The Science Alert Generation system of the Cherenkov Telescope Array

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ABSTRACT

The Cherenkov Telescope Array (CTA), with dozens of telescopes located in both the Northern and Southern Hemisphere, will be the largest ground-based gamma-ray observatory and will provide broad energy coverage from 20 GeV to 300 TeV. The large effective area and field-of-view, coupled with the fast slewing capability and unprecedented sensitivity, make CTA a crucial instrument for the future of ground-based gamma-ray astronomy. To maximise the scientific return, the array will send alerts on transients and variable phenomena (e.g. gamma-ray burst, active galactic nuclei, gamma-ray binaries, serendipitous sources). Rapid and effective communication to the community requires a reliable and automated system to detect and issue candidate science alerts. This automation will be accomplished by the Science Alert Generation (SAG) pipeline, a key system of the CTA Observatory. SAG is part of the Array Control and Data Acquisition (ACADA) working group. The SAG working group develops the pipelines to perform data reconstruction, data quality monitoring, science monitoring and real-time alert issuing during observations to the Transients Handler functionality of ACADA. SAG is the system that performs the first real-time scientific analysis after the data acquisition. The system performs analysis on multiple time scales (from seconds to hours). Alerts must be issued 20 s from the data taking and with sensitivity at least half of the CTA nominal sensitivity. These challenging requirements must be fulfilled by managing trigger rates of tens of kHz from the arrays. Dedicated and highly optimised software and hardware architecture must thus be designed and tested. In this work, we present the general architecture of the ACADA-SAG system.

Supported by:

1. The Cherenkov Telescope Array

CTA will receive and send science alerts and detect and monitor gamma-ray transients in the Very High Energy domain at a short timescale, thanks to its unprecedented scientific performance. In addition, CTA can operate in a wide range of configurations and observe different targets with multiple sub-array.

2. The Science Alert Generation

The automated and rapid detection of candidate science alerts will be performed by the Science Alert Generation (SAG) pipeline (Fig. 1), part of the Array Control and Data Acquisition (ACADA). The main SAG requirements are:

1. **The ability to generate candidate science alerts within 20 s from the last acquired event and send them to the Transients Handler system.**
2. **The Capability to work with different array configurations and with many sub-arrays in parallel.**
3. **The Flexibility in terms of scientific targets, science tools and analysis methods.**
4. **SAG will run on-site with the telescopes.**

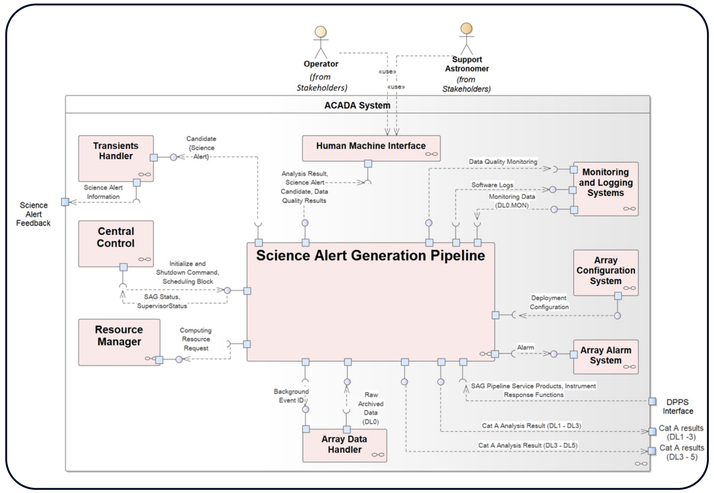

Fig. 1: General overview of the SAG context. The diagram uses the UML component notation, and the basic entities are the software components, depicted as pink boxes. Each UML component is an ACADA subsystem. Blue squares are "ports" that identify the interfaces of the systems. Those ports in the boundary of the ACADA identify the external interfaces of the system, and those in the components the internal interfaces.

3. General Software Architecture

The SAG is composed of three main pipelines that will run in parallel during CTA operations. (Fig. 2):

1. **The Low-Level Reconstruction pipeline (sag-reco) receives the DL0 (telescope data) from the Array Data Handler (ADH) and produces the DL3 (photon list) data in less than 15 s.**
2. **The Online Data Quality pipeline (sag-dq) performs an online data quality analysis on each data level.**
3. **The High-Level Reconstruction pipeline (sag-sci) analyses the DL3 data to produce scientific results DL4 (counts maps and analysis) and candidate science alerts in less than 5 s.**

The results will be visualized using an Operator HMI.

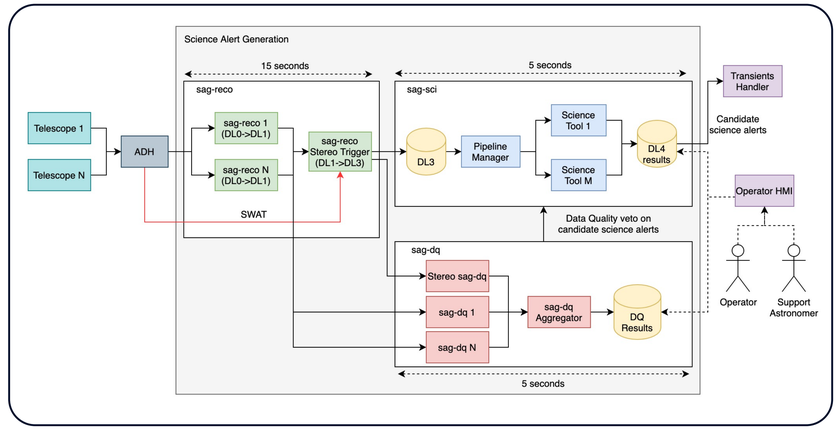

Fig. 2: SAG pipelines and dataflow

4. Conclusions

The SAG is a crucial system for CTA to maximise the science return on transient phenomena in the multi-wavelength and multi-messenger context. Thanks to the unprecedented sensitivity that the SAG pipelines will achieve, CTA will follow astrophysical phenomena and provide feedback to science alerts received from other observatories in real-time.

ACKNOWLEDGEMENTS
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