ALICE CONTROL SYSTEM – READY FOR LHC OPERATION

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Abstract

ALICE is one of the four experiments at the Large Hadron Collider (LHC) currently being built at CERN in Geneva. The experiment and its control system is well advanced and is presently being installed, commissioned and prepared for operation which is due to start in 2008. This paper gives an overview of the control system and describes the tools and components that are used to build it. Some examples of chosen technical solutions are given as well as a brief report on the installation and commissioning status.

INTRODUCTION

The ALICE experiment is dedicated to heavy ion physics but will also fully participate in the proton-proton physics program of LHC. The experiment is composed of as many as 18 different sub-detectors which are being built by about 1000 people from 90 institutes in 30 countries.

The Detector Control System (DCS) is built by a small central team at CERN in close collaboration with the sub-detector groups in the various institutes and with controls and technical services groups at CERN. In total about 100 people are involved.

The primary task of the control system is to ensure safe and correct operation of the experiment [1] [2]. The system shall provide remote control and monitoring of all experimental equipment in such a way that the experiment can be operated from a single workplace, the ALICE Control Room (ACR) at LHC point 2, through a unique set of operator panels. The system shall provide the optimal operational conditions so that the physics data taken with the experiment is of highest quality.

ARCHITECTURE

The hardware architecture can be sub-divided in three layers; a supervision, a process control and a field layer. The supervision layer consists of Operator Nodes (ON's) that provide the user interfaces to the operators. The process control layer consists of Worker Nodes (WN's), PLC's and PLC like devices that interface to the experiment equipment. The field layer comprises field devices such as power supplies, field bus nodes, sensors, actuators, etc. In total the system comprises about 150 computers and servers and a few thousand devices. Computers and devices are connected to a dedicated, highly protected and partly redundant DCS LAN that runs through all the experimental locations [2] and to standard field-buses. It is interesting to note that Ethernet is massively used not only for inter-process communication but also as field-bus for device control and that as many as 1200 devices are connected to the DCS LAN.

The software architecture, representing the structure of sub-detectors, their sub-systems and devices, is composed of three basic building blocks; a Control Unit (CU), a Logical Unit (LU) and a Device Unit (DU). The CU and LU model and control the sub-tree below it and the DU 'drives' a device, see figure 1. The behaviour and functionality of each unit is modelled and implemented as a Finite State Machine (FSM) and it transits between stable states by executing 'actions' [1][2][3].

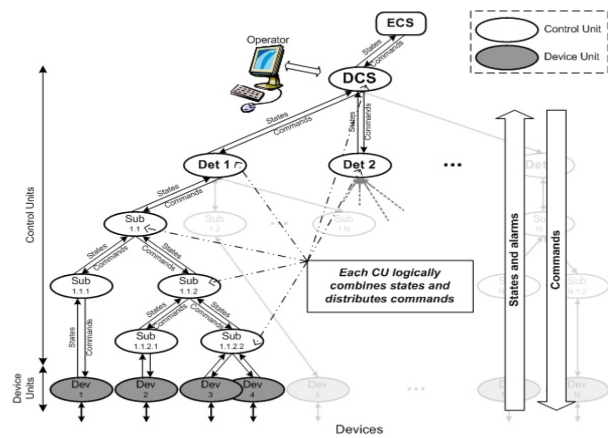

Figure 1: Software architecture.

This concept allows for distributed and decentralized decision making and actions can be performed autonomously, even when controlled centrally. This naturally leads to parallelism in automated operations such as error recovery, and thus increases the efficiency of the system. The concept also allows for independent and concurrent operation which is essential during the installation and commissioning phase as well as for debugging, tests and calibration during normal operation.

TOOLS AND COMPONENTS

The core component of the controls system is a commercial Supervisory Control and Data Acquisition (SCADA) system, PVSSII, a modular, distributed and equipment oriented system offering many of the basic functionalities required by the control system.

A software framework of tools and components has been built around PVSSII to complement and add functionalities and to simplify design and implementation for the application designers, see figure 2. The main tools are Finite State Machine (FSM), alarm handling, configuration, archiving, access control and communication tools. Interface components to several commonly used hardware devices have also been implemented [4]. Communication with the hardware has been restricted to the two protocols OPC (OLE for Process Control) and DIM (Distributed Information Management) one commercial and the other CERN-developed.

These tools and components are used by the sub-detector experts to build their applications. They are accompanied by a set of rules and guidelines to ensure the homogeneity and to simplify the integration of independently developed components.

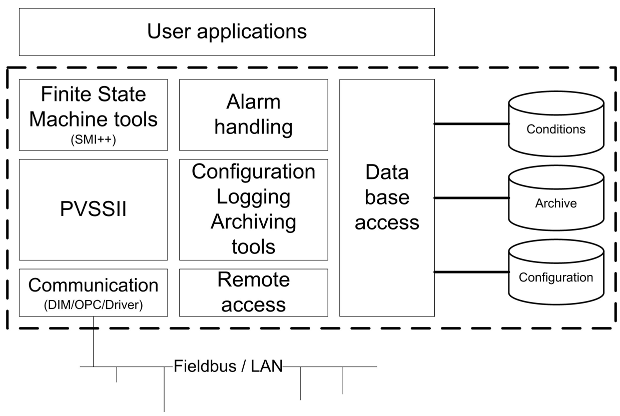

Figure 2: Control system components.

The use of a commercial SCADA system complemented by a software framework is a new approach in physics experiment controls. The framework has been developed in common between the four LHC experiments and the IT controls group in the frame of the Joint Control Project (JCOP) [5] and it has considerably reduced the development efforts needed.

APPLICATIONS

The ALICE experiment consists of more than 150 different sub-systems for which controls applications are required. The 18 sub-detectors have each up to 15 sub-systems to control and a number of sub-systems are also required for the control of the technical services and the experiment infrastructure.

Much emphasis has been put on standardization and use of common solutions across the sub-detectors to limit the development effort. At the device level the sub-detector users have been encouraged to use similar types of devices whenever possible. Common specifications and purchasing have been carried out and manufacturers have been asked to provide controls interfaces based on OPC and CERN field bus standards.

The control applications for the Front-End Electronics (FEE) sub-systems are the most complex and challenging. The hardware is customized and different for each sub-detector; however a software interface common to all FEE systems has nevertheless been defined and implemented. This relies on a the definition of a Front-End Device (FED) [6] that represents a hardware abstraction layer and on a common FED client-server model that hides the implementation details to higher software layers.

The low level systems consist in general of Single Board Computers (SBC's), processors and custom VLSI chips communicating internally over various busses in a detector specific architecture. All of this is integrated and located directly on the detector elements, which are inaccessible during long periods of time and subject to radiation and high magnetic fields. Autonomous and redundant control functionality has been built into the custom chips and into the low level system by the electronics designer.

It is interesting to note that in previous generation systems this functionality was contained in modular electronics systems such as VME and was engineered by a controls expert rather than by an electronics designer.

DATA-FLOW

The ALICE control system has to cope with much larger amounts of data than in previous generation systems [7]. At the start of a physics run, when the experiment needs to be set-up and configured to the actual run conditions, up to 6 GB of data is loaded from a configuration database to the hardware devices. The chips and processors in the FEE require particularly large amounts of configuration data and the performance of the database access and the FEE loading mechanism have therefore been much optimised.

Once configured, all devices are controlled and monitored and the resulting data is stored in the archival database. The steady archival rate for ALICE is estimated to 1000 inserts/s throughout the year. The database service, consisting of an Oracle RAC server located at the experimental site, is designed to cope with a steady rate of 150 000 inserts/s, which corresponds to a peak load during the ramp-up periods, when most of the channels change.

A subset of the archived data is transferred to the Conditions Database and is used in the physics data analysis. This data is also used in calibration procedures to prepare new configurations for the sub-detectors.

USER INTERFACE

All interaction with the experiment is done through Graphical User Interfaces (GUI) and this is actually the only part that the end-user will see from the control system.

In order to facilitate the operation of the various parts of the experiment, a major effort has been made to achieve the same 'look and feel' for all user interfaces. Such standardization is essential for an efficient operation of the experiment, as a small shift crew will operate a large set of different sub-detectors. This crew should therefore be able to rapidly diagnose problems in any of the ALICE sub-detectors; a task that is greatly facilitated by a high level of uniformity across the user interfaces.

An ALICE GUI component has therefore been developed which is used by all application developers to create their specific interfaces. The component defines the layout and fixes specific zones for control and monitoring. It provides a hierarchical system browser as well as general utilities for alarms, access control, system monitoring, etc. See figure 3.

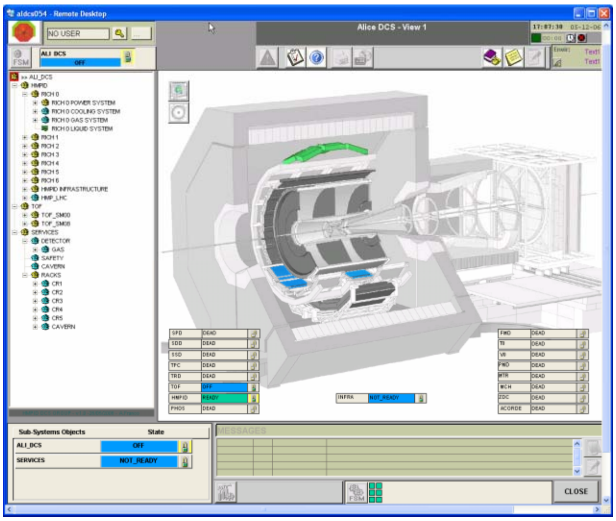

Figure 3: ALICE DCS User Interface.

INSTALLATION AND COMMISSIONING

The controls infrastructure at the experimental site has been installed and is operational since early 2007. This includes the controls network, the computers with their basic software systems and the database servers. The controls for the technical services such as power distribution, gas, cooling and safety has also been installed and is presently being commissioned.

The installations of the sub-detector applications is synchronized with the sub-detector installations in the experimental cavern following a very precise sequence and planning and at present 13 out of the 18 sub-detectors have been installed and are being commissioned.

The sub-systems are first commissioned individually and then joined together via its FSM structure to form homogeneous sub-detector control systems [3]. The sub-detector systems are further integrated with the technical services and with the other on-line systems DAQ, Trigger and High Level Trigger (HLT) to form the complete ALICE on-line system.

A first 'dry run' using cosmic triggers and involving the majority of the ALICE sub-detectors is planned for the end of 2007. This will be a dress rehearsal for the physics operation with LHC that will start in 2008.

CONCLUSION

The usage of a commercial SCADA system combined with a software framework developed in common at CERN is a new approach in physics experiment controls. It has largely facilitated the design and construction of the control systems for the four LHC experiments. For ALICE it has resulted in a new generation, high quality control system characterized by the integration of large amounts of distributed processors located on the sub-detector elements, massive use of Ethernet for both inter-process communication and device control and integration of a high performance database configuration and archival system.

The design and construction of the ALICE control system is now being completed and the basic controls infrastructure has already been installed and is operational at the experimental site. The system fulfils all the requirements and is presently used with success during the commissioning of the experiment. The final detector applications are presently being installed and the complete system will be ready for operation at the start-up of LHC in 2008.

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