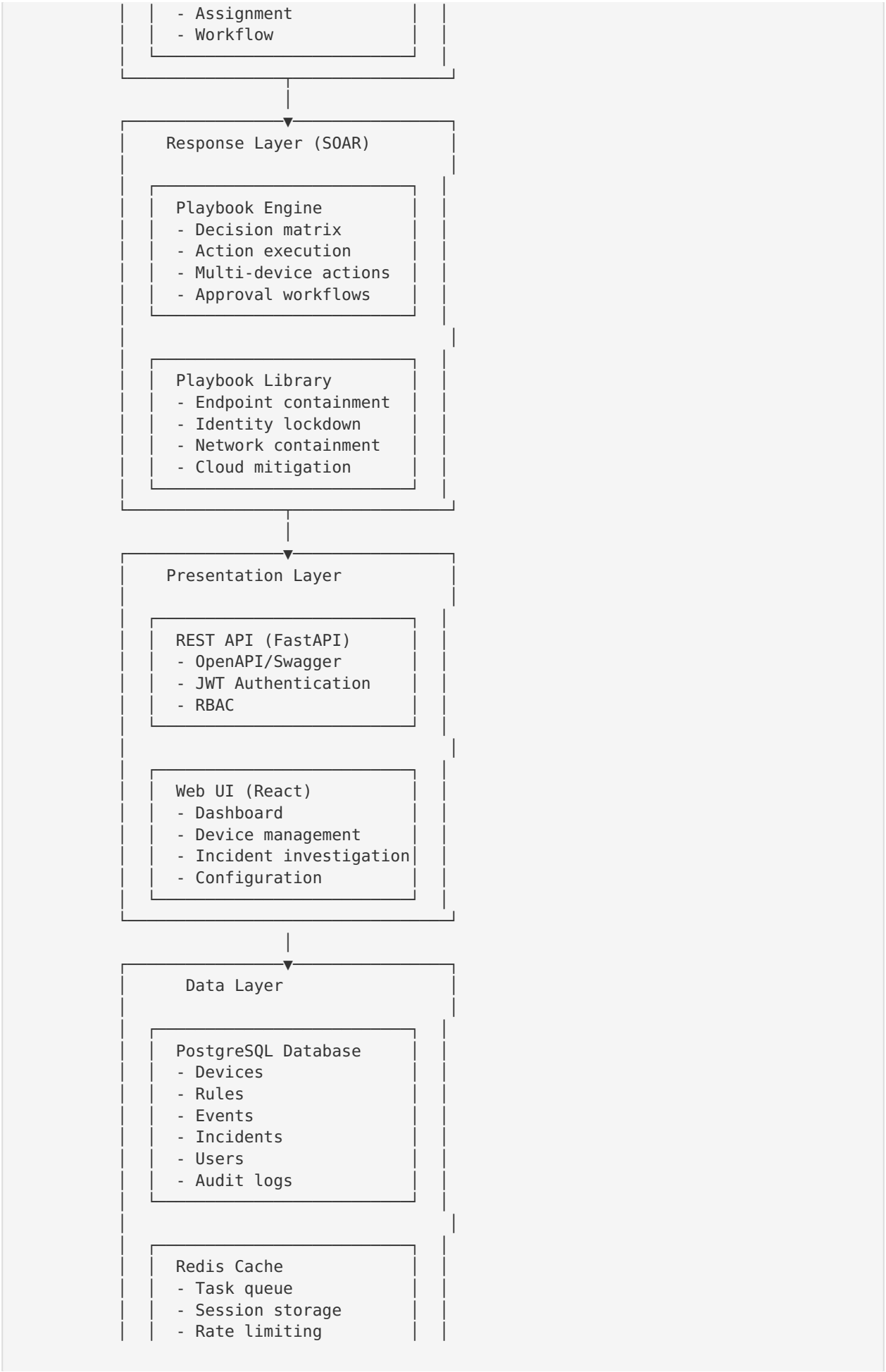
SOaC Framework Architecture

Overview

The SOaC Framework is built on a modern, microservices-inspired architecture that enables scalable, maintainable, and extensible security operations automation.

Architecture Diagram


Security Infrastructure
Palo Alto NGFW
Entra ID (Azure)
SIEM (Splunk)
Falcon EDR
...
API Integration Layer
Device Connectors
- Base Connector
- PaloAlto Connector
- EntraID Connector
- SIEM Connector
Data Processing Layer
Event Ingestion
- Normalization
- Validation
- Enrichment
Detection Layer
Correlation Engine
- Multi-phase detection
- Entity tracking
- Temporal correlation
- Confidence scoring
Operational Models
- Ransomware
- Data Theft
- Intrusion
- Fraud
- DoS
Incident Management Layer
Incident Manager
- Case creation
- Enrichment


- Assignment
- Workflow
Response Layer (SOAR)
Playbook Engine
- Decision matrix
- Action execution
- Multi-device actions
- Approval workflows
Playbook Library
- Endpoint containment
- Identity lockdown
- Network containment
- Cloud mitigation
Presentation Layer
REST API (FastAPI)
- OpenAPI/Swagger
- JWT Authentication
- RBAC
Web UI (React)
- Dashboard
- Device management
- Incident investigation
- Configuration
Data Layer
PostgreSQL Database
- Devices
- Rules
- Events
- Incidents
- Users
- Audit logs
Redis Cache
- Task queue
- Session storage
- Rate limiting

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```

Core Components

1. API Integration Layer

Purpose: Communicate with external security devices and collect data.

Components:
- **Base Connector**: Abstract base class with common functionality
- **Device-Specific Connectors**: Implementations for each platform
- PaloAlto Connector (PAN-OS REST API)
- EntraID Connector (Microsoft Graph API)
- SIEM Connector (Splunk/Elastic REST APIs)

Key Features:
- Connection pooling and retry logic
- Rate limiting and throttling
- Credential management
- Health checking
- Mock mode for testing

2. Data Processing Layer

Purpose: Normalize, validate, and enrich security events from different sources.

Components:
- **Event Ingestion Service**: Background service for continuous event collection
- **Normalization Engine**: Convert vendor-specific formats to common schema
- **Validation Service**: Ensure data quality and completeness
- **Enrichment Service**: Add context (geolocation, threat intel, asset info)

Common Event Schema:

```
{
  "id": "uuid",
  "source": "device_name",
  "source_type": "paloalto|entraid|siem",
  "timestamp": "2025-11-14T10:00:00Z",
  "event_type": "authentication|network|process|file",
  "severity": "critical|high|medium|low|info",
  "entities": {
    "user": "john.doe@company.com",
    "host": "LAPTOP01",
    "ip": "192.168.1.100",
    "file": "malware.exe",
    "hash": "sha256:abcd1234..."
  },
  "raw_data": {...}
}
```

3. Detection Layer

Purpose: Correlate events across time and sources to detect complex attacks.

Components:

Correlation Engine

- **Multi-Phase Detection**: Track attack progression through multiple stages
- **Entity Tracking**: Follow users, hosts, IPs across events
- **Temporal Windowing**: Correlate events within time windows (5 min - 24 hours)
- **Confidence Scoring**: Calculate confidence based on matched phases

Correlation Logic:

```
# Pseudocode for correlation
def correlate_events(events, time_window, min_phases):
    entities = extract_entities(events)

    for entity in entities:
        event_chain = get_events_by_entity(entity, time_window)
        matched_phases = match_phases(event_chain, operational_model)

        if len(matched_phases) >= min_phases:
            confidence = calculate_confidence(matched_phases)
            create_incident(entity, event_chain, confidence)
```

Operational Models

Pre-built detection patterns for common attacks:
- **Ransomware**: Delivery → Execution → Encryption → Impact
- **Data Theft**: Collection → Staging → Exfiltration
- **Intrusion**: Foothold → Privilege Abuse → Lateral Movement
- **Fraud**: Compromise → Transaction → Exfiltration
- **DoS**: Flood → Degradation → Exhaustion

Model Structure:

```
{
  "name": "Ransomware Detection",
  "phases": [
    {
      "name": "Delivery",
      "sources": ["proofpoint", "email_gateway"],
      "indicators": ["attachment with .exe", "suspicious links"]
    },
    {
      "name": "Execution",
      "sources": ["falcon", "endpoint_edr"],
      "indicators": ["powershell -enc", "suspicious process tree"]
    },
    {
      "name": "Encryption",
      "sources": ["falcon", "file_monitoring"],
      "indicators": ["mass file rename", ".locked extension"]
    }
  ],
  "correlation_fields": ["user", "computer", "ip"],
  "time_window": "60 minutes",
  "min_phases": 3
}
```

4. Incident Management Layer

Purpose: Manage security incidents through their lifecycle.

Components:
- **Incident Manager**: CRUD operations for incidents
- **Workflow Engine**: State transitions and approvals
- **Assignment Engine**: Auto-assign based on severity/type
- **Enrichment Service**: Add threat intel and context

Incident Lifecycle:

```
New → Assigned → Investigating → Contained →
  Resolved → Closed
```

Incident Structure:

```
{
  "id": "INC-12345678",
  "title": "Ransomware Attack Detected",
  "severity": "critical",
  "confidence": "high",
  "status": "investigating",
  "assignee": "analyst@company.com",
  "operational_model": "ransomware",
  "matched_phases": ["delivery", "execution", "encryption"],
  "entities": {
    "user": "john.doe@company.com",
    "host": "LAPTOP01",
    "ip": "192.168.1.100"
  },
  "events": [...],
  "timeline": [...],
  "playbooks_executed": [...]
}
```

5. Response Layer (SOAR)

Purpose: Automate security response actions across multiple platforms.

Components:

Playbook Engine

- **Decision Matrix**: Determine which playbooks to execute
- **Action Executor**: Execute actions across devices
- **Approval Workflow**: Manual approval for sensitive actions
- **Rollback**: Revert actions if needed

Playbook Library

Standard playbooks for common responses:

1. **Endpoint Containment**
   - Isolate host from network
   - Kill malicious processes

- Capture memory/disk for forensics
- Tag device in CMDB

2. **Identity Lockdown**
   - Disable user account
   - Revoke active sessions
   - Reset MFA
   - Force password change

3. **Network Containment**
   - Block IP/domain at firewall
   - Enable packet capture
   - Rate limit connections
   - Create quarantine VLAN

4. **Cloud Mitigation**
   - Revoke API keys/tokens
   - Lock cloud resources
   - Snapshot for forensics
   - Roll back configuration

Playbook Structure:

```
{
  "name": "Ransomware Containment",
  "trigger_conditions": {
    "operational_model": "ransomware",
    "confidence": "high",
    "matched_phases": [">=3"]
  },
  "steps": [
    {
      "action": "isolate_endpoint",
      "device": "falcon_edr",
      "params": {"host": "${incident.entities.host}"}
    },
    {
      "action": "disable_account",
      "device": "entraid",
      "params": {"user": "${incident.entities.user}"}
    },
    {
      "action": "block_ip",
      "device": "paloalto_ngfw",
      "params": {"ip": "${incident.entities.ip}"}
    },
    {
      "action": "create_ticket",
      "device": "servicenow",
      "params": {"incident_id": "${incident.id}"}
    }
  ],
  "approval_required": false,
  "auto_execute": true
}
```

6. Presentation Layer

Purpose: Provide user interfaces for security operations.

Components:

REST API (FastAPI)

- **OpenAPI/Swagger Documentation**: Auto-generated API docs
- **JWT Authentication**: Stateless authentication
- **Role-Based Access Control**: Admin, Analyst, Viewer roles
- **Rate Limiting**: Prevent abuse
- **Audit Logging**: Track all API calls

Key Endpoints:
- `/api/v1/auth/*` - Authentication
- `/api/v1/devices/*` - Device management
- `/api/v1/rules/*` - Detection rules
- `/api/v1/events/*` - Event management
- `/api/v1/incidents/*` - Incident management
- `/api/v1/detection/*` - Detection engine
- `/api/v1/playbooks/*` - Playbook execution

Web UI (React + TypeScript)

- **Dashboard**: Real-time metrics and status
- **Device Management**: Configure and monitor devices
- **Rule Management**: Create and manage detection rules
- **Event Browser**: Search and filter events
- **Incident Investigation**: Full incident details and timeline
- **Operational Models**: View and configure detection patterns
- **Playbook Management**: Configure and test playbooks

7. Data Layer

Purpose: Persistent storage for all framework data.

Components:

PostgreSQL Database

Primary data store with tables for:
- **devices**: Security device configurations
- **rules**: Detection rules and mappings
- **events**: Collected security events
- **incidents**: Security incidents
- **users**: User accounts and roles
- **playbooks**: Response playbook definitions
- **audit_logs**: Complete audit trail

Redis Cache

Used for:
- **Task Queue**: Celery background jobs
- **Session Storage**: User sessions

- **Rate Limiting**: API rate limit counters
- **Caching**: Frequently accessed data

Data Flow

Event Collection Flow

```
1. Scheduled Task (every 5 min)
   ↓
2. Sync Service calls Device Connector
   ↓
3. Device Connector fetches events via API
   ↓
4. Events normalized to common schema
   ↓
5. Events validated and enriched
   ↓
6. Events saved to PostgreSQL
   ↓
7. Events sent to Correlation Engine
```

Detection Flow

```
1. New event arrives
   ↓
2. Correlation Engine extracts entities
   ↓
3. Query recent events for same entities
   ↓
4. Match events against Operational Models
   ↓
5. Calculate confidence score
   ↓
6. If threshold met, create Incident
   ↓
7. Incident triggers Decision Matrix
   ↓
8. Appropriate Playbooks executed
   ↓
9. Actions performed on devices
   ↓
10. Incident updated with results
```

Scalability Considerations

Horizontal Scaling

- **Backend API**: Stateless design allows multiple instances
- **Event Ingestion**: Can be split by device type
- **Correlation Engine**: Can process events in parallel
- **Database**: Read replicas for queries

Performance Optimizations

- **Database Indexing**: Optimized indexes on frequently queried fields
- **Caching**: Redis for frequently accessed data

- **Background Jobs**: Celery for async processing
- **Connection Pooling**: Reuse connections to devices and database

High Availability

- **Load Balancing**: Distribute traffic across backend instances
- **Database Replication**: PostgreSQL streaming replication
- **Redundant Workers**: Multiple Celery workers
- **Health Checks**: Kubernetes liveness/readiness probes

Security Architecture

Authentication & Authorization

- **JWT Tokens**: Short-lived access tokens
- **Refresh Tokens**: Long-lived refresh tokens
- **Role-Based Access**: Admin, Analyst, Viewer roles
- **API Keys**: For service-to-service communication

Secrets Management

- **Environment Variables**: For development
- **AWS Secrets Manager**: For AWS deployments
- **Azure Key Vault**: For Azure deployments
- **Kubernetes Secrets**: For K8s deployments

Network Security

- **TLS/SSL**: All communication encrypted
- **Network Segmentation**: Isolated network zones
- **Firewall Rules**: Whitelist-based access
- **VPN**: Secure access to management interfaces

Data Security

- **Encryption at Rest**: Database encryption
- **Encryption in Transit**: TLS for all connections
- **Credential Encryption**: Device credentials encrypted in DB
- **Audit Logging**: Complete audit trail

Technology Choices

Why FastAPI?

- Modern Python web framework
- Automatic OpenAPI documentation
- Built-in data validation (Pydantic)
- Async support for performance
- Type hints for better code quality

Why React + TypeScript?

- Modern, component-based UI
- Type safety reduces bugs

- Large ecosystem of libraries
- Excellent developer experience
- Strong community support

Why PostgreSQL?

- ACID compliance
- Powerful query capabilities
- JSON support for flexible schemas
- Strong ecosystem
- Proven reliability

Why Docker/Kubernetes?

- Consistent environments
- Easy deployment
- Horizontal scaling
- Service isolation
- Industry standard

Monitoring & Observability

Application Metrics

- Request rate and latency
- Error rates
- Event ingestion rate
- Incident creation rate
- Playbook execution success rate

Infrastructure Metrics

- CPU and memory usage
- Database connections
- Queue depth
- Network I/O
- Disk usage

Logging

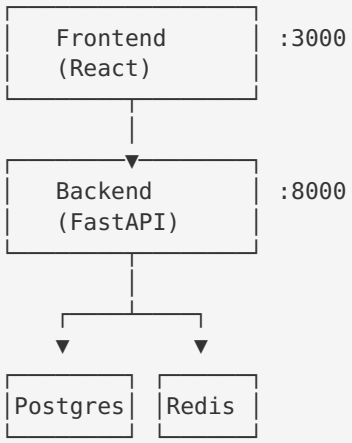
- Structured JSON logs
- Centralized log aggregation
- Log levels (DEBUG, INFO, WARNING, ERROR)
- Correlation IDs for request tracking

Alerting

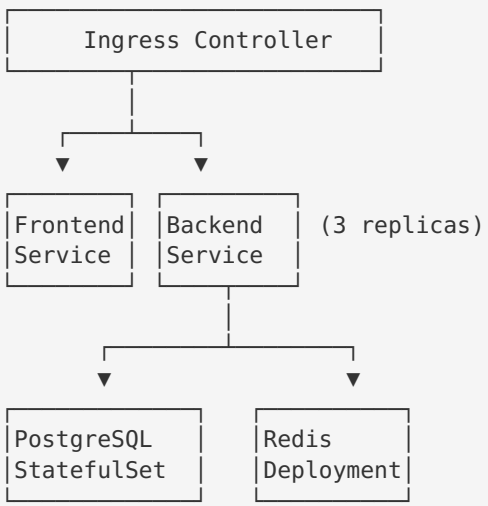
- Application health alerts
- Database performance alerts
- Integration failures
- Security events

Deployment Architecture

Docker Compose (Development)



Kubernetes (Production)



Future Architecture Enhancements

Version 1.1

- Message queue (RabbitMQ/Kafka) for event streaming
- Elasticsearch for event search
- Grafana for advanced dashboards
- Multi-tenancy support

Version 2.0

- AI/ML for anomaly detection
- Graph database for entity relationships
- Real-time streaming analytics
- Advanced threat hunting

For implementation details, see the Development Guide (./DEVELOPMENT.md)