Chapter 5

Adaptive Sensor Aggregation With Self-Monitoring:

A Rust-Based Concurrent Data Pipeline

Ruiman Huang
The Hong Kong Polytechnic University, Hong Kong

Shuxin Jia
The Hong Kong Polytechnic University, Hong Kong

Zeyu Min
The Hong Kong Polytechnic University, Hong Kong

Haoyue Zhang
The Hong Kong Polytechnic University, Hong Kong

Hewa Majeed Zangana
http://orcid.org/0000-0001-7909-254X
Duhok Polytechnic University, Iraq

ABSTRACT

This chapter implements a Rust-based sensor data aggregation platform, achieving zero data loss in the case of multiple sensors running at the same time. The system faces three main challenges: preventing overflow in each sensor's 128-element internal buffer, supporting real-time statistical aggregation, and ensuring storage integrity during concurrent writes. In order to solve these problems, we adopt a

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multi-layer design: the front end is per-sensor reader threads, and the reading frequency is dynamically adjusted in combination with adaptive polling; a bounded mpsc::sync_channel is used as the intermediate buffer to provide backpressure when downstream processing becomes slow. A multi-worker aggregation engine processes sensor data in time-sliced windows. Additionally, we also implemented advanced features including real-time visualization, adaptive thread pooling and automated benchmarking suite. The Benchmark results show that the system sustains zero data loss under stress and achieves high throughput in large-scale tests.

1 INTRODUCTION

1.1 Problem Statement and Motivation

Nowadays, devices are equipped with various sensors to gain perception of the physical world in fields like the internet of things (Gubbi et al., 2013; Sethi & Sarangi, 2017). While becoming more powerful, these devices also provide high-frequency data streams in many cases. Then, the real-time data collection and processing become an important problem to be solved (Mohammed & Zangana, 2026).

With the need from the real-world industry, a self-contained sensor aggregation platform was built as an endeavor. This platform handles hundreds of heterogeneous sensors such as thermometers, accelerometers, and force sensors which run at 10 to 50 Hz. It aggregates the readings into fixed time windows, detects anomalies, and writes results to disk. The focus is on concurrent data processing: reading from limited sensor buffer without losing data; aggregating sensor readings using concurrent worker threads; leaving larger storage buffer for data storage; and showing the results on a web server. Our platform was implemented in Rust. Rust is chosen because Rust enforces memory safety at compile time through its ownership model and borrow checker; and GC-related pauses do not occur with absence of garbage collector (Matsakis & Klock, 2014; Jung et al., 2018; Klabnik & Nichols, 2023).

1.2 Chapter Objectives

The main objective in this chapter is the data loss prevention in concurrent sensor data collection. Each provided sensor has a small internal buffer holding only 128 readings (effectively 127 usable slots). If the reading speed is not fast enough, the new data will overwrite the oldest one, which causes information loss forever. This constraint simulates real-world embedded systems with common memory limitations. There are other objectives worth mentioning: concurrent access coordination that means reading threads must coordinate to store readings before aggregation workers

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