Sensor for Wind Turbine

System Description

Abstract

This document provides the System Description (SysD) for the *Sensor for Wind Turbine* system. The system measures turbine operational parameters such as vibration, temperature, and rotational speed, and provides this data as telemetry to Arrowhead-compliant clients via the *telemetrySensorTurbine* service.

Contents

1 Overview

This document describes the **Sensor for Wind Turbine** system, which provides real-time measurement and reporting of key mechanical and environmental parameters from a wind turbine's nacelle and rotor. It integrates sensors, embedded control software, and Arrowhead-compliant communication interfaces.

The sensor system produces data used for predictive maintenance, turbine control optimization, and performance analytics.

A SysML use case diagram would show: - The sensor node as an actor providing data to the Supervisory Control System. - The produced telemetry data flowing via Arrowhead Service interfaces. - Connections to local controllers, gateways, and monitoring dashboards.

1.1 Significant Prior Art

The system builds upon the Eclipse Arrowhead framework for secure and interoperable service-based industrial systems. It leverages standard IoT sensor communication technologies such as MQTT and HTTP/TLS, along with JSON and SensML data encoding. The architecture follows best practices for distributed monitoring systems in renewable energy sectors.

1.2 How This System Is Meant to Be Used

The Sensor is deployed in each turbine, typically within the nacelle. It continuously measures temperature, vibration, and rotor speed, periodically transmitting aggregated telemetry data to a central monitoring service.

Typical usage scenarios include: - **Predictive maintenance:** detecting early signs of bearing wear or imbalance. - **Performance tracking:** correlating environmental data with turbine efficiency. - **Condition monitoring:** enabling real-time dashboards.

A SysML block diagram would illustrate: - Sensor hardware nodes (temperature, vibration, rotational speed) - Embedded microcontroller system - Secure communication stack (HTTP/TLS) - Arrowhead service interfaces for telemetry publication

1.3 System Functionalities and Properties

1.3.1 Functional properties of the system

- Continuous acquisition of vibration, temperature, and rotation speed data.
- Aggregation and timestamping of telemetry data.
- Transmission of telemetry data via the `turbineTelemetryServicee` service.
- Health monitoring and echo capability to check availability.

1.3.2 Configuration of system properties

Configuration parameters include:

- Sampling frequency for each sensor type.
- Communication interval for telemetry transmission.
- Calibration coefficients for each sensor channel.

1.3.3 Data stored by the system

The system stores:

- Recent telemetry history (rolling buffer).
- Device metadata (ID, location, calibration).
- Security credentials (Arrowhead certificates, tokens).

1.3.4 Non-functional properties

- **Security:** All communication uses TLS 1.3 and Arrowhead certificate-based authentication.
- **Reliability:** Buffered telemetry ensures delivery after connection loss.
- **Energy consumption:** Low-power embedded controller with adaptive sleep.
- **Latency:** Data transmission typically under 500 ms.
- **Safety:** Electrically isolated from turbine control bus.

1.3.5 Stateful or stateless

The system is partially stateful. It maintains state for:

- Measurement buffers and timestamps.
- Registration and validity of Arrowhead service endpoints.
- Security session data for TLS connections.

1.4 Important Delimitations

- The system does **not** perform local fault prediction — analytics are done by external systems.
- It does **not** control turbine actuators directly.
- Connectivity assumes stable power and network infrastructure.

2 Services

2.1 Produced Services

Sensor Service (turbineTelemetryService)
The system produces the *turbineTelemetry* service, which is fully described in:

- Service Description (SD): `turbineTelemetryService-SD`
- Interface Design Description (IDD): `turbineTelemetryService-IDD`

This service provides real-time and historical telemetry data generated by turbine sensors. It is consumed by turbine controllers, monitoring dashboards, and analytics systems that rely on accurate and timely sensor readings for operational optimization, predictive maintenance, and performance tracking.

The following operations are supported:

- `registerTelemetry` – Register new telemetry readings from the turbine sensor.
- `getSensorData` – Retrieve current or historical telemetry values.
- `echo` – Verify the operational and communication status of the sensor.

System Monitor Service (sysMonitor)
Additionally, the system produces the *sysMonitor* service, providing system-level health, performance, and diagnostic metrics. This service enables system operators or supervisory controllers to assess the operational state of the sensor subsystem and detect anomalies or degraded performance conditions.

2.2 Consumed Services

The sensor system consumes several core Arrowhead framework services to enable secure, orchestrated, and discoverable operation within the local cloud:

- **Service Discovery** : To discover available infrastructure and application services in the Arrowhead local cloud.
- **Device Discovery** : To detect connected sensor devices and manage their identity and connectivity parameters.
- **GetPublicKey** : To retrieve public keys for establishing secure communication channels and verifying digital signatures.
- **Service Orchestration** : To dynamically orchestrate service consumption and facilitate flexible data exchange with subscribers.
- **Consumer Authentication** : To authenticate external consumers before granting access to telemetry data.
- **Global Service Discovery** : To enable communication between local clouds.

Each consumed service adheres to the Arrowhead framework's interoperability requirements and security model, ensuring reliable, authorized, and traceable data exchange within the local automation environment.

3 Security

3.1 Overview

The system supports both secure and non-secure operation modes, with secure mode being the default. It uses Arrowhead-compliant X.509 certificates issued by the local cloud's certificate authority.

3.2 Security Model

- **Protocols supported:** HTTP 1.1 with TLS 1.3.
- **Data protection:** End-to-end encryption of telemetry payloads.
- **Authentication:** Mutual TLS authentication between provider and consumer.
- **Authorization:** Enforced via Arrowhead Authorization Core System.
- **Integrity:** Hash-based message integrity checks.
- **Availability:** Echo endpoint enables system liveness verification.

4 References

5 Revision History

5.1 Amendments

No.	Date	Version	Subject of Amendments	Author
1	2024-06-05	4.4.1	Initial draft for turbine Sensor system	Arrowhead IoT Team
2	2024-09-20	4.4.1	Added service linkage to telemetrySensorTurbine IDD	Arrowhead Consortium
3	2025-02-14	4.4.1	Security and non-functional updates	Arrowhead Security WG

5.2 Quality Assurance

No.	Date	Version	Approved by
1	2025-02-15	4.4.1	Arrowhead Architecture Board