The Detector Control System for ALICE
Architecture and Implementation

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Abstract

The ALICE experiment will include more than 10 individual detectors of different technologies and with specific operating conditions. The instrumentation required to run and control the operation of each sub-detector will include commercial and custom hardware of various standards.

The detector control system (DCS) for the ALICE experiment will allow a hierarchical consolidation of the participating systems to obtain a fully integrated detector operation. This goal will be achieved by clearly defined interfaces between system layers. In addition, sub-detectors will continue to be able to access their equipment independently from other sub-detectors for maintenance, upgrading and debugging. The architecture will, therefore, be based on partitioning into self-contained sub-systems, which can be separately developed, maintained and operated. Horizontal communication between sub-systems will consequently be avoided.

The DCS will use, where possible, commercial hardware components and software.

The clear vertical separation and hierarchical structure of the system should also allow implementing of a single user interface to the experiment, which can access the DAQ control and the DCS.

The technologies which will be used for the controller level hardware and the software options are explained. Also described are the current development status and the experience to date with the small-scale prototypes that are used to verify design choices.

1. JUSTIFICATION

The detectors for the LHC experiments will be installed in underground caverns. The location of the equipment in the underground caverns removes the possibility of intervention during the operation of the LHC accelerator. Consequently, remote access becomes a primary condition.

The operational conditions of each detector have to be controlled and known permanently and with limited delay.

The detectors will be operated in a hostile environment. They will be constructed to very advanced specifications and contain sophisticated and complex apparatus which requires the maintaining of precise and stable operating conditions. Consequently, manual operation would be very difficult or impossible and remote monitoring and control become prerequisites.

All detectors of an experiment must be operated simultaneously in a coherent and compatible way. More than 10 sub-detectors will have to co-operate in the ALICE experiment. Some, like the Inner Tracking System are mechanically and geographically very tightly coupled. All detectors are correlated for physics data taking. Consequently, the operation of the experiment must be centralised and all participating detectors synchronised in a common control system.

Data exchange with other systems like DAQ, Trigger and external sources must be guaranteed. The physics data is strongly dependent on the operational conditions of the sub-detectors. Consequently, status and other data from the detector operation must be available to the DAQ and Trigger. This will require an automated data exchange between the systems. In addition information from external systems must be accessed by the detector control system.

The ALICE experiment has no static configuration. It will evolve during the life of the experiment and undergo rather frequent modifications and upgrades. Nor is there a single operation mode. Detectors will be operated in several modes and the experiment itself will be set up in different configurations. Consequently, it must be possible remotely to remove or insert detectors in the current experiment set-up without physical intervention.

Different groups in a number of institutes in several countries are developing the sub-detectors in ALICE.

Before the installation in the experiment they need to be completely tested. Consequently, the control of the detectors will be developed in various places. But it must be possible to integrate the individual control applications in one global and coherent system.

Each of these global requirements in it self justifies the implementation of a state of the art control system.

2. ARCHITECTURE

The ALICE detector control system (DCS) is characterised in ref. [1].

The DCS will have to operate in two major modes:

- In normal operation during physics data taking controlled start, operation and shutdown of the different sub-detectors will have to be guaranteed. Standard operator commands will be available for this purpose through the global experiment control system. Malfunctioning will be signalled through centralised alarms. Defined variables will be made accessible by other systems like DAQ and archived for later retrieval and analysis.

- During other periods, the detectors will be operated in a less coherent manner. It will be necessary to run a detector or sub-systems separately for maintenance or upgrade. Nevertheless, interference to the operation of other equipment or external services must be prevented.

The architecture to satisfy the preceding requirements and constraints will be based on distributed intelligence. A set of generic requirements has been defined and described in the URD [2]. The essential features are scalability and modularity since the system configuration will undergo modifications and extensions throughout the life of the experiment. The general structure of the DCS will be based on a client/server model.

The ALICE DCS will be structured in several well-distinguished layers (table 1).

Table 1 DCS hardware architecture

SCADA (Supervision & Control)	Workstations (PCs) Server Stations External Systems
Controllers & Network (Device Control & Data Acquisition)	PCs, VME, PLCs Power supplies Gas Control Instruments Magnet Control
Detector (Process parameters)	Custom HW (FEE) Sensors (T, B, F, P,) Actuators (Vvs,Sws)

At the level of the experiment networked general-purpose workstations will be dedicated to the management of the configuration data for all detectors and equipment, alarms, logging, archiving and data communication.

Dedicated controller stations will control the individual detectors. In this context, a controller station is not necessarily a single computer but can be clustered if a high channel count or the heterogeneity of the equipment leads to this requirement.

The communication links at the controller level will be based on general CERN fieldbus recommendations [3].

Remote sensing and actuator equipment at the detector level and in the electronic crates and ancillary equipment, such as safety and general electricity, will be connected directly to one of the proposed standard buses or via suitable interface modules. The field buses will be interfaced to the dedicated controller stations.

Access to the DCS will also be required from remote locations. However, it is planned to introduce access restrictions depending on the client location.

A supervisory and configuration software system shall provide a uniform and coherent user interface to all detectors [4].

2.1. Process Layer

Field instrumentation like sensor heads and actuators will be of various types and in different locations.

The instrumentation at the process level will be tributary to the requirements for the detector hardware. Some of the items, like power-supplies, will be bought as commercial units.

Most of the systems, however, differ from detector to detector and are assembled from a variety of more or less complex instruments, i.e. temperature control including sensors, valves and switches. However, the interfaces to the control equipment will follow well-established electrical standards like 0 – 10 V for voltage interfaces or 4 – 20 mA for current loop interfaces. Where this is not possible for technical reasons, signal-conditioning interfaces will have to be added for the connection to the controller stations. This is for example the case for pneumatic valves or switches. Complex instruments generally feature already defined communication interfaces and protocols, i.e. gas analysers, voltmeters.

The ALICE detectors are in principle, with the exception of the inner tracker system, fairly accessible. Nevertheless, the amount of material due to sensors and cabling has to be restricted. Mechanical and electrical requirements for the detectors necessitate in addition in many cases the use of custom designed hardware or the adaptation to these constraints. In the case of the ITS special front-end chips have been designed which include already the electronics for detector control. A specific feature of the ITS detectors is the use of the JTAG/BS protocol [5] for access of detector control parameters.

Hardware interlocks of components will be implemented wherever possible. This is the case, for example, for automatic switch off of front-end chips in presence of possible latch-up conditions, or for automatic ramp-down of high voltages in presence of over-currents.

2.2. Control Layer

The process equipment will be interfaced to multipurpose control computer equipment of PLC (Programmable Logic Controller) type, in compliance with the relevant recommendation [6].

However, wherever convenient, like in case of large number of field instrumentation channels to be controlled, VME based controllers may be used. It is foreseen to use a dedicated control computer for each detector. Depending on the complexity of the sub-detectors, it is envisaged to introduce a further grouping at the level of the controller stations. Self-contained instruments like gas-analysers and high- and low-voltage power supplies will also be integrated at this level.

The controller stations will be connected by one of the proposed standard field bus systems or a dedicated general purpose LAN, i.e. Ethernet and TCP/IP.

2.3. Supervisory Layer

The equipment of this layer consists of general-purpose workstations, which will be linked to the control layer through a LAN providing TCP/IP communication.

The workstations will be set up as supervisory stations to act as Man Machine Interface (MMI) to the detector control system and will be configured as server stations for detector monitoring and data logging. In addition, access from remote locations will also be possible provided that a proper network connection and access authorisation can be established.

A global experiment control system (ECS) will provide a unified view of the whole experiment to the operator and manage the data exchange between the DCS and external systems like DAQ, Trigger control, magnet control and general alarm and safety system (fig. 1).

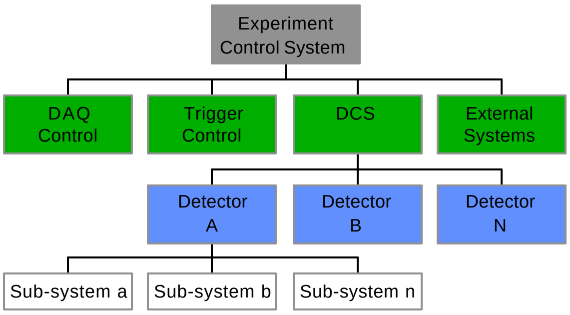

Figure 1 Experiment control system

During normal operation the DCS will be accessed through this Supervisory Control layer and no peer-to-peer connection between DCS sub-systems and other systems is envisaged. The ECS will only provide a limited set of macroscopic actions to generate the sequence of operations necessary to bring the experiment to a given working condition. However, the detailed actions will be executed by the sub-systems, i.e. DCS, DAQ, etc..

In addition the ECS will monitor the operation of the sub-systems, generate alarms and provide the interlock logic where necessary.

This control layer is also responsible for the dynamic splitting of the experiment into independent partitions and the possibility of concurrent data taking from the partitions. Nevertheless, the direct access to each sub-system in order to gain detailed information and control will always be possible through the dedicated MMI.

2.4. Communication

The data transmission links can be categorised in layers equivalent to the hardware architecture (table 2).

Table 2 Communication system architecture

SCADA (Supervision & Control)	Internet LANs (Ethernet) TCP/IP
Controllers & Network (Device Control & Data Acquisition)	LAN (TCP/IP) Fieldbuses (Profibus, CAN) GPIB, RSxxx
Detector (Process parameters)	Custom (JTAG) Wired ptp Fieldbus

As the DCS also involves safety aspects the hardware links used are independent from the DAQ. At the field instrumentation level, point to point links for voltage or current signals will be the general case. An exception will be necessary for some of the ITS components. The severe constraints for the cabling and connection volume led to the adoption of the JTAG/BS protocol for many control data. Each ITS detector will have its own DCS JTAG channels, independent from the DAQ JTAG channels which are used for down-loading individual detector configuration data.

Where feasible, intelligent probe heads and/or actuators will be used; these devices will be connected to the controller level via one of the proposed standard field buses. This does not change the hardware architecture since the bus system will be seen as an extension of the controller station.

A field-bus or a dedicated LAN, which is also connected to the supervisory level, will establish the connection between different sub-systems.

Access to the equipment will be allowed from remote locations. However access restrictions are planned depending on the locations to avoid conflicts.

2.5. Software

The controller level software, which will reside in the control computers that are directly linked to the process, will be configured individually for each sub-detector. For development and maintenance of the detectors each group will also configure a personalised MMI.

This software will be based on the same product(s) as for the general ALICE DCS system and allow, consequently, the integration in the overall system during experiment operation and alternatively separate access and control of each sub-system during other periods.

It is planned that the driver software for the controller stations to interface the field instrumentation to the

ALICE DCS architecture will be based on the OLE (Object Linking and Embedding) [7] for Process Control (OPC) [8] standard.

The objective of OPC is to provide an industry-standard mechanism to communicate and exchange data between clients and servers by using OLE technology from Microsoft. It should allow a standardised access method and unified interface between the field level and a SCADA (Supervisory Control And Data Acquisition) system or office applications, i.e. Excel, running under Windows.

The goal of OPC is to provide interoperability between multiple vendors' products. In the past, each product or instrument required a dedicated suite of servers / drivers to meet the end-users needs. OPC shall allow to develop generic servers, independent of location and number of clients.

The OPC interface standard is defined and developed by the OPC Foundation which includes the major companies in the automation sector (Siemens, Fisher-Rosemount, National Instruments, Rockwell software, etc.).

The OPC Foundation and the OPC Foundation member companies will focus on making sure that products are interoperable together, and by definition, vendors push the OPC Foundation to make sure that performance and throughput expectations are not compromised to achieve interoperability. Therefore, the Objects, Interfaces and functionality defined by OPC will continue to evolve and change as the technology continues to grow.

A wide range of OPC servers and applications is already available now and additional companies have announced their adherence.

3. DEVELOPMENTS AND VALIDATION

The CERN JCOP project [9] has been set up in 1997 to work on a common solution for the DCS of all LHC experiments. One activity concerns the study and evaluation of SCADA. An important number of other activities have also started, i.e. system architecture, data interchange with external systems [10], communication drivers.

However, these developments are mainly concerned with the upper layers of the system. Hardware related aspects, like power supply control, gas distribution, and fieldbuses, have also been addressed in this context but they are treated in a rather generic approach, since all experiments are concerned.

In ALICE some key aspects are being looked at in a complimentary way. They can be classified in three fields:

a) Hardware architecture
b) Communication systems
c) Software architecture

3.1. Hardware architecture

A partial control system for the ALICE HMPID detector has been implemented in 1998 [11], [12]. The purpose was to gain first experience to validate the use of PLC, communication through TCP/IP and a small-scale SCADA system. The development includes all layers of the planned ALICE DCS.

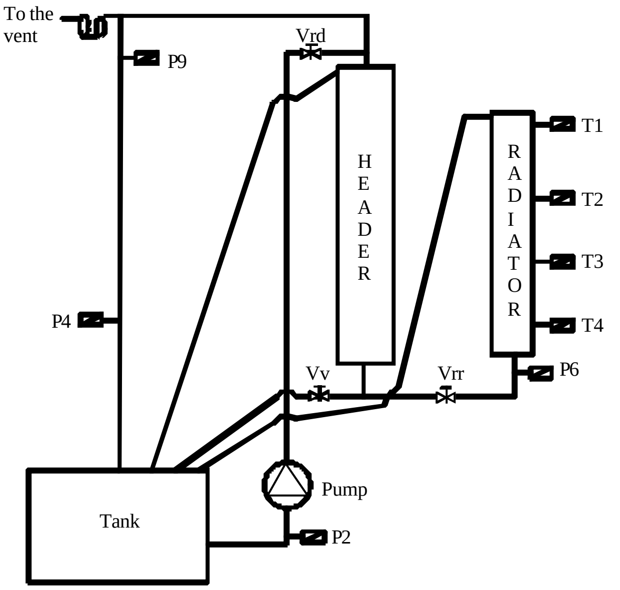

Figure 2 HMPID control prototype

The prototype includes one circulator module (fig. 2), controlled by a PLC. The supervisory level has been implemented with Bridgeview, which was chosen as interim solution by the JCOP in order to provide a common migration level towards the final SCADA system. Despite the use of a mock-up hardware system, the implementation of the liquid circulator is based on real operating conditions. A second version has now been configured which will be used in the Cherenkov detector of the Star experiment at RHIC.

3.2. Communication systems

Important effort is put by the major automation system manufacturers in the promotion of the OPC standard.

The use of compliant communication drivers in the DCS system is believed to take advantage from this development. In order to validate the efficiency and suitability of the communication mechanism, several implementations for the control of high voltage power supplies have been developed. A first development uses the proprietary CAENnet to access a power supply from this manufacturer [13]. A second development has been completed for a Lecroy power supply using the default serial interface connection [14]. The aim of the latter implementation was to provide a complete remote access application which can use the basic communication interface of any PC and is independent from the location where the power supply is installed, provided it can be connected to a networked PC (fig. 3).

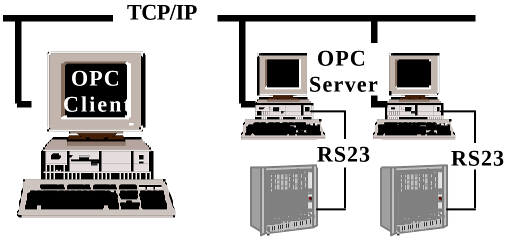

Figure 3 High Voltage power supply control

A later upgrade to a communication via TCP/IP will simply require replacing the medium access object. This allows to preserve an identical user interface independent from the communication system.

3.3. Software architecture

A number of heterogeneous control systems will have to interchange data in the ALICE environment. Like for the control systems of the sub-detectors, they will be developed separately by different groups. Similar to the detectors they will, however, be operated closely coupled during ALICE data-taking. It is, therefore, proposed to implement a high-level experiment run control system [15]. This project involves three major parts.

3.3.1. DCS control

The current supervisory system for the ALICE HMPID liquid circulator prototype (based on BridgeView) will be re-engineered using a SCADA system.

One aspect of the planned development consists, therefore, in the evaluation of the necessary migration effort.

An extended system is currently being configured for use in a HEP experiment. This could provide the opportunity to test features like replication and scaling.

3.3.2. DATE control

The current DAQ control (DAQC) through DATE [16] (the ALICE DAQ prototype) will be re-engineered using a SCADA system. The new run control will access the processors involved in the DAQ via the present interface, based on an exchange of messages over TCP/IP sockets. No other interface is required, in particular no sharing of a database is foreseen.

The operator interface will emulate the facilities provided now by a Tcl/Tk program. The implementation will require writing an OPC driver to access the remote machines under control in the same way as a PLC.

Problems to be tackled include the formatting of presentation windows according to a configuration file and the possibility of cloning complex objects without re-defining all the tags and procedures.

3.3.3. Supervisory control

An experiment supervisory control (ECS) will be configured using a SCADA system. This part will provide the main control window for the operator. The first phase will be the connection of the DAQC and the DCS to a common SCADA. This work includes the design of an organisation of the control system based on layers, corresponding to different levels of visibility and access rights (fig. 4).

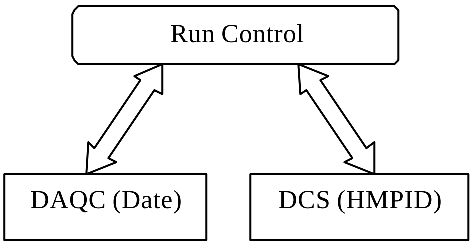

Figure 4 Run control prototype

The higher layer will provide a global view, and will be only allowed to make a reduced set of actions. Lower layer, i.e. DAQC and DCS, will have access to detailed information and control attached to each system.

The communication between layers will be based on a message-passing client-server model, with no sharing of memory structures (including databases). Systems on the same layer can only communicate via the layer above.

In a subsequent phase, the problem of splitting the entire system into independent partitions will be addressed. It should be possible to develop and operate sub-systems independently from the ECS. But it must also be possible to easily integrate the sub-systems in the ECS. The ECS control may also be split into different control domains that may operate independently and concurrently.

4. CONCLUSIONS

Major benefits of common hardware choices are well-supported controls- and communication interfaces. A reduction of the development and maintenance effort is also expected through the use of commercial software and strong recommendations of hardware standards. This can be enhanced by the commitment to adopt wherever reasonable common solutions for all LHC experiment.

During a first phase, the requirements seen from an operational point of view have been collected and analysed. However, this needs to be matched with the process level hardware.

Consequently, with the development of a better knowledge of the final detector implementation a second iteration starting bottom-up from the inventory of the parameters to be monitored and controlled, the connection to the operation requirements must be established. This has now been started and should be completed during the next year.

A number of technical choices, described in the DCS architecture have been tested successfully with small-scale prototypes. We are entering now the phase where implementation of complete sub-system controls has to be started. The layered architecture of the ALICE DCS and the independence from the DAQ control system will allow the separate development and later integration of partitions into a global experiment control system. The adoption of standard and unique interfaces furthermore guarantees that technical progress can be easily accommodated by exchanging obsolete system parts by future developments.

It must be emphasised that most of the ALICE control systems are conceived on Unix platforms. The possibility to integrate these systems with the required functionality in the planned Experiment Control System is therefore of high importance.

REFERENCES

1 Data Acquisition, Control and Trigger, ALICE Internal Note/98-23

2 Detector Control System for an LHC Experiment User Requirement Document, ALICE/98-03

3 Recommendation for the use of Fieldbuses at CERN in the LHC era, proc. 1997 ICALEPS, Beijing, China

4 Technology Survey, Summary of study report, A. Daneels, W. Salter, IT-CO/98-08-09, CERN

5 IEEE std. 1149.1a, 1993

6 Recommendations for the Use of PLCs at CERN, PLCWG, SL/98-007 (CO)

7 The OLE/COM and DCOM technologies, http://www.microsoft.com/activex/default.asp

8 OPC Foundation, http://www.opcfoundation.org

9 Joint Controls Project, http://itcowww.cern.ch/jcop/

10 LdiWG, LHC data interchange Working group

11 Test and Evaluation Station (TESt), ALICE Internal Note/99-13

12 First experience with PLC, OPC and Bridgeview in the context of the HMPID liquid distribution prototype, ALICE Internal Note/99-14

13 An OPC Server for Caen SY127 High Voltage Power Supply, P.Gras private communication, CERN 1998

14 OPC Server and HMI application for Lecroy 1458 High Voltage Power Supply, B. Perrin, D. Swoboda, ALICE Internal Note/99-42

15 Supervisory Experiment Control, D. Swoboda, A. Vascotto, private communication, CERN 8/6/99

16 ALICE DATE V3 User's Guide, CERN ALICE DAQ group, ALICE Internal Note/98-44