Chapter 3
Rust-Driven Real-Time Sensor Aggregation for Industrial IoT:
Zero-Loss Data and Web Visibility

Chenyu Liu
http://orcid.org/0009-0006-0400-4983
The Hong Kong Polytechnic University, Hong Kong

Liyuan Fan
http://orcid.org/0009-0004-0977-3939
The Hong Kong Polytechnic University, Hong Kong

Yaxin Luo
http://orcid.org/0009-0005-0026-0667
The Hong Kong Polytechnic University, Hong Kong

Mingyuan Tang
The Hong Kong Polytechnic University, Hong Kong

Jingyan Zeng
The Hong Kong Polytechnic University, Hong Kong

Cong Wu
http://orcid.org/0000-0002-8652-3501
Liaoning Technical University, China

ABSTRACT

The ever-increasing volume of data and the need for real-time data processing make preventing data loss a major challenge. This chapter aims to solve this problem. A distributed sensor data aggregation platform based on Rust was designed and implemented. This aggregation platform enables the entire process of efficiently acquiring real-time data from multiple sensors, processing the data, storing it, and accessing it via the web. Its main supporting technology is a one-thread reading strategy for each sensor, a shared queue to absorb the problem of mismatched producer and consumer rates, and finally, multi-threaded aggregation for calculation within a fixed window. Through stress testing, data loss verification, and bench marking,

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this platform achieved zero data loss, correct and stable aggregation, and safe web access. Overall, this platform provides a scalable foundation for future deployment in industrial IoT environments, which require continuous and low-latency data access, reliable buffering, and strong fault tolerance.

1. INTRODUCTION

1.1 Problem Statement and Motivation

Modern infrastructure systems rely heavily on real-time sensor networks to monitor structural health and operational safety. These systems require accelerometers, force sensors, and temperature sensors. Accelerometers detect vibrations, force sensors measure load distribution, and temperature sensors track thermal stress. These sensors continuously generate high-frequency data streams that must be collected, processed, and presented in real time. Accuracy and timeliness are crucial to the reliability of infrastructure systems. Any data loss or latency can lead to missed detection, delayed alerts, or even catastrophic failures.

The main challenge is from the mismatch between sensor hardware limitations and the actual demands of the application. Each provided sensor is limited to a small internal buffer that holds only 128 elements, while the downstream components (aggregation, storage, and web server) require significant time and memory. In practice, multiple sensors generate data simultaneously, multiple worker threads perform aggregation, and a web server must serve live results to multiple clients.

This chapter addresses these operating-system-level challenges by building a distributed sensor data aggregation platform. The implementation is written in Rust, chosen for its memory safety guarantees and fearless concurrency model.

1.2 Chapter Objectives

This chapter has four major technical objectives:

Buffer Management: Design and implement a SensorBufferManager that utilizes reader threads to continuously poll and drain the constrained 128-element internal buffers provided. The manager guarantees zero data loss by ensuring that readings are extracted before the sensor buffers reach capacity.
Aggregation Engine: Implement a statistical processing AggregationEngine that performs statistical processing (min, max, average, standard deviation) from the shared buffer. The engine distributes workload efficiently across