Farm Controller Layer (Local / Federated)

See overview: System Architecture Overview

The **Farm Controller Layer** is the on-site AOFS controller that provides **local supervision, configuration, and federation**. It sits between the Field Controller (authoritative safety layer) and HQ / Federated Controllers.

This layer is **offline-first**, **federation-capable**, and **authoritative for non-critical decisions**.

1. Responsibilities

The Farm Controller Layer **must**:

- Aggregate telemetry from Field Controllers:
  1. Soil moisture sensors
  2. Tank levels
  3. Flow meters
  4. Power usage
  5. Optical monitoring data
- Provide a **local operator interface** for monitoring and configuration.
- Validate all operator requests against Field Controller safety rules.
- Manage irrigation schedules and configuration updates locally.
- Enable **push/pull federation** with other Farm Controllers or HQ Controllers.
- Log all local actions, operator inputs, and synchronization events for auditability.

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2. Offline Operation

1. **Full local autonomy:**

- Must operate independently of network connectivity.
- Irrigation schedules, sensor monitoring, and fail-safe enforcement continue uninterrupted.

2. **Local operator interface:**

- Operators can view data and update configurations.
- Only non-critical adjustments are applied locally; safety-critical overrides are blocked by Field Controller logic.

3. **Local data storage:**

- Telemetry and logs are persisted locally.
- Data is queued for synchronization when connectivity is restored.

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3. Federation Model

Farm Controllers support a **Git-like push/pull model**:

- **Pull:**
  1. Farm Controller can pull configuration, software, or firmware updates from HQ or peer controllers.
  2. Pulled changes are validated against local rules and logged.
- **Push:**
  1. Farm Controller can push logs, irrigation events, and audit data to HQ or peer controllers.
  2. Push is queued if connectivity is unavailable.
- **Peer-to-peer:**
  1. Farm Controllers can synchronize directly with other farms for configuration and data exchange.
  2. Conflicts are resolved using deterministic rules (see section 4).

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4. Conflict Resolution

When multiple controllers modify configurations or schedules:

1. **Timestamp precedence:**
   - The most recent authorized change takes effect.
1. **Operator approval:**
   - In case of conflicting schedule changes, local farm operators must approve before applying.
1. **Field Controller enforcement:**
   - Field Controller always vetoes any configuration that violates **safety constraints**.
1. **Logging:**
   - All conflict events must be logged with timestamps, operator ID, and resolution outcome.

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5. Authority Rules

1. **Safety authority:**

- Field Controller is authoritative for safety-critical decisions.
- Farm Controller cannot override irrigation cut-offs, pump safety, or flood prevention rules.

2. **Configuration authority:**

- Farm Controller is authoritative for **non-critical configurations** and local schedules.
- HQ or peer controllers may propose updates, but local rules take precedence.

3. **Audit and compliance:**

- All configuration changes, operator interactions, and sync operations must be logged.
- Logs must be retained locally and transmitted to upstream controllers when possible.

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6. Human Interface

- The Farm Controller **must provide a full local UI**:
  1. Monitoring dashboards for all irrigation zones
  2. Configuration of schedules and thresholds
  3. Alerts and notifications for operators
- Operator actions are validated against Field Controller safety rules.
- The interface supports **manual requests**, but these cannot bypass critical safety decisions.

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7. Implementation Notes

- Hardware: Industrial-grade single-board computers (e.g., NanoPi, Raspberry Pi).
- Communication protocols: LAN, WiFi, or cellular for synchronization.
- Data format: Structured, versioned, and compatible with HQ controller ingestion.
- Security: All communications must be encrypted; operator authentication is required.
- Scalability: Supports multiple Field Controllers per farm; multiple zones; multi-farm federation.

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8. Compliance Notes

- Any AOFS-compliant Farm Controller **must implement offline operation, federation, logging, and safety validation**.
- Failure to preserve Field Controller authority or provide audit logs **invalidates compliance**.
- Synchronization conflicts must follow the deterministic resolution rules defined above.

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