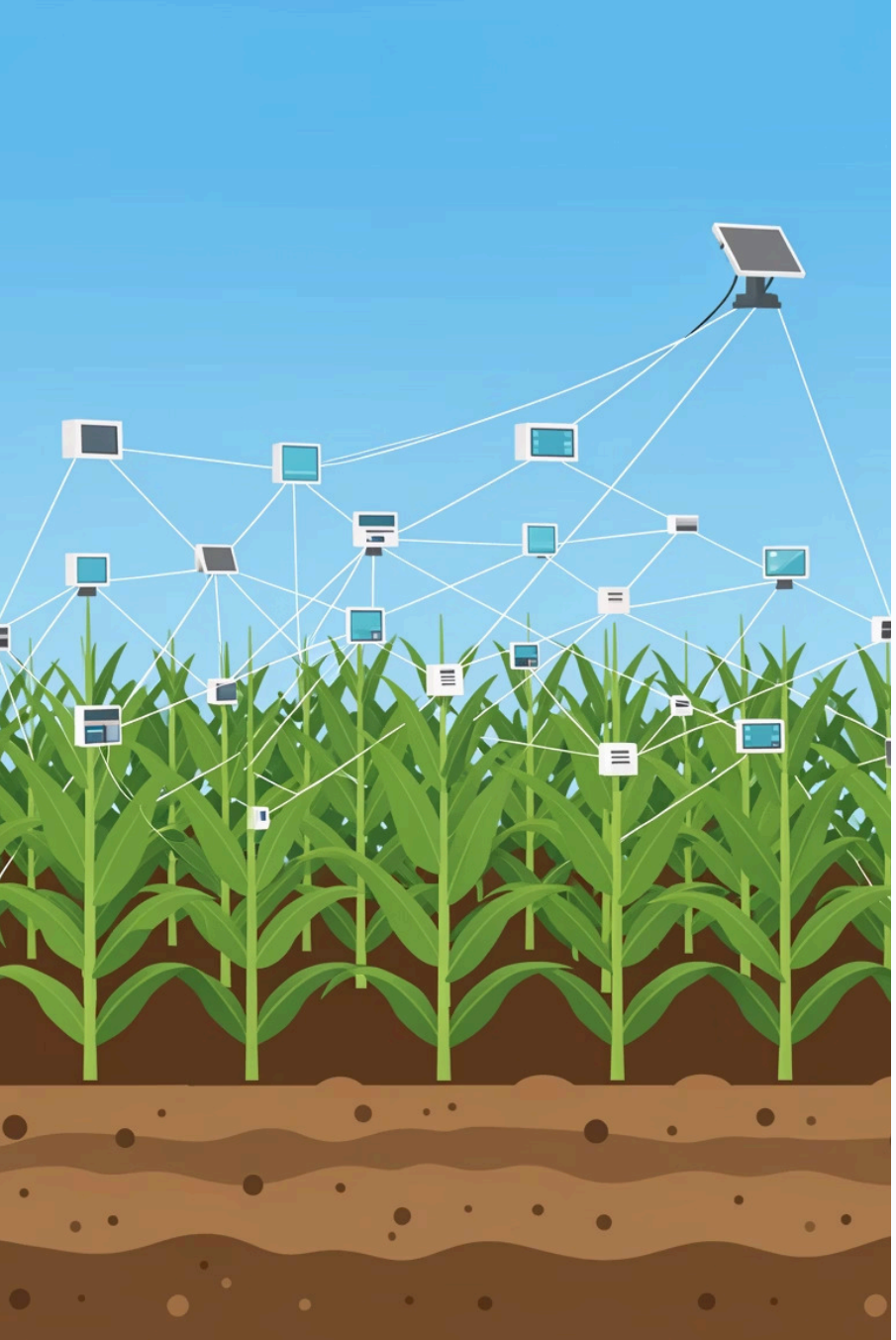
Distributed Cloud-Edge-IoT Architecture for Precision Agriculture

Real-time soil monitoring, anomaly detection, and intelligent crop recommendations



CHALLENGE

The Agricultural Data Problem

Traditional Approach

- Direct cloud transmission
- High latency (seconds)
- Network dependency
- Single point of failure

Our Solution

- Distributed processing
- Edge intelligence
- 0.4-0.9s response time
- Fault-tolerant design

ARCHITECTURE

Three-Layer Computing Continuum

01

IoT Layer

5 simulated devices measuring N, P, K, temperature, humidity, pH, rainfall

02

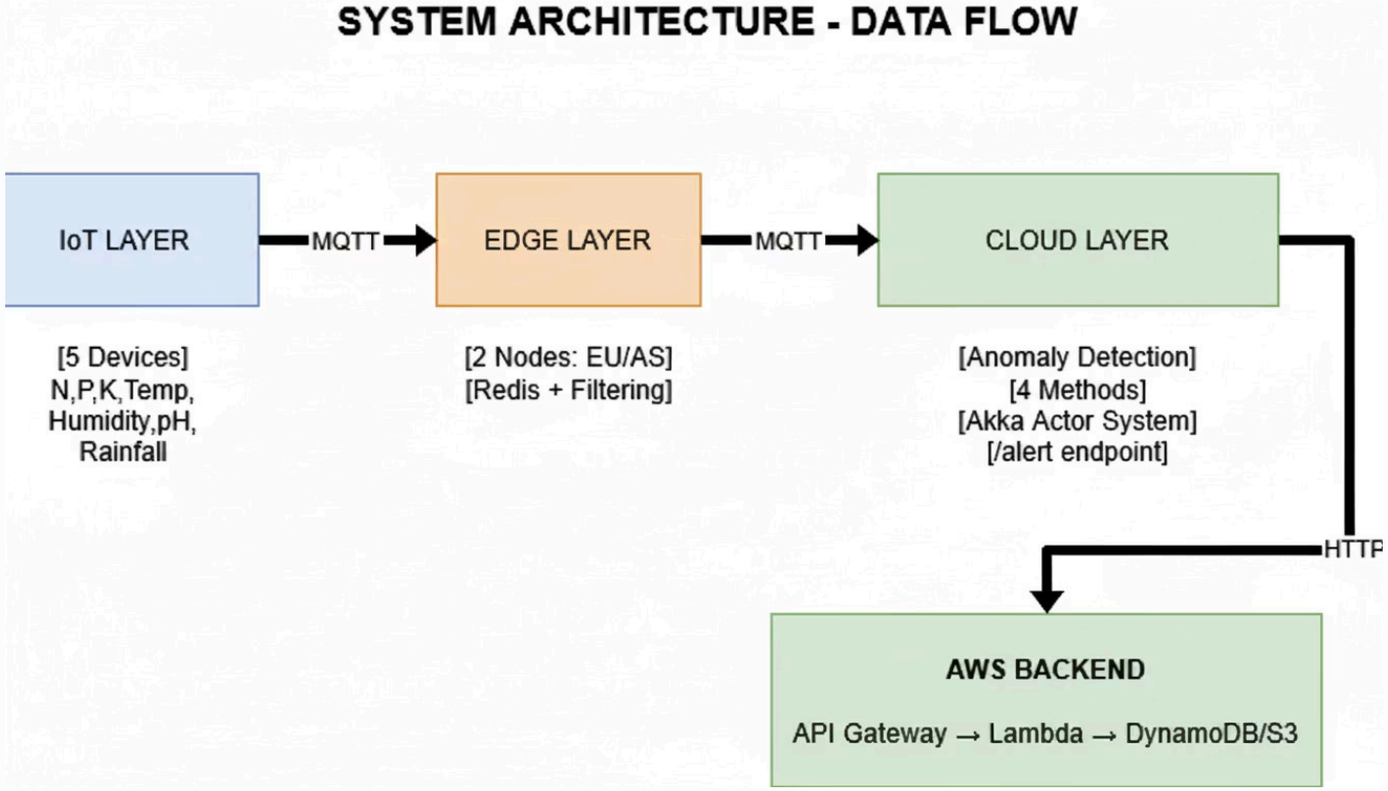
Edge Layer

2 geographic nodes (Europe/Asia) with Redis state management and filtering

03

Cloud Layer

Multi-method anomaly detection + Akka actor coordination system



Data Flow & Communication

IoT Devices

MQTT publish to farm/data

Edge Nodes

Geographic filtering + Redis state

Cloud Analysis

Statistical detection + Akka coordination

AWS Backend

Lambda → DynamoDB/S3

Protocol stack: MQTT for streaming, HTTP for coordination, Akka messaging for internal communication

DETECTION

Multi-Method Anomaly Detection

Z-Score Analysis

Flags deviations >2.5σ from historical mean

IQR Method

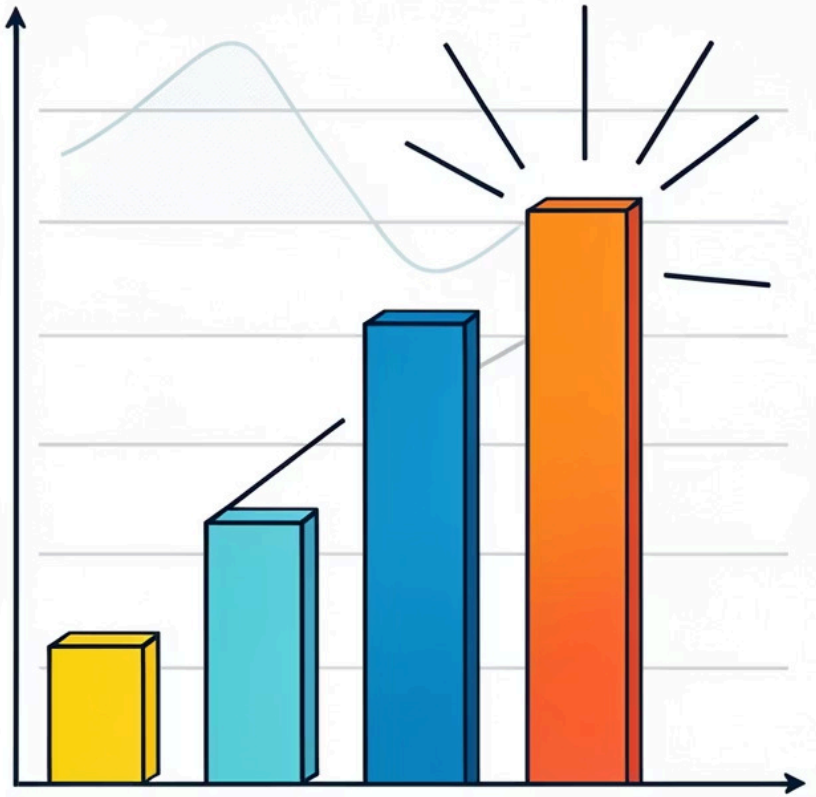
Statistical outlier identification

Change Rate

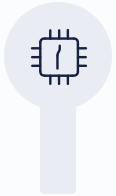
Detects sudden >30% parameter shifts

Threshold Validation

Cross-reference agronomic limits

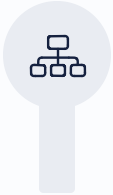


Akka Actor System Architecture



Device Actors

Individual sensor stream management



Region Actors

Geographic aggregation + soil classification

Global Coordinator

System-wide orchestration

Alarm Dispatcher

Notification propagation

Benefits

- Concurrent processing
- Fault isolation
- Location transparency
- Type-safe protocols

AWS INTEGRATION

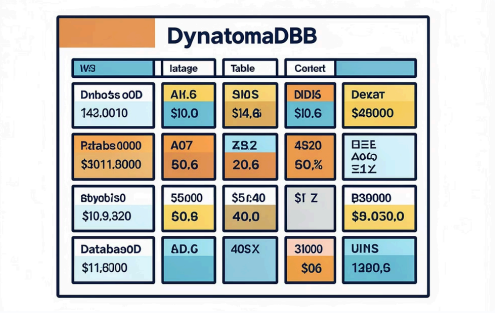
Serverless Cloud Backend

API Gateway

HTTP endpoint /cloud/update with 100ms response

Lambda Functions

Python event processing, 50-200ms execution time



DynamoDB

Single-digit ms writes, structured event storage

S3 Archives

Long-term log retention, 99.9% availability

System Performance Metrics

0.4-0.9s

End-to-End Latency

From sensor reading to cloud processing

95%

Detection Rate

For clear anomalies (3σ deviations)

700MB

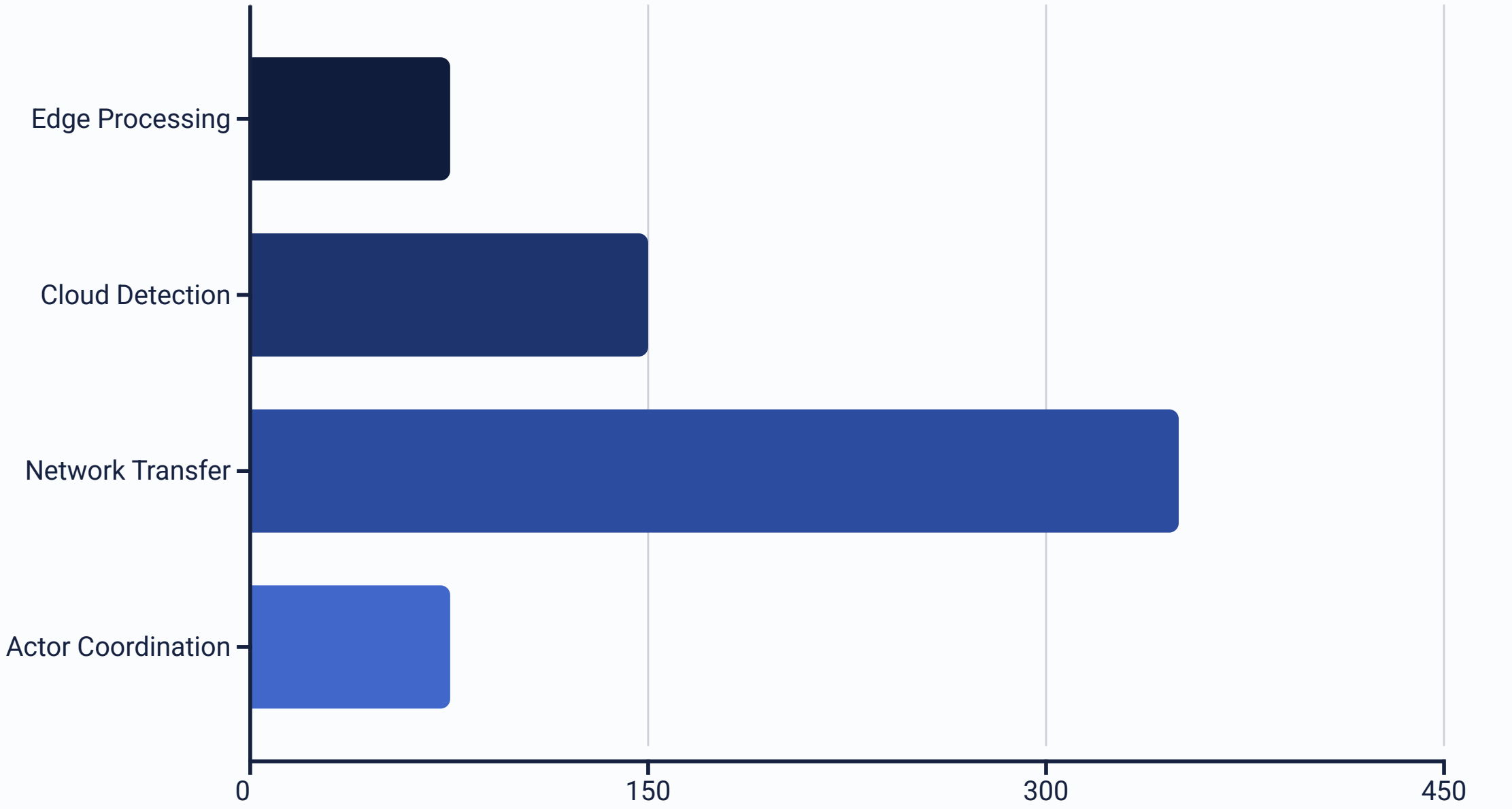
Total Memory

Across all Docker containers

5-10%

False Positives

Under normal operating conditions



FUTURE

Key Takeaways & Next Steps

Achievements

- Complete IoT-Edge-Cloud continuum
- Robust multi-method detection
- Scalable Akka coordination
- Full AWS serverless integration
- Containerized deployment

Future Enhancements

- Machine learning models
- Akka Cluster distribution
- Real hardware integration
- Web monitoring dashboard
- Federated learning research

> *"Enabling sustainable, data-driven farming through distributed systems"*