

# Smart Factory IoT - System Architecture

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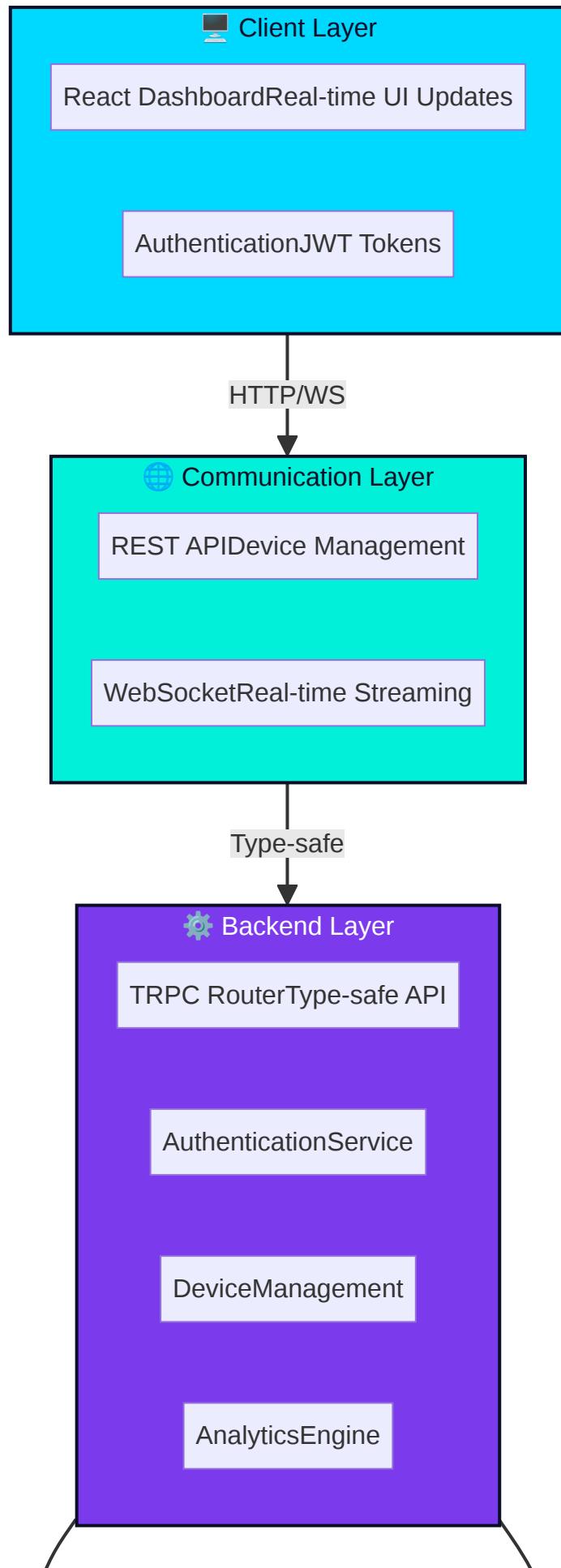
## Overview

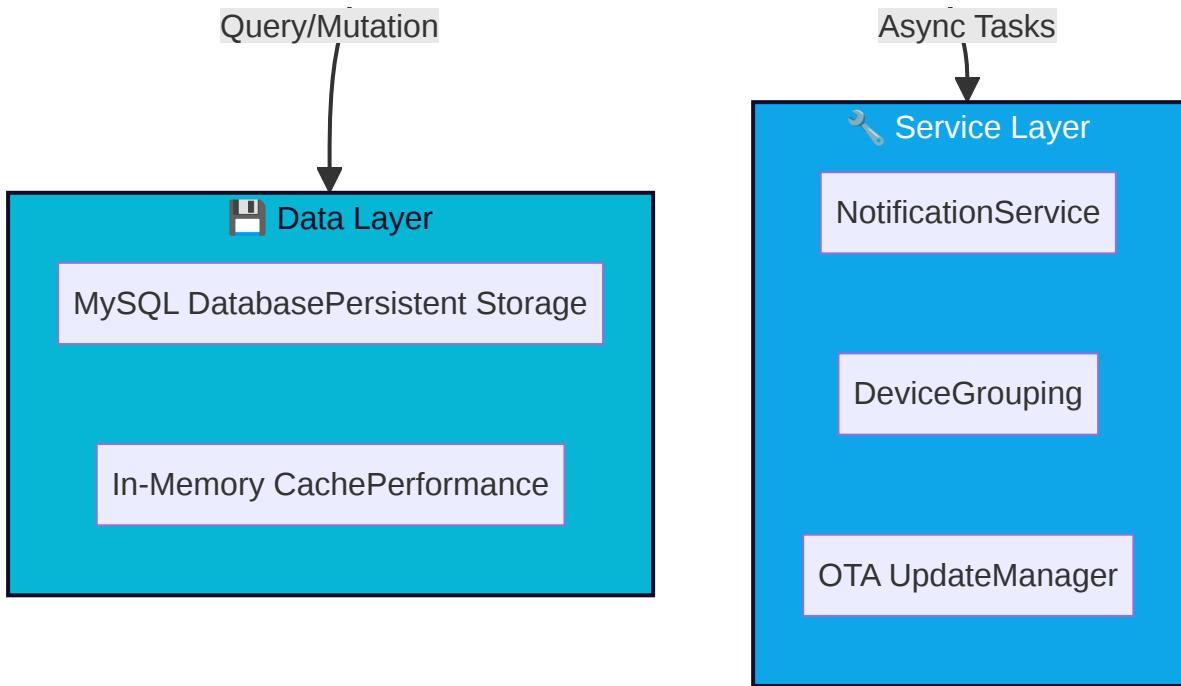
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The Smart Factory IoT platform is a comprehensive real-time industrial monitoring and control system built with modern web technologies. It provides real-time device monitoring, alert management, and analytics for manufacturing environments.

# System Architecture Diagram

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## Component Details

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### Client Layer

- **React Dashboard:** Interactive UI for real-time monitoring
- **Authentication:** JWT-based secure authentication
- **State Management:** React Context + TRPC Query Client

### Communication Layer

- **REST API:** Device CRUD operations, configuration
- **WebSocket:** Real-time sensor data streaming
- **TRPC:** Type-safe RPC framework for frontend-backend communication

### Backend Layer

- **TRPC Router:** Centralized API endpoint management
- **Authentication Service:** JWT token validation and user management
- **Device Management:** CRUD operations and device grouping
- **Analytics Engine:** OEE calculations and reporting

## Data Layer

- **MySQL Database:** Persistent storage for all entities
- **In-Memory Cache:** Performance optimization for frequently accessed data

## Service Layer

- **Notification Service:** Email/SMS alerts for critical events
- **Device Grouping:** Batch operations and analytics aggregation
- **OTA Update Manager:** Firmware update distribution and tracking

## Data Flow

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### Real-time Monitoring Flow

```
Device → WebSocket → Backend → Database  
↓  
Dashboard ← Real-time Updates
```

### Alert Flow

```
Sensor Reading → Threshold Check → Alert Generated  
↓  
Notification Service  
↓  
User Notification
```

## Device Management Flow

```
User Action → REST API → Backend Service  
↓  
Database Update  
↓  
Response to Client
```

## Technology Stack

Layer	Technology	Purpose
Frontend	React 19	UI Framework
Frontend	TypeScript	Type Safety
Frontend	Tailwind CSS	Styling
Frontend	TRPC Client	Type-safe API
Backend	Node.js	Runtime
Backend	Express.js	Web Framework
Backend	TRPC	RPC Framework
Database	MySQL	Data Storage
Real-time	WebSocket	Live Updates
Auth	JWT	Token-based Auth

## Key Features

### 1. Real-time Monitoring

- Live device status updates via WebSocket
- Sensor data streaming with minimal latency

- Automatic reconnection handling

## 2. Alert Management

- Threshold-based alerts
- Multiple severity levels (critical, warning, info)
- Alert acknowledgment and resolution tracking

## 3. Device Management

- CRUD operations for devices
- Device grouping and batch operations
- Device health monitoring

## 4. Analytics

- OEE (Overall Equipment Effectiveness) calculation
- Historical data analysis
- Trend reporting

## 5. Firmware Management

- OTA (Over-The-Air) update distribution
- Update status tracking
- Rollback capability

# Security Architecture

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## Authentication

- JWT-based token authentication
- Secure password hashing with bcryptjs
- Token refresh mechanism

## Authorization

- Role-based access control (RBAC)
- User, Operator, Admin roles
- Resource-level permissions

## Data Protection

- HTTPS/TLS encryption in transit
- Database encryption at rest
- Input validation and sanitization

# Scalability Considerations

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## Horizontal Scaling

- Stateless backend design
- Database connection pooling
- Load balancing ready

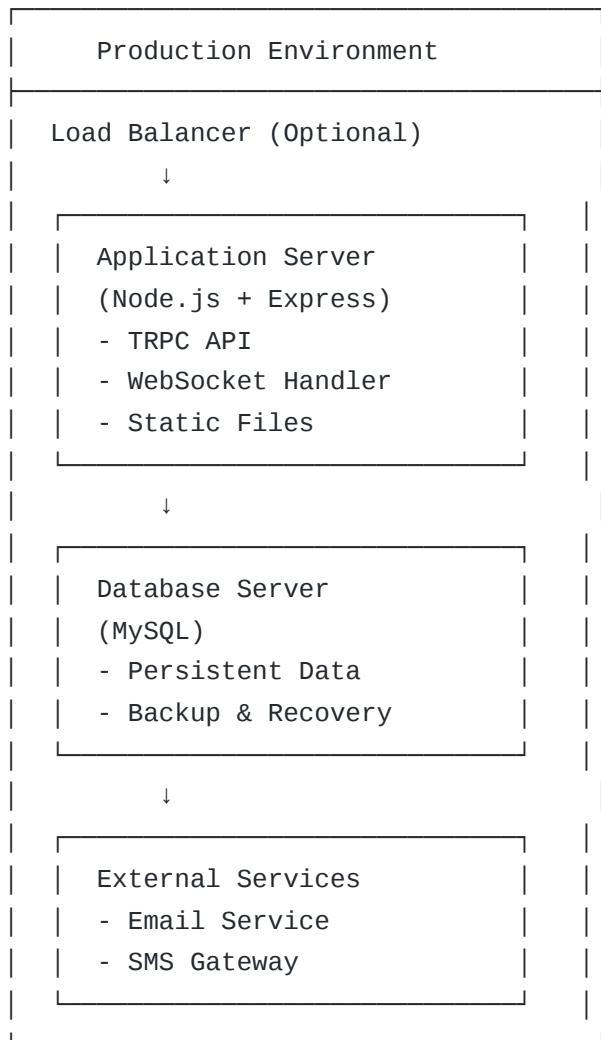
## Performance Optimization

- Query optimization with indexes
- Caching layer for frequently accessed data
- Batch operations for bulk updates

## Monitoring & Observability

- Comprehensive logging
- Error tracking
- Performance metrics

# Deployment Architecture



# Development Workflow

## 1. Local Development

- Start dev server: `pnpm dev`
- Hot module reloading enabled
- Mock data seeding available

## 2. Testing

- Unit tests: `pnpm test`

- Type checking: `pnpm check`
- Build verification: `pnpm build`

### 3. Deployment

- Build production bundle: `pnpm build`
- Run deployment script: `./deploy.sh`
- Database migrations: `pnpm db:push`

## SOLID Principles Implementation

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### Single Responsibility

- Each component has one clear purpose
- Services are focused and specialized
- Separation of concerns throughout

### Open/Closed

- Components extensible through props
- Services extensible through interfaces
- Plugin architecture for notifications

### Liskov Substitution

- Consistent interfaces across services
- Predictable behavior across implementations
- Type-safe substitution

### Interface Segregation

- Minimal required props per component
- Focused service interfaces
- Specific API endpoints

## Dependency Inversion

- Services depend on abstractions
- Dependency injection pattern
- No hard dependencies on implementations

## Performance Metrics

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- **API Response Time:** < 200ms (p95)
- **WebSocket Latency:** < 100ms
- **Dashboard Load Time:** < 2s
- **Database Query Time:** < 50ms (p95)
- **Memory Usage:** < 512MB
- **CPU Usage:** < 50% under normal load

## Future Enhancements

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### 1. Machine Learning

- Predictive maintenance
- Anomaly detection
- Pattern recognition

### 2. Advanced Analytics

- Real-time dashboards
- Custom reporting
- Data export capabilities

### 3. Integration

- Third-party API integrations
- MQTT support
- Cloud connectivity

#### **4. Scalability**

- Microservices architecture
- Kubernetes deployment
- Multi-region support