

Data Flow Management and Service of New Plasma Control System

Jianqiu Zhu¹, Qiping Yuan¹, Ruirui Zhang¹, Gen Xu^{1,2}, Zhongmin Huang^{1,2},
Junjie Huang¹, Bingjia Xiao¹

¹Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

²University of Science & Technology of China, Hefei, China

*Email: jqzhu@ipp.ac.cn

ABSTRACT: To achieve the complex control of high-temperature, nonlinear fusion plasmas, the overall control task is decoupled into multiple parallel sub-tasks. To host these parallel tasks, the modular Lingshu plasma control architecture is designed. Architecturally, a unified data flow management system is implemented to coordinate all parallel components, thereby enabling integrated control over the plasma discharge. This data flow management framework centers on a Data Engine, which uniformly manages intra-component data through a key-value mapping structure. Furthermore, Data Engine integrates a Shared Memory Manager (ShmMgr) to provide efficient, zero-overhead data exchange between components. Upon this, the system features two critical data services: a Just-In-Time Configuration Distribution Service that dynamically resolves and delivers control parameters within each microsecond-level control cycle, and a Real-time Data Archiving Service designed for long-pulse operations, which ensures persistent storage without interfering with deterministic real-time performance. The proposed framework has been validated through extensive experimental campaigns on the EAST. Configuration resolution and data archiving introduce minimal overhead (<20 μ s and <12 μ s, respectively), meeting strict real-time requirements. A simulated 25-hour discharge further confirmed its steady-state operational capability

1. Introduction

ASIPP dedicates to the fusion research and development based on EAST-CRAFT-BEST-CFETR facilities. To support the steady-state operation of EAST and CFETR, a new plasma control system named Lingshu has been designed. Lingshu PCS demonstrates excellent capability:

- Real-time performance: **Minimum control cycle < 50 μ s.**
- Steady-state support: **Support > 24 hours continuous running.**

These achievements benefit significantly from its advanced data flow management and services.

2. Lingshu Plasma Control System Architecture

2.1 Component-based framework

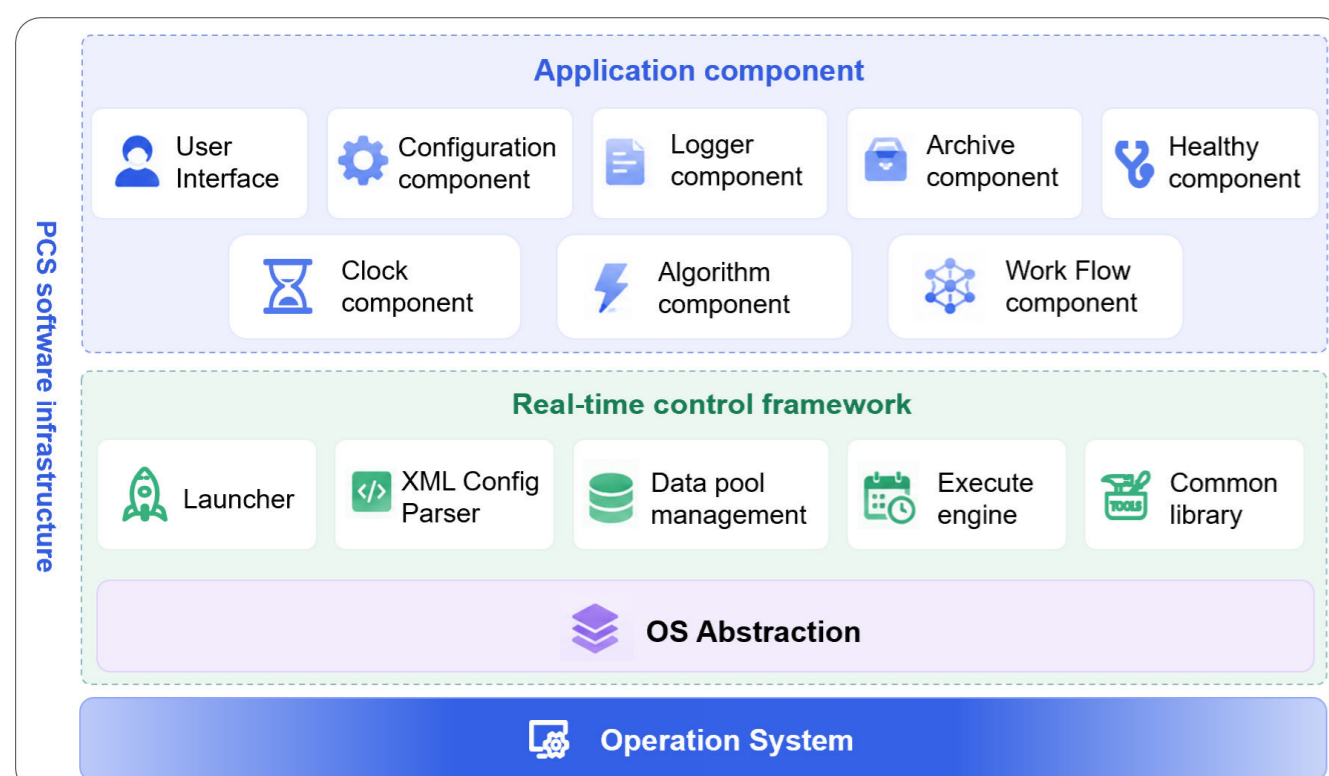


Figure 1. Component-based real-time control framework

- The core framework provides XML Configuration Parser, execution engine, data management, etc.
- Components, as the minimal executable units, can be extended like Lego blocks to flexibly support various plasma operation functions.

2.2 Data Flow Overview

All system functions are built as components following the software architecture. Components related to data management are deployed on three servers in a cluster.

- **Pre-shot:** Configure algorithms via Host Node UI.

- **During discharge:**

- Parallel components cooperate through data interaction.
- Configuration (Cfg) Parameter Distribution
- Real-Time Data Archiving

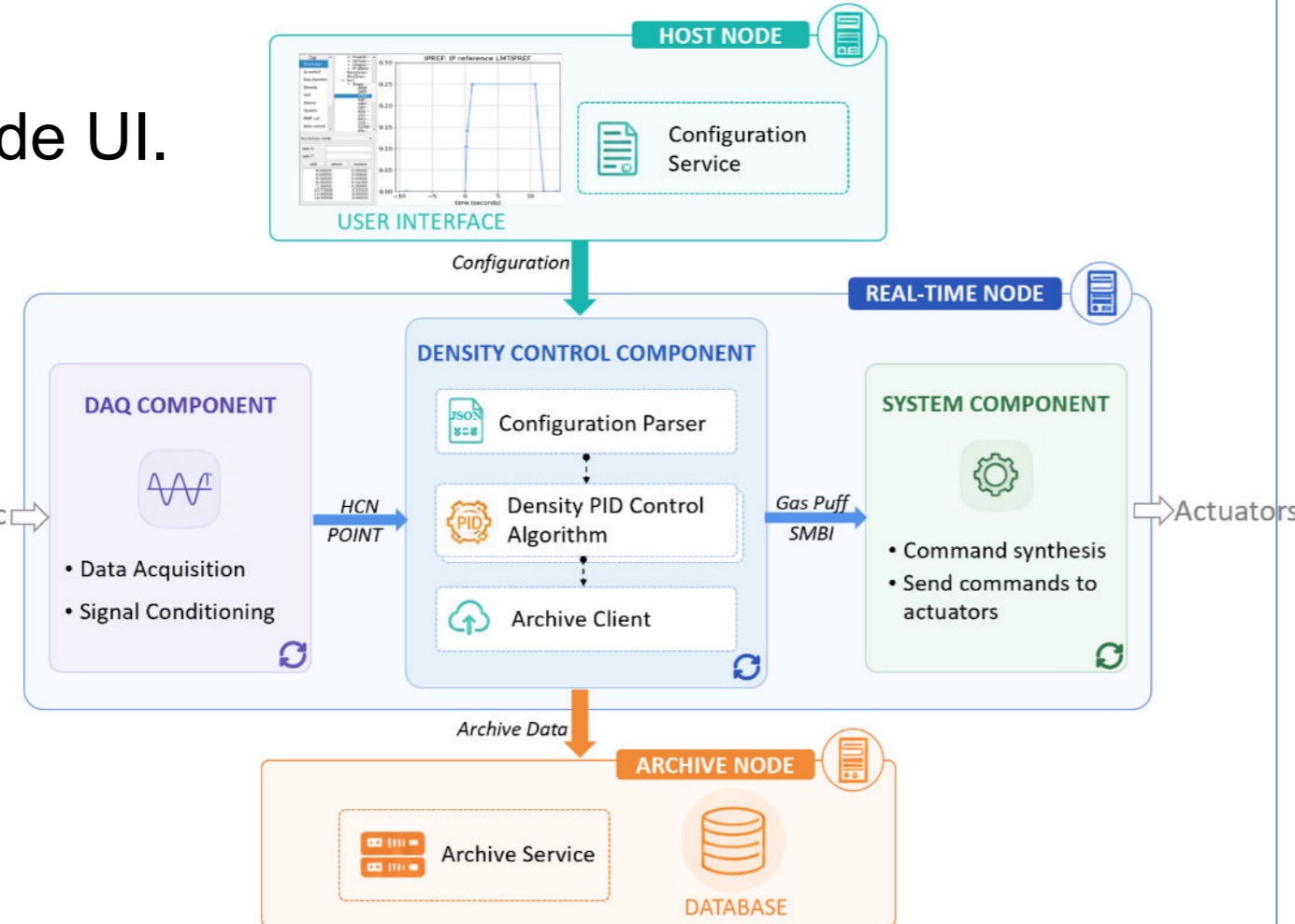


Figure 2. Component Deployment and Data Flow Overview

3. Design of Data Management

3.1 Zero-Overhead Data Engine

Data Engine (DE) equipped on each component

- Data management and abstraction
- Hides storage details (Heap/SHM)

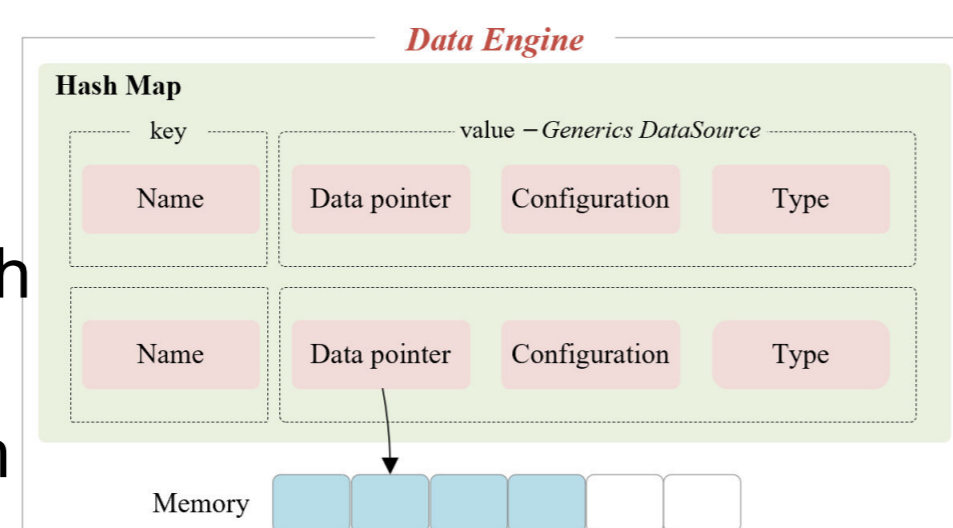


Figure 3. Data engine structure

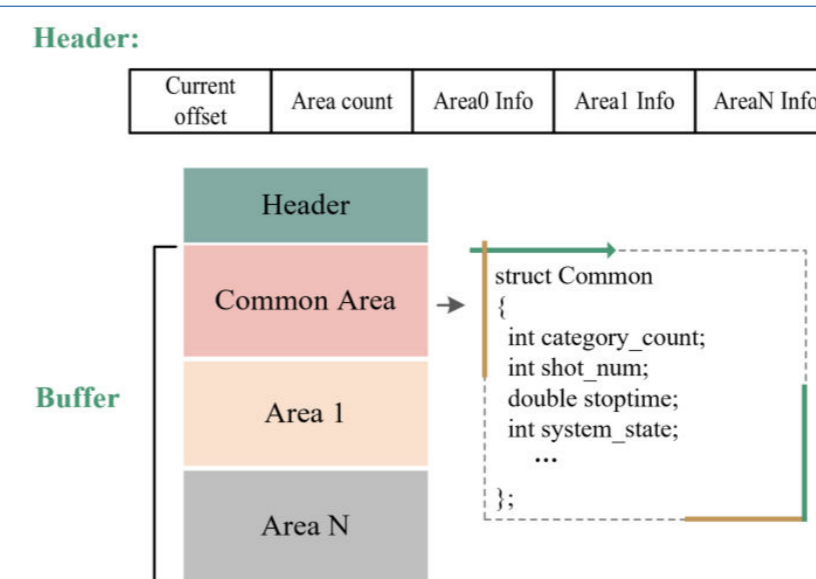


Figure 4. Data pool structure

shmMgr manages data pool

- Handles allocation, sync, access control, and lifecycle

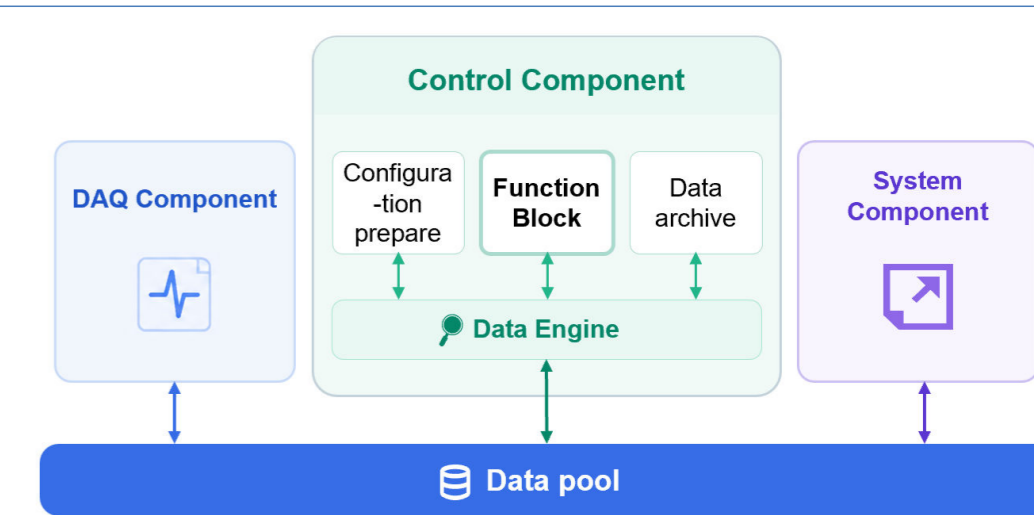


Figure 5. Transparent Data View
Data Engine + ShmMgr

- Provides flattened, unified access.
- Enables low-latency, efficient, transparent usage.

3.2 Configuration Real-time Resolution

Cfg services - deployed on host nodes

- Manage & transfer

Support component - run on real-time nodes

- Acquisition & forwarding

Cfg Parser - embedded in component

- Loading & on-demand real-time parsing

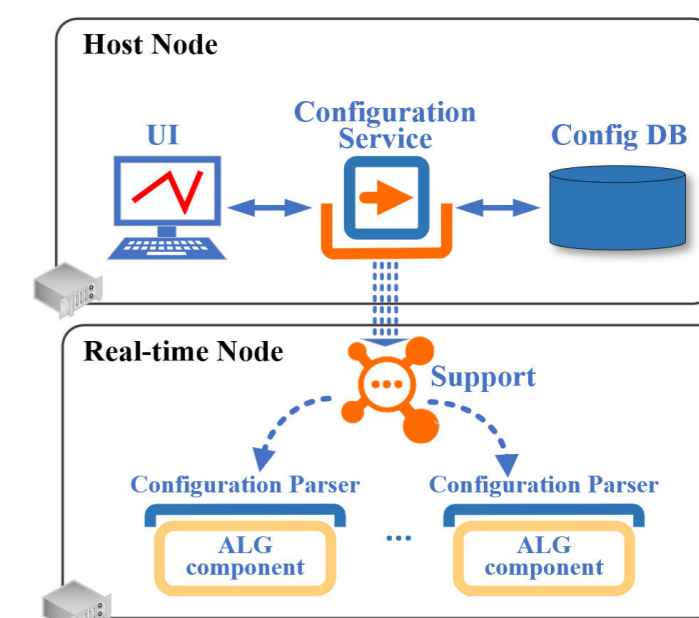


Figure 6. Deployment of Config Modules

3.3 Real-time Data Archiving Client-server architecture

Client - embedded in each component

- Write periodic data from DE to SHM.

Service - independent component

- organize and archive data.

SHM structure - supporting algorithm switch

- pre-stored metadata & only active algorithm name delivery.

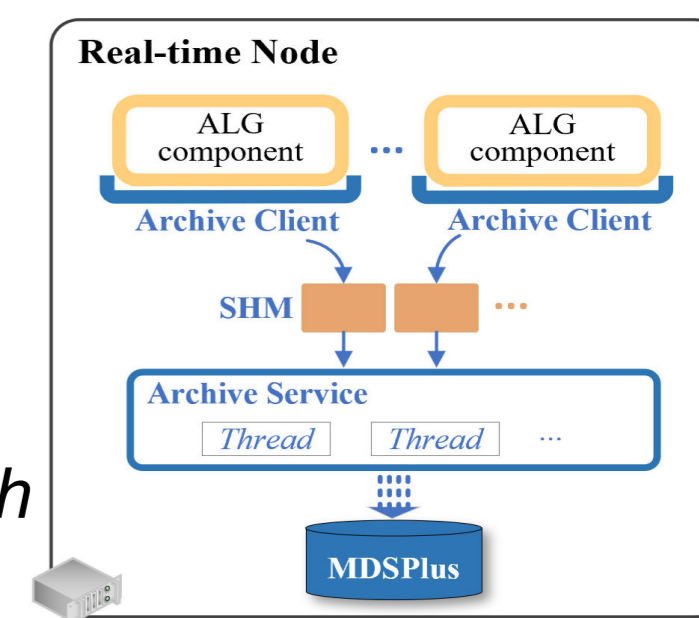
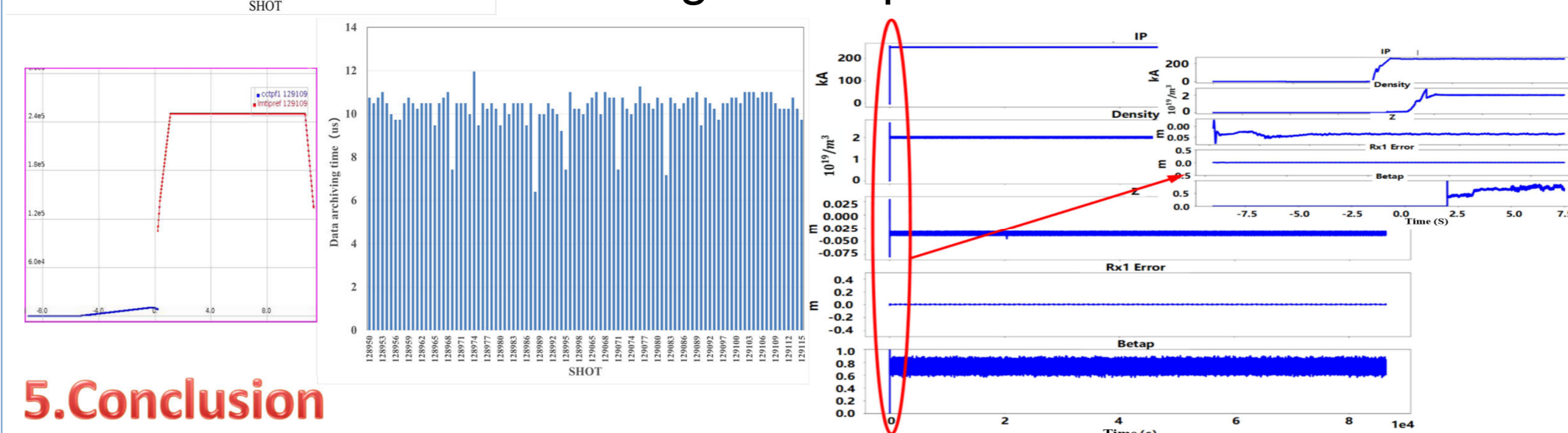
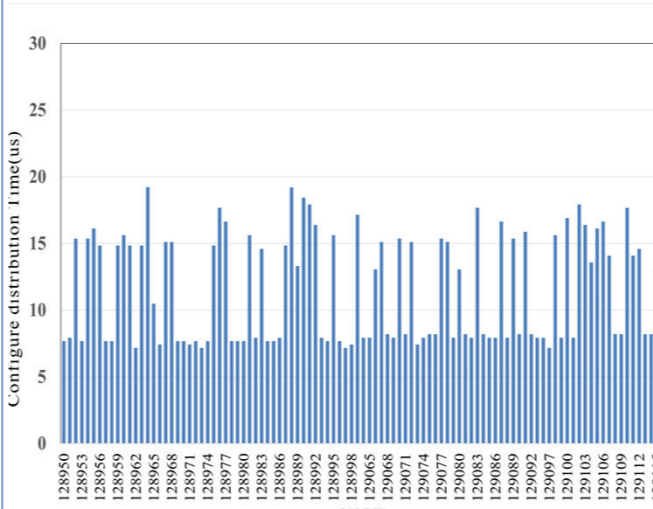


Figure 7. Real-time Data Archiving Architecture

4. Test Result

- ✓ Configuration Parsing: Parsing time < 20 μ s
- ✓ Real-time Archiving: Max client overhead < 12 μ s, seamless adaptation during algorithm switching.
- ✓ Long-pulse Simulation: Stable operation for 25 hours with steady current, density and configuration parameters.



5. Conclusion

Adopting dual-layer Data Engine+ShmMgr architecture, the system achieves unified zero-overhead data transmission. Its real-time configuration distribution and dynamic archiving balance real-time performance, memory efficiency and long-pulse stability. The data management services empower Lingshu PCS to implement long-pulse high-parameter operation control for EAST and future fusion devices like BEST.