THE ALICE EXPERIMENT CONTROL SYSTEM

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Abstract

The Experiment Control System (ECS) is the top level of control of the ALICE experiment.

Running an experiment implies performing a set of activities on the 'online systems' that control the operation of the detectors. In ALICE, 'online systems' are the Trigger, the Detector Control Systems (DCS), the Data-Acquisition System (DAQ) and the High-Level Trigger (HLT).

The ECS provides a framework in which the operator can have a unified view of all the 'online systems' and perform operations on the experiment seen as a set of detectors.

ALICE has adopted a hierarchical -yet loose- architecture, in which the ECS is a layer sitting above the 'online systems', still preserving their autonomy to operate independently. The interface between the ECS and the 'online systems' applies a powerful paradigm based on inter-communicating objects. The behavioural aspects of the ECS are described using a finite-state machine model.

The ALICE experiment must be able to run either as a whole (during the physics production) or as a set of independent detectors (for installation and commissioning). The ECS provides all the features necessary to split the experiment into partitions, containing one or more detectors, which can be operated independently and concurrently.

This paper will present the architecture of the ALICE ECS, its current status and the practical experience acquired at the test beams.

INTRODUCTION

ALICE (A Large Ion Collider Experiment) is the heavy-ion experiment being prepared for the Large Hadron Collider (LHC) at CERN. The ALICE heavy-ion detector [1] consists of several particle detectors. In the final setup the detectors will mainly operate all together to collect physics data. In the present phase, however, detectors are prototyped, debugged, and tested as independent objects. While this operation mode, called 'standalone mode', is absolutely vital in the commissioning and testing phase, it will also be required during the operational phase to perform calibration procedures on individual detectors. It will therefore remain an essential operation mode during the whole life cycle of ALICE.

Running an experiment implies performing a set of activities on the detectors. In ALICE these activities are grouped into four 'Activity Domains':

- Detector Control System (DCS)
- Data Acquisition (DAQ)
- Trigger (TRG)
- High Level Trigger (HLT)

Every Activity Domain requires some form of coordination and control: independent control systems have been developed for all the Activity Domains. These systems, called 'online systems', have the following common features:

- Every 'online system' may interact with all the detectors.
- Every 'online system' allows 'partitioning': partitioning is the capability of concurrently operate groups of ALICE detectors.
- Every 'online system' ignores the existence of other 'online systems'.
- Every 'online system' accepts commands issued by an external operator.

The Experiment Control System (ECS) is the top level of control of the ALICE experiment. Its role is manifold. First, it has to provide the operator with a unified view of the experiment and a central point from where to steer the experiment operations. Second, it also has to permit independent concurrent activities on part of the experiment by different operators. Finally, it has to coordinate the operations of the 'online systems' acting on the detectors.

REQUIREMENTS

The major functional requirements that the ECS has to fulfil are the following:

Handling of experiment partitions

The ECS provides the framework in which different teams can work on different groups of detectors at the same time, without interfering one with another. This is possible by splitting the experiment into sections called 'partitions'. A partition is a collection of detectors operated together to acquire correlated data: it must contain at least one full detector.

A detector may belong to several partitions but can only be operational in one while it is disabled in the others. The ECS handles the access conflicts.

Coordination of the Activity Domains

The ECS coordinates and synchronizes the activities going on in every partition. It takes care of all the correlations existing between different Activity Domains.

The Activity Domains are controlled by 'online systems' having their own standards, methods and tools and they can be operated autonomously. The 'online systems' are independent: there are no direct exchanges of information between them and they interact only with the ECS giving information to it and receiving commands from it.

The ECS interacts with all the 'online systems' using uniform interfaces based on a common technology.

Coordination of calibration and configuration procedures

All the detectors require calibration and configuration procedures, in particular for their Front-End Read Out (FERO). These procedures are detector dependent, since each detector requires a specific sequence of operations, but are not partition dependent because the sequence of operations remains the same when the detector is operational in one partition or another.

The ECS allows concurrent calibration and configuration procedures on different detectors within a partition. When a detector is moved from one partition to another, or just removed from a partition, a calibration or configuration procedure already performed remains valid, and there is no need to repeat it.

Coordination of ALICE activities with LHC status

The ALICE experiment will be operated in different ways depending on the LHC status (beam on/off) and on the type of beams (heavy-ion beams or protons). The ECS will steer the running of ALICE according to the LHC status information.

ARCHITECTURE AND COMPONENTS

The ECS is a layer of software on top of the 'online systems' controlling the four Activity Domains. Domain-dependent interfaces allow the integration of these systems with the ECS. The resulting hierarchy of systems is shown in Fig. 1.

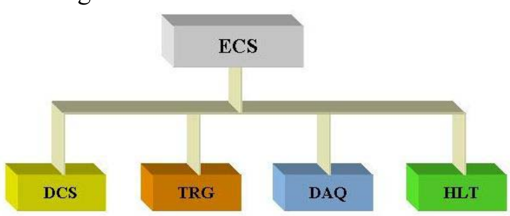

Figure 1: Hierarchy of systems.

The domain specific interfaces allow the ECS to get information from the 'online systems' and to send them coordinated commands. The execution of these commands is controlled by the 'online systems'.

The ECS sees whole objects endowed with macroscopic conditions and is not aware of their internal structure and detailed conditions. When a finer level of detail is necessary, the operator can access directly the 'online system'. The 'online systems' do not need the use of the ECS and experts can operate their detectors by directly using the 'online systems' in 'manual mode'.

Finite-state machines

The technology of the ECS is based on Finite-State Machines (FSMs). Finite-state machines are a simple way for modeling the behavior of a component using the states that it can be in and the transitions that can take place between these states. This technique is ideal to describe control systems: complex systems can be broken down into small and simple FSMs that are hierarchically controlled by other FSMs.

FSMs constitute the ideal paradigm for the implementation of the major ECS components and of the interfaces between the ECS and the 'online systems'.

The specific implementation of FSMs that has been chosen in ALICE is the SMI++ package [2]. SMI++ is a strategic choice of ALICE, since it is used for the implementation of all the ALICE 'online systems'.

Components of the ECS

The major software components of the ECS are: the Partition Control Agent (PCA), the Detector Control Agent (DCA), the ECS database, and the Human Interfaces (HI).

The **Partition Control Agen**t controls the running of a partition as a whole during physics runs, when the detectors belonging to the partition are operated to take data all together. It also coordinates the calibration and configuration procedures concurrently performed on different detectors of the partition when the detectors are not taking data all together. There is one PCA per partition.

The **Detector Control Agent** controls a detector operated in standalone mode or the execution of calibration and configuration procedures on a detector belonging to a partition. There is one DCA per detector.

Both the PCA and the DCA are based on FSMs. Several operators can concurrently use Human Interfaces and watch the same PCA or the same DCA, but only one is master and can send commands to it.

When a detector is operated in standalone mode, an operator controls its DCA. When a detector is assigned to a partition, its DCA is under the control of the PCA. Operators can still use Human Interfaces and watch the DCA, but only the PCA sends commands to it.

The **ECS database** describes the partitions in terms of ALICE detectors seen as partition building blocks.

Each partition includes a list of detectors assigned to it. The database includes information on whether each detector is presently active or not. Additional information on the status (running/not running) of the PCA controlling the partition and on the Human Interface process having mastership over the PCA is also given.

For every detector the ECS database contains the status of its DCA (running/not running), the partition name when the detector is active in a partition, information on the Human Interface process having mastership over the DCA when the detector is operated in standalone mode.

Three different **Human Interface programs** give access to a DCA (**DCAHI**), to a PCA (**PCAHI**), and to the ECS database (**ECSHI**).

The **PCAHI** allows an operator to watch a partition. It can also get mastership over the PCA and allow its operator (called 'partition master operator') to control it, if the mastership over its PCA has not been taken by another PCAHI. When the partition master operator releases the mastership, another operator can take the control over the partition.

The **DCAHI** allows an operator to watch a detector. It can also get mastership over the DCA and allow its operator (called 'detector master operator') to control it, if the detector is not included in a partition and the mastership over its DCA has not been taken by another DCAHI. The detector is then in standalone mode and cannot be included in a partition. When the detector master operator releases the mastership, the detector can be included in a partition or, of course, be taken by another operator and again work in standalone mode.

The **ECSHI** gives access to the ECS database. This process allows the definition of new partitions, gives an overall view of what is going on within the experiment, and presents details about the detectors and their usage within partitions or acting in standalone mode.

Interfaces between the ECS and the 'online systems'

The interfaces between the ECS and the 'online systems' controlling the ALICE Activity Domains have the following common features:

- They are based on FSMs modeling the behavior of objects actually existing in the Activity Domains such as detectors, hardware modules, or software processes.
- They offer a simplified model of the Activity Domain: the interface contains only the objects whose states may influence the decisions taken by the ECS and the objects that can be the target of commands issued by the ECS.
- Hide the complexity of the real objects: structured objects become 'atomic' in the interface; they are described by global states and accept state-dependent sets of commands.
- They associate an access control mechanism to every object appearing in the interface. This mechanism grants or revokes the right of controlling the object to the ECS. When the control rights is revoked, the ECS does not send commands to the object: the control of the object is left to the 'online system'.

During the lifetime of the experiment, the level of automation will gradually increase and the interfaces between the ECS and the 'online systems' will evolve accordingly. In the present commissioning and testing phase, the interfaces are kept as simple as possible:

- The **DCS interface** consists of one object per detector, representing the detector from the hardware point of view (high voltages, low voltages, temperatures, pressures).
- The **DAQ interface** consists of objects representing Run Control processes. A Run Control process is a DAQ process that controls a data acquisition activity, where data produced by one or many detectors are collected.
- The **TRG interface** contains one object per detector, representing the Local Trigger Unit (LTU) associated to the detector, and a Trigger Partition Agent (TPA) for every partition. LTUs and TPAs are described in [3].
- The **HLT interface** is a single object representing the HLT as a whole.

The four interfaces are represented in Fig. 2. It shows an example with two detectors, called 'a' and 'b', and a partition, called 'a+b' including the two detectors. The figure also shows the DCAs associated to the two detectors, the PCA controlling the two DCAs, the ECS database and several Human Interfaces. The represented PCAHI is used by the partition master operator to control the partition. The two represented DCAHIs are used by two operators to watch the two detectors that are under the PCA control.

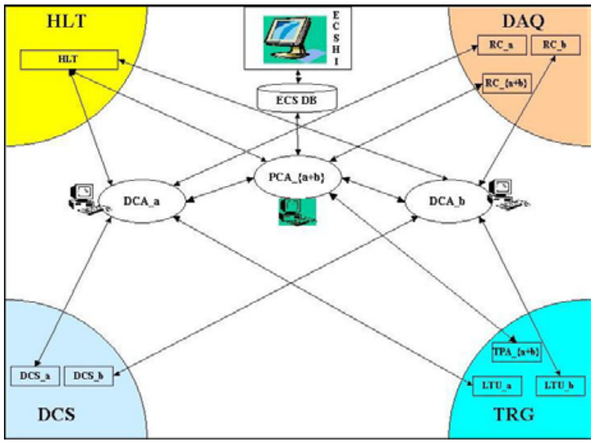

Figure 2: Interfaces between ECS and 'online systems'.

OPERATIONS

The smallest entity that can be controlled by an operator is a detector operated in 'standalone mode'. An operator controlling a standalone detector is allowed to perform the following set of operations:

- Issue all the commands that are accepted by its DCA and, in particular, the commands that are required for testing and calibration purposes. The list of valid commands is different between the various detectors and will probably grow during the lifetime of the experiment.
- Send 'manual' commands, mainly for debugging purposes, to the 'online systems' controlling the Activity Domains.
- Reduce or extend control rights using the access control mechanism contained in the interfaces with the 'online systems'. The operator can use this possibility to avoid access conflicts when some operations must be performed by experts directly using the 'online systems'.

The largest entity that can be controlled by an operator is a partition. The experiment administrator defines partitions by assigning resources to them, using the interactive tools of the ECS. The assignments are recorded in the ECS database. Several partitions can be active at the same time, being operated by independent teams. An operator controlling a partition runs it as if it was the full experiment with the following possible operations:

- Run the partition as a whole: the operator can start or stop physics runs where the detectors take data all together.
- Perform calibrations and tests on individual detectors when the partition is not running as a whole. These calibration and tests can be concurrently performed on different detectors.
- Exclude detectors from the partition or re-introduce in the partition previously excluded detectors.
- Send 'manual' commands, mainly for debugging purposes, to the 'online systems' controlling the Activity Domains.
- Reduce or extend control rights using the access control mechanism contained in the interfaces with the 'online systems'. The operator can use this possibility to avoid access conflicts when some operations must be performed by experts directly using the 'online systems'.

The operator controlling a partition or a detector operated in standalone mode ignores the existence of other partitions or other detectors. An overall view of the experiment with all the partitions and all the detectors is however provided to the experiment administrator, and eventually to any other operator, by the ECSHI. Using this program the operator can get information about all the defined partitions, check whether they are active or not, get the list of resources assigned to them, and find out who operates the partitions. Information is also provided about every detector: the operator can check whether a detector is used or not, get information on where it is used and in which mode, and find out who has the control of it.

IMPLEMENTATION STATUS AND PROTOTYPING

The implementation of all the major components of the ECS is well advanced.

A first prototype of the DCA, handling DCS, DAQ, and TRG, was developed in 2003 for the HMPID detector.

The prototype was successfully tested in October 2003, with the DCS running on Windows PCs and the DAQ, the Trigger and the ECS running on Linux PCs. An improved version of the DCA for the same detector has been used during the HMPID test beam in July-August 2004.

The Human Interface of the Detector Control Agent (DCAHI) has been implemented as well.

A first version of the PCA has been implemented. It handles partitions with any number of detectors and is interfaced with three 'online systems': DCS, DAQ, and TRG. This prototype will be put into operation during the Inner Tracking System (ITS) test beam in October 2004, where three detectors will be involved: Silicon Strip Detector (SSD), Silicon Pixel Detector (SPD), and Silicon Drift Detector (SDD).

The Human Interface of the Partition Control Agent (PCAHI) has been realized. Fig. 3 shows the Human Interface that will be used during the ITS test beam in October 2004.

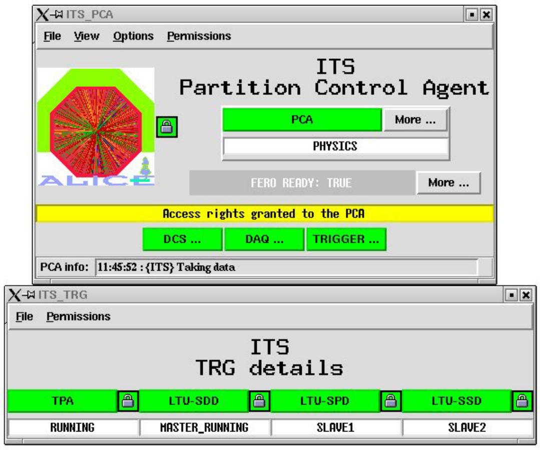

Figure 3: ITS Partition Control Agent.

A first version of the ECS database has been designed and implemented using MySQL. The Human Interface (ECSHI) giving access to the ECS database has been completed.

SUMMARY AND CONCLUSIONS

The ALICE ECS provides a unified view of the experiment and a central point where all the operations to manage the different aspects of the experiment are initiated and controlled. It also allows independent concurrent activities on parts of the experiment at the partition and detector levels.

The experience acquired during beam tests proves that the adopted architecture satisfies the functional requirement, allows parallel development of the 'online systems'. Moreover, the adopted technologies make the ECS extremely flexible: during the detector tests and commissioning phases, the ECS will be continuously adapted to new requirements that might turn up; during the operational phase of ALICE, the ECS will continue its evolution to include more and more automatic procedures.

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