The evolution of the ALICE Detector Control System

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The ALICE experiment at CERN

Collaboration:
- 37 countries
- 154 institutes
- 1500 members

The Detector:
- 10 000 tons
- 19 subdetectors built on different technologies
- 2 magnets

Main physics focus:
- Heavy ion physics at LHC energies
- Proton-proton physics
ALICE Detector Control System (DCS)

- Guaranties:
  - 24/365 safe and stable operation of the experiment

- Partial detector control systems are built by experts of the detector teams

- The Central DCS Team provides:
  - Distributed control system based on commercial components
  - Computing and network infrastructure
  - Software framework and tools
  - Implementation guidelines and operational rules
  - Integration of detector systems
  - Interfaces to external systems and LHC
  - Training of operators and uninterrupted expert on call service
  - First line support for software developers
The ALICE DCS – Context and Architecture

User Interface, External Systems Interface

ALICE Framework

CERN JCOP Framework

SCADA System (WINCC OA)

Device Interface Layer (OPC or custom)

Devices (Industrial and custom)

Devices with similar functionality are grouped into subsystems. About 100 different subsystems are implemented in ALICE.
Each detector builds its own distributed control system

Each detector system is built as an autonomous distributed system of 2-16 WINCC systems

For example to restore from SAFE:
- Some detectors end in Configured state
- Other detectors need special configuration
- Other do not change state at all

The state of the experiment depends on:
- The state of each subdetector, each having its own control logic
- Internal and external services
- ALICE online and offline systems...
The central systems connect to detector system and form one large distributed system sharing the data and the control.
Using the CERN SMI++ framework, the control system is presented as hierarchical tree of controlled objects.
Central DCS connects to all detector trees
The ALICE DCS scale

- 19 autonomous detector systems
- 120 WINCC OA systems
- >100 subsystems
- 180 control computers
- >700 embedded computers
- 1200 network attached devices
- 300,000 OPC and frontend items
- 1,000,000 supervised parameters
Simplified complexity

- The behavior of controlled objects is modeled as a finite state machine (FSM).
- At the channel level, the logic is simple.
Simplified complexity

- Devices need to be configured (target values, trip limits...)
The detector FSM covers advanced actions related to its operation.
... each detector has specific requirements

For example to restore from SAFE:
- Some detectors end in Configured state
- Other detectors need special configuration
- Other do not change state at all...
... and finally the experiment ...

- Are the magnet settings compatible with datataking?
- Are radiation levels within tolerance?
- Are safety systems OK?
- What is the status of LHC?
- Is the infrastructure OK?

The state of the experiment depends on:
- The state of each subdetector, each having its own control logic
- Internal and external services
- ALICE online and offline systems...
The DCS is operated by a single operator.

In 2015 more than 150 operators were trained to ensure the 24/7 operation.

- Most of the operators did not have prior experience with the DCS.

The interface to the DCS is based on set of intuitive graphics interfaces.

- From a single screen, the operator can access all controlled parameters.
Lessons learned – simplicity and documentation are essential

- Main changes in the DCS were focused on human interfaces and operational procedures.
- Although all information is accessible through the UI, the top level interfaces display only the essential information.
- The operational panels guide the operators.
- To cope with the experiment complexity, the FSM actions are not invoked by the operator. The high-level procedures take care of the complex actions, using FSM as a underlying technology.
- Many actions can be executed in parallel. Configurable panels allow for grouping detectors for certain operations. Instead of operating individual detectors, the operator sends a command to a group.
Lessons learned – backdoors are useful

- Partitioning is a powerful mechanism implemented in SMI++
  - Part of the controls tree can be detached (excluded) from the system, e.g. for troubleshooting
  - Excluded components do not react to commands sent by the central operator and do not report back their states
- For critical actions alternative reporting has been implemented – specialized procedures monitor critical parameters directly
- The central operator can force the commands also to excluded parts, overwriting the settings done by the local expert
(Some of) the present ALICE and DCS challenges

**ALICE Pixel detector (SPD):**
- 10,000,000 configurable pixels
- 1.3 kW power dissipation on (200+150)\(\mu\text{m}\) assemblies
- Contingency in case of cooling failure less than 1 minute

**ALICE Transition Radiation Detector (TRD):**
- 760 m\(^2\) covered by drift chambers
- 17TB/s raw data
  - processed by 250,000 tracklet processors directly on the detector
- 65kW power provided by 89 LV power supplies

**ALICE Time Projection Chamber (TPC):**
- 96 m\(^3\) gas volume (largest ever)
  - stabilized at 0.1°C
  - Cooling system has to remove 28kW of dissipated power
  - Installed just next to TRD
- 557,568 readout pads
- 100kV voltage in the drift cage
The ALICE O2 Project

ALICE 2007-2017

~10GB/s
The ALICE O2 Project

ALICE 2007-2017

ALICE 2019-2027

LHC will provide for RUN3 ~100x more Pb-Pb collisions compared to RUN2 ($10^{10}$ – $4.10^{11}$ collisions/year)

- ALICE O2 Project merges online and offline into one large system
  - TDR approved IN 2015!

- Some O2 challenges:
  - New detector readout
    - 8400 optical links
  - Data rate 1.1 TB/s
  - Data storage requirements: ~60 PB/year
The O2 architecture

- 250 First Level processors (FLP)
- 1250 Event Processing Nodes (EPN)
- ~100 000 processor cores

Detectors:
- ITS
- TPC
- TRD
- EMC
- PHO
- TOF
- DCS
- FTP

Trigger Detectors

Farm Network

Storage Network

Data Storage

10 Gb/s
DCS in the context of O2

- DCS provides input to O2
- ~100,000 conditions parameters are requested for the event reconstruction
- Data has to be injected into each 20ms data frame
The ALICE Data Collector receives data from the DCS.
- Depending on the type and priority of the data, the Data Collector can connect to different layers of the system.
- A process image, containing conditions data, is sent to O2.
DCS-O2 interface

- Prototypes proved the feasibility of the concept
- Larger scale prototypes being prepared
- ...but... This is just the beginning of the story
Conclusions

- The DCS provides stable and uninterrupted services to the ALICE experiment since 2007
- Modular and scalable design minimized the need for system modifications and coped well with the evolution of hardware and software
- As a response to increased complexity of operational procedures, high-level procedures and parallel operations were introduced
- Challenging O2 project requires the full redesign of ALICE DCS data flow
  - Prototyping ongoing
  - More to come...