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AI-Driven Control and Optimization SoS

System Description

Abstract

This document describes the AI-Driven Control and Optimization System of Systems (SoS) for an ore handling process with three cascaded levels of control and optimization. The SoS integrates multiple subsystems (e.g., PowerSensor, Conveyor Motor Control, Ore Feeder) through Arrowhead-compliant service-oriented communication.

Contents

1 Overview

This document describes the **AI-Driven Control and Optimization System of Systems (SoS)** designed for an ore handling process with three cascaded levels of control and optimization. The SoS integrates multiple subsystems such as the PowerSensor, Conveyor Motor Control, and Ore Feeder through Arrowhead-compliant service-oriented communication [1].

The system aims to optimize energy efficiency, process operation, and operational safety by enabling local control at the subsystem level and coordinated optimization at the supervisory and cloud levels.

The rest of this document is organized as follows. In Section 1.1, we reference major prior art capabilities of the SoS. In Section 1.2, we describe the intended usage of the SoS. In Section 1.3, we describe fundamental properties provided by the SoS. In Section 1.4, we describe important delimitations of the SoS. In Section 2, we describe the microsystems (abstract level with references to their SysDs) which constitute the SoS. In Section 3, we describe the security capabilities of the SoS.

1.1 Significant Prior Art

The concept of hierarchical and distributed control originates from traditional industrial automation and process optimization systems. This SoS extends these ideas by combining distributed sensing, supervisory coordination, and cloud-based AI optimization using service-oriented interoperability [1].

1.2 How This SoS Is Meant to Be Used

The SoS is designed for continuous monitoring and control of ore handling operations, enabling optimal performance under varying conditions.

It consists of three cascaded levels:

- **Level 1 – Local Control:** Each subsystem (PowerSensor, Ore Feeder, Conveyor Motor) executes its own low-level control logic, performs real-time measurements, and runs self-diagnostic routines to ensure stable operation.
- **Level 2 – Supervisory Control:** The supervisory level manages and coordinates the operation of all local subsystems. It optimizes energy consumption, balances material flow between the feeder and conveyor, and performs fault detection and recovery actions when anomalies are detected.
- **Level 3 – Cloud Optimization:** The top layer collects combined process data from the supervisory system and applies AI-based optimization. It continuously optimizes control parameters and schedules predictive maintenance tasks to improve system performance and efficiency.

1.3 SoS functionalities and properties

1.3.1 Functional properties of the SoS

- Collect and aggregate sensor data from multiple PowerSensor subsystems.
- Execute AI-based optimization algorithms in the cloud.
- Distribute optimized control parameters back to the local controllers.
- Handle fault detection and system recovery.

1.3.2 Configuration of SoS properties

System configuration includes:

- Network addresses and Arrowhead registry information.
- Subsystem calibration and scaling constants.
- Data transmission intervals and optimization cycles.

1.3.3 Data stored by the individual microsystem

Each subsystem (PowerSensor, MotorControl, etc.) may temporarily buffer measurement data in memory for validation or short-term averaging. For long-term data storage and trend analysis, the system is intended to integrate with a **historian service**. The historian collects and stores time-series process data from all subsystems, enabling analysis of performance trends and energy usage. (Not included in the current course system implementation.)

1.3.4 Non functional properties

- **Security:** Arrowhead-compliant TOKEN authentication and TLS encryption [1, 2].
- **Safety:** Redundant communication channels and error detection.
- **Energy consumption:** Optimization targets reduced power use during low-load periods.
- **Latency:** Real-time responsiveness at the local control level; batch updates for cloud optimization.
- **Scalability:** Modular structure allows new subsystems to be added with minimal reconfiguration.

1.3.5 Stateful or stateless

The SoS is **stateful**, maintaining operational history, calibration data, and learned optimization parameters across its distributed components.

1.4 Important Delimitations

This SoS focuses solely on ore-handling process optimization and control. It does not include physical actuator design, network infrastructure, or detailed AI model implementation. External systems (e.g., ERP or maintenance scheduling) are considered out of scope.

2 Services

This section describes the services produced and consumed by the constituent subsystems (System Descriptions, SysDs) within the *AI-Driven Control and Optimization SoS*. Each service entry specifies the provider (SysD), the purpose of the service, and references to associated Arrowhead documentation artifacts (SysD, SD, IDD, SysDD).

2.1 Produced service

with references to SD and IDD documents

- **MotorControl_SD** — provided by the *Conveyor Motor SysD*.
  Purpose: Supplies control functionality for the conveyor motor subsystem. It receives optimized parameters from higher-level controllers and executes them to regulate speed, torque, and operational safety.
  References: MotorControl SysD, MotorControl SD, MotorControl IDD, Conveyor Motor SysDD.
- **FeederControl_SD** — provided by the *Ore Feeder SysD*.
  Purpose: Enables control of the ore feeder subsystem. The service accepts optimized setpoints for feed rate and synchronizes its output with the conveyor subsystem to ensure continuous material flow.
  References: FeederControl SysD, FeederControl SD, FeederControl IDD, Ore Feeder SysDD.

2.2 Consumed services

with references to SD and IDD documents

- **PowerMeasurement_SD** — consumed by the *Supervisory Control and AI Optimization subsystems*.
  Purpose: Provides real-time electrical measurement data required for predictive optimization and feedback control. The AI optimization layer processes this data to calculate updated control parameters for the feeder and conveyor systems.
  Provided by: PowerSensor SysD.
  References: PowerSensor SysD, PowerMeasurement SD, PowerMeasurement IDD, TP-2 Compact Power Sensor SysDD [3, 4, 5, 6].

3 Security

The SoS can operate exclusively in **Arrowhead secure mode** [1]. All communication uses mutual authentication and encrypted data exchange.

3.1 Security model

Property	**Value**
Protocol supported	HTTP 1.1
Data protection supported	TLS 1.3
System authentication capability supported	Arrowhead TOKEN-based (JWT) [2]
Produced service authorisation checking	Managed via Arrowhead Authorization System [1]
Certificates	X.509, ApplicationSystem level

4 References

[1] "Eclipse arrowhead framework documentation," Eclipse Arrowhead Project, 2024, https://eclipse-arrowhead.github.io/.

[2] M. Jones, J. Bradley, and N. Sakimura, "Json web token (jwt)," RFC 7519, 2015, https://www.rfc-editor.org/rfc/rfc7519.

[3] ricbli 7, "Powersensor_sysd – system description," 2025, course project document (D7560E Embedded Intelligence, LTU).

[4] ——, "Powermeasurement_sd – service description," 2025, course project document (D7560E Embedded Intelligence, LTU).

[5] ——, "Powermeasurement_idd – interface design description," 2025, course project document (D7560E Embedded Intelligence, LTU).

[6] ——, "Tp-2 compact power sensor – system design description (sysdd)," 2025, course project document (D7560E Embedded Intelligence, LTU).

5 Revision History

5.1 Amendments

No.	Date	Version	Subject of Amendments	Author
1	2025-10-16	1.0	Initial version of AI-Driven Control and Optimization SoSD.	ricbli-7

5.2 Quality Assurance

No.	Date	Version	Approved by
1	2025-10-16	1.0	Supervisor