Air Node (Gaia sentinel)

Gaia Sentinel

Standard Operating Procedure (SOP)

Project Name: Gaia Sentinel – Smart Environmental Monitoring Ecosystem
Version: 2.0
Prepared By: Gaia Sentinel Development Team

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1. Purpose

This document defines the Standard Operating Procedure (SOP) for the development, deployment, operation, maintenance, and cloud integration of the Gaia Sentinel system.

Gaia Sentinel is a complete IoT-based environmental monitoring ecosystem designed to collect, process, store, and visualize environmental data both locally and through a private cloud infrastructure hosted on a home server.

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2. System Overview

Gaia Sentinel is a scalable environmental monitoring platform consisting of:

- Air Node (Hardware Monitoring Unit)
- Local Web Dashboard (ESP32 hosted)
- Gaia Sentinel Cloud System (Home Server Hosted)
- Central Database (Self-hosted)
- Real-time Data Streaming via WebSocket

The system supports both standalone local deployment and cloud-synchronized multi-node architecture.

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3. System Architecture

3.1 Hardware Architecture

Core Controller

- ESP32 Microcontroller

Sensors Used

Sensor	Parameter Measured	Purpose
DHT22	Temperature & Humidity	Environmental monitoring
MQ135	Air Quality (CO_2, NH_3, Benzene, Smoke)	AQI estimation
MQ7	Carbon Monoxide (CO)	Toxic gas detection
MQ6	LPG, Butane	Gas leak detection
MQ2	Smoke, Methane	Combustion detection

Power Requirements

- 5V regulated input
- Optional battery backup

Enclosure

- Carbon-neutral material
- Ventilated for accurate gas sensing
- Weather-resistant for deployment

3.2 Software Architecture

Communication Layer

- WebSocket server for real-time bidirectional communication
- HTTP server for configuration and dashboard

Local System

- ESP32 hosts a local web interface
- Real-time data visualization
- WiFi configuration portal

Cloud System (New Integration)

Gaia Sentinel Cloud System runs on a dedicated home server.

Features include:

- Centralized database storage
- Multi-node Air Node integration
- Long-term data retention
- Historical analytics
- Remote access capability

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4. Data Collection Parameters

The system continuously monitors the following parameters:

4.1 Air Quality Index (AQI)

Calculated using MQ135 sensor readings with calibrated gas concentration mapping.

4.2 Carbon Monoxide (CO)

Measured using MQ7 sensor and converted to ppm for health risk evaluation.

4.3 Temperature

Measured using DHT22 sensor.

4.4 Humidity

Measured using DHT22 sensor as relative humidity percentage.

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5. Deployment Procedure

5.1 Hardware Setup

1. Connect sensors to ESP32:
   - DHT22 → Digital GPIO
   - MQ sensors → Analog GPIO
2. Ensure proper voltage regulation.
3. Install components inside enclosure.

4. Verify adequate ventilation for gas sensors.

5.2 Firmware Installation

1. Connect ESP32 to system.
2. Upload Gaia Sentinel firmware.
3. Verify:
   - Sensor initialization
   - WiFi setup mode
   - WebSocket server startup
   - Cloud endpoint configuration

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6. Network Configuration

6.1 First-Time Setup

- ESP32 creates an access point.
- User connects to the device WiFi.
- Access configuration portal via:
  http://192.168.4.1

6.2 WiFi Setup

- Enter SSID
- Enter Password
- Save configuration
- Device reboots and connects to network

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7. Local Dashboard Features

The local web interface allows:

- Real-time AQI display
- Carbon Monoxide monitoring
- Temperature and Humidity display
- Graph-based visualization
- Alert status indicators
- WiFi configuration management

The interface is designed to be user-friendly and requires no coding knowledge.

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8. Gaia Sentinel Cloud System

8.1 Cloud Architecture

The cloud system runs on a private home server and includes:

- Backend API service
- WebSocket gateway
- Database server
- Web dashboard interface

8.2 Database Hosting

The database is self-hosted on the home server.

Functions include:

- Storing timestamped sensor data
- Node identification and mapping
- Historical data retrieval
- Data export capability
- Multi-node scalability

8.3 Data Flow

1. Sensors collect data.
2. ESP32 processes raw values.
3. Data is streamed locally via WebSocket.
4. Simultaneously, data is transmitted to Gaia Sentinel Cloud.
5. Cloud stores data in database.
6. Cloud dashboard provides remote analytics and visualization.

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9. Alert System

9.1 Alert Levels

Level	Condition	Action
Normal	Within safe range	No action
Moderate	Slight deviation	Warning indicator
High	Unsafe levels	Alert triggered
Critical	Hazardous	Continuous alert and notification

9.2 Trigger Conditions

- Carbon monoxide exceeding threshold
- High AQI levels
- Gas leak detection
- Abnormal temperature spikes

Alerts can be generated both locally and on the cloud dashboard.

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10. Standalone and Scalable Deployment

Gaia Sentinel supports:

- Single standalone Air Node operation
- Multiple Air Nodes connected to central cloud
- Indoor and outdoor deployment
- Educational and industrial applications

The modular design allows easy expansion.

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11. Maintenance Procedure

Weekly

- Inspect sensor readings
- Verify network stability

Monthly

- Clean sensor openings
- Recalibrate MQ sensors

Annually

- Replace degraded gas sensors
- Perform firmware updates
- Database backup verification

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12. Security Considerations

- Secure WiFi credentials
- Encrypted communication (recommended for cloud)
- Firewall protection for home server
- Regular database backups

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13. Future Enhancements

- AI-based pollution prediction
- GPS-based pollution heatmaps
- Mobile application integration
- Cloud backup redundancy
- Government data integration
- Automated report generation (PDF/CSV)

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14. Conclusion

Gaia Sentinel is a comprehensive IoT environmental monitoring ecosystem combining:

- Embedded hardware sensing
- Real-time local visualization
- Private cloud infrastructure
- Centralized database hosting
- Intelligent alert system

The system is scalable, cost-effective, modular, and suitable for smart home, research, educational, and industrial applications.