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The Software Architecture of the Startup System for the ASTRI Mini-Array

ASTRI Mini-Array

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ASTRI Mini-Array Project

Introduction

The **ASTRI Mini-Array** is an international project led by the Italian National Institute for Astrophysics (INAF) to construct and operate an array of nine dual-mirror Imaging Atmospheric Cherenkov Telescopes [1,2]. The primary goal is to study very high-energy (TeV) gamma-ray sources and perform stellar intensity interferometry [3,4,5]. This paper describes the design and implementation of the Startup System, a critical subsystem for the ASTRI Mini-Array software system [6].

The **Startup System** is responsible for managing the startup and shutdown sequence and critical monitoring of all on-site ASTRI Mini-Array systems, including Power, Environmental, Timing and ICT, Safety and Security, Service Cabinets, Telescopes and the SCADA system, a software system that supervises, controls, acquires data and manages observations.

The development and deployment are described in [7]. In this poster the focus is on the architecture.
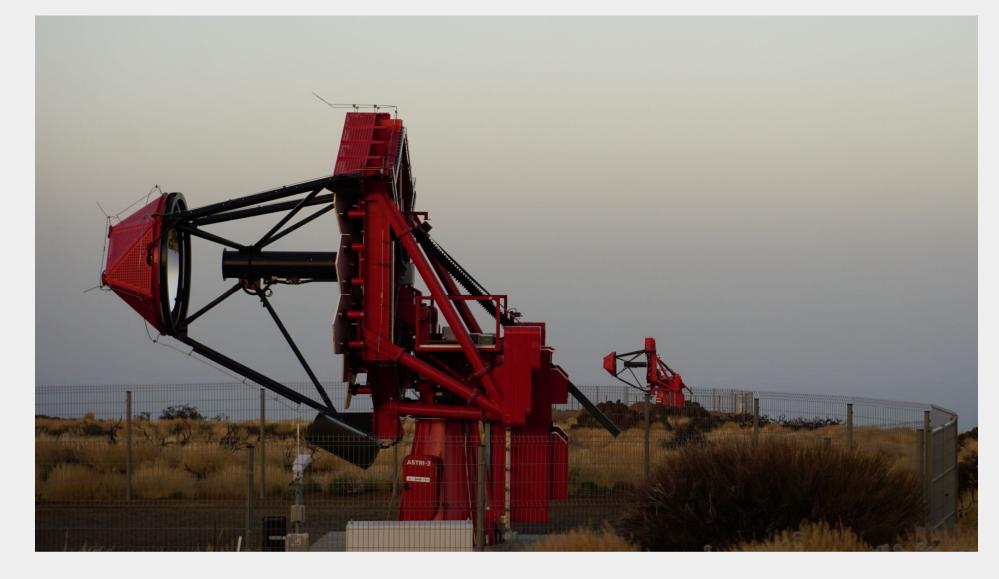

Figure 1: The telescopes of the ASTRI Mini-Array

The ASTRI Mini-Array scientific objectives span very-high-energy gamma-ray astronomy (above a few TeV) and extend to stellar intensity interferometry, leveraging the array's fast, wide-field optical design.

Observatory subsystems for power, networking, timing, telescope control, data acquisition, and monitoring are coordinated by an integrated SCADA/ACS framework.

The Startup System addresses a fundamental operational need: bringing the entire observatory from a powered-off (or standby) state to a pre-observing-ready state in a safe, automated, and reproducible way with minimal operator intervention. In essence, the Startup System check the status and reliability of all ASTRI Mini-Array subsystems and is able to startup a subset of them, verifying that the system is healthy and ready before observing begins.

A reliable startup sequences is mandatory due to the complexity of coordinating many subsystems. In ASTRI, the challenge is to sequence and monitor diverse elements (from power distribution units to telescope control systems) such that the observatory can be declared ready for night operations without manual toggling of each subsystem.
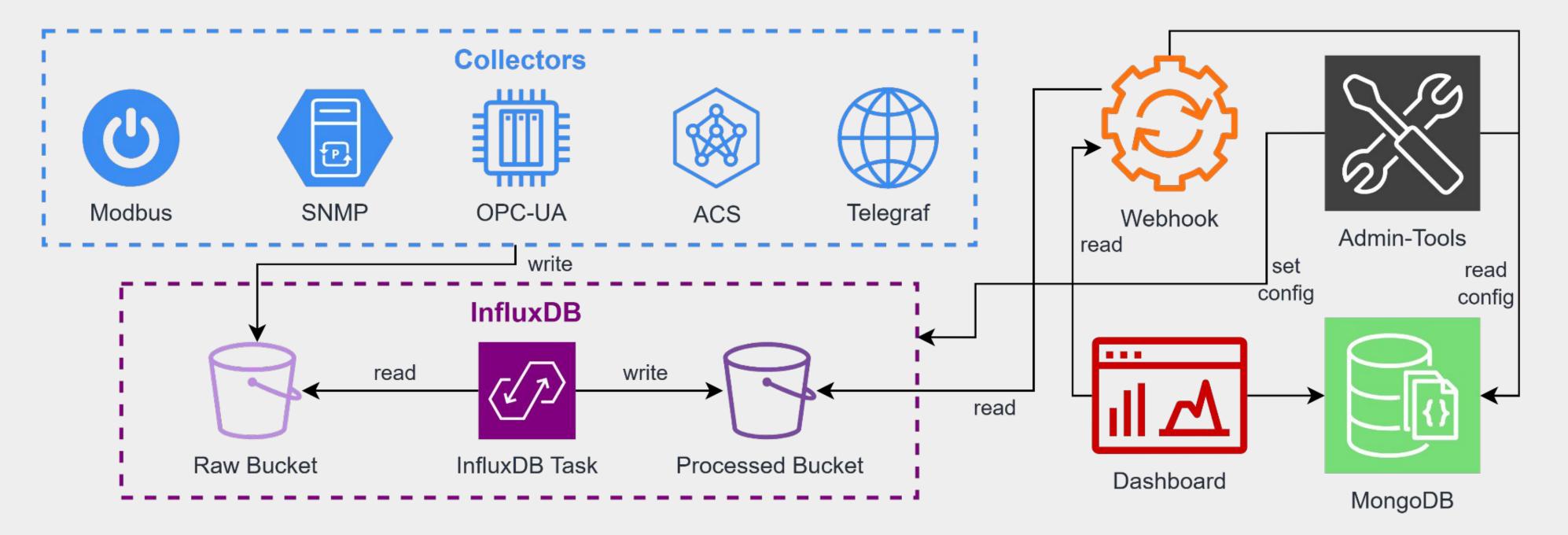

Figure 2: The Software Architecture of the Startup System, showing key microservice components and data flow. Solid arrows indicate data flow (telemetry, configuration, or control messages), and dashed boxes group related components. The Core services (SCDB, InfluxDB, Admin-Tools) initialize first, followed by telemetry Collectors, and finally the Frontend (Webhook and Dashboard UI).

Software Architecture

The Startup System support this via a microservice architecture: a network of containerized services that manage configuration data, telemetry streams, health checks, and user interfaces. This architecture is designed with an emphasis on modularity, containerization, and testability, ensuring that incremental development and deployment could proceed without jeopardizing the strict safety and timing requirements of array operations.

At a high level, the Startup System is composed of loosely coupled services that communicate over well-defined interfaces. The main components are:

1. The **System Configuration Database** (SCDB) holds static JSON configuration files for each assembly or subsystem of ASTRI Mini-Arra. SCDB is implemented via a MongoDB instance. On startup, an Admin-Tools service reads these configurations and deploy them into the runtime environment, by provisioning also database buckets of InfluxDB, setting initial parameters, and configuring alert

2. **InfluxDB Time-Series Data Store** is deployed as the telemetry repository. It stores all time-series metrics coming from the various collectors.

3. **Multiple Collector** services interface with the hardware and software subsystems to gather live status and telemetry, forwarding these time-series data into an InfluxDB, that is used as the central repository for all telemetry streams and provides integrated processing and alerting capabilities. The collectors are specialized by protocol/domain: for example, SNMP collectors query computing units and network switches for status metrics, OPC UA collectors subscribe to telescope mount or weather station data exposed via OPC UA servers, and Modbus collectors read registers from power management systems (PMS) and UPS devices. Each collector runs in a separate container. This is integrated with Telegraf agent for certain data sources.

Once in InfluxDB, telemetry data can be processed by Flux tasks. The Startup System configures InfluxDB tasks (via Admin-Tools) to compute derived status metrics or perform threshold checks on incoming data.

The Frontend comprises a Webhook Server and a React Dashboard. The **Webhook Server** is a Node.js service that plays a dual role: (1) it receives incoming alerts or status updates (via HTTP callbacks from InfluxDB or by polling the status buckets) and (2) it provides a real-time channel to forward these updates to the operator's dashboard UI.

The **React Dashboard** is the operator's front-end web application, providing an integrated view of the startup progress and system status. The dashboard connects to the Webhook server to receive live updates of telemetry and alert statuses. It also can fetch static configuration info (e.g. lists of subsystems or preset parameters) from the SCDB

Conclusions

We have presented the software architecture and implementation of the Startup System for the ASTRI Mini-Array, a crucial infrastructure that automates the observatory initialization. The system's microservice architecture – incorporating a configuration database, time-series database with alerting, protocol-specific telemetry collectors, an orchestration/relay service, and a real-time web dashboard.

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