Chapter 1
An Integrated Framework for Real-Time Sensor Data Aggregation and Adaptive Buffer Management in Concurrent Systems

Licheng Huang
http://orcid.org/0009-0000-6046-5406
Hong Kong Polytechnic University, Hong Kong

Bochen Xue
Hong Kong Polytechnic University, Hong Kong

Yiming Chen
Hong Kong Polytechnic University, Hong Kong

Peihang Wu
Hong Kong Polytechnic University, Hong Kong

Yuezhong Wang
Hong Kong Polytechnic University, Hong Kong

Aquil Mirza Mohammed
http://orcid.org/0000-0001-7756-4363
The Hong Kong Polytechnic University, Hong Kong

ABSTRACT

This chapter presents an integrated framework for real-time sensor data aggregation and adaptive buffer management in concurrent systems. The architecture comprises a two-level buffer inspired by two-stage caching principles: a internal queue inside each sensor and a central buffer manager that receives data via unnamed pipes. The buffer manager employs dynamic capacity expansion to prevent overflow. The

DOI: 10.4018/979-8-2600-1101-0.ch001

aggregation engine uses multiple worker threads that process readings concurrently; per-sensor windows are stored in a hash map protected by an RwLock. It supports three anomaly detection methods with explainable outputs. A data storage module provides thread-safe file persistence with automatic rotation, and a multi-threaded web server delivers a live dashboard, file statistics, and an API. Evaluation demonstrates zero data loss at 80k entries/s. The framework offers a blueprint for embedding cognitive capabilities into sensor-based research infrastructures.

1. INTRODUCTION

1.1 Introduction to Sensor Data Acquisition and Analysis Systems

In practical application scenarios such as the Industrial Internet of Things and smart industrial monitoring circumstances, data acquisition, processing, and analysis of sensors are crucial components for data stimulation, equipment status monitoring (Mohammed et al., 2026), early anomaly detection, and decision-making support. However, current existing lightweight sensor data processing systems still face certain serious challenges, that's where this chapter is playing its role.

Insufficient decoupling of data acquisition and processing: The difference between sensor acquisition rates and data processing rates can easily lead to data loss or processing bottlenecks, which especially occurs when using multiple sensor types such as temperature, accelerometers, and force sensors. For mixed acquisition, the rate differences even exacerbate this problem.

Lack of relevant real-time anomaly detection capabilities: Traditional sensor data processing heavily relies on the offline analysis approaches, making it impossible to identify anomalies in real time during the data acquisition phase, thus delaying early detection of equipment failures.

Lack of data management methods: Traditional methods lack reliable and standardized data storage strategies, the lack and weak points of data storage method could lead to transmission errors after processing.

Lack of visualization methods: The raw data acquisition and analysis results lack easy-to-use visualization methods, making it difficult for maintaining personnel to intuitively monitor the system's operating status.

Low System Modularity architecture: The high coupling between sensor simulation, data buffering, aggregation analysis, and storage functions makes it complex and confusing to modify or replace components as needed, such as later operations of changing relevant anomaly detection algorithms or adjusting storage strategies.

Large-Scale Software-Defined IoT Platform for Provisioning IoT Services on Demand

Chau Thi Minh Nguyenand Doan B. Hoang (2020). *International Journal of Smart Sensor Technologies and Applications (pp. 42-64).*
www.irma-international.org/article/large-scale-software-defined-iot-platform-for-provisioning-iot-services-on-demand/261118