ALICE DETECTOR CONTROL STATUS REPORT

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ABSTRACT

The ALICE (A Large Ion Collider Experiment) detector is a heavy ion experiment, one of the four new large detectors currently being built at CERN's new LHC accelerator, which is due to start operations in 2007. The year 2005 is a key year for the ALICE control system; it will see the transition from prototype systems to the installation of a production system at the experimental site. The controls infrastructure needs to be operational for the installation and commissioning of the first sub-detectors by the end of this year. The development of a coherent control system for 18 different sub-detectors is a major challenge.

Therefore the ALICE Controls Coordination team (ACC) put great emphasis on a structured method to design a uniform control system for the experiment. This paper describes the approach that was used and the architecture that was adopted for the detector control system, highlighting some of the key features. We will report on the status of the installation of the final control system and its infrastructure. An outlook to the final installation of the control system and its use during the installation and commissioning of the sub-detectors will be given.

INTRODUCTION

Although the ALICE detector is dedicated to heavy ion physics, it will also fully participate in the proton-proton program of LHC. The detector is designed to be general-purpose and combines several different detector technologies. The ALICE detector will be composed of 18 different sub-detectors which are being built by over 1000 people from 86 institutes in 29 countries. Although the physical size of the ALICE detector with its two magnets is comparable to the size of the LEP experiments, the number of channels to be read out and the parameters to be controlled has increased considerably due to the use of modern technologies.

The primary task of the Detector Control System (DCS) is to ensure safe and correct operation of the experiment. It will provide configuration, remote control, and monitoring of all experimental equipment from a single workplace in an efficient way. The system shall allow for optimal operational conditions: an efficient control system will have a positive impact on the quality of the physics data by maximizing the number of channels operational at any time, and by measuring and storing all parameters necessary for efficient offline analysis of the physics data. The DCS shall provide a coherent interface to a wide variety of, in many cases, very complex devices. The selection of the equipment is largely determined by the detector hardware, and the implementation of its control is the responsibility of the sub-detector groups. The majority of these groups, with members from several institutes in different countries, have little expertise in controls; especially in the context of such large scale experiments as the ones at LHC. The controls coordination team has therefore put a great effort in coordinating, supporting and guiding the controls activities in the sub-detector groups.

CONTROL SYSTEM DESIGN

This section describes the main requirements of the control system and reviews the methods and strategies that are used for the design of the ALICE detector control system.

Design goals and requirements

The DCS will cover a large number and a wide variety of systems, the control of which will be developed in parallel by various groups. It shall still be a coherent and homogeneous system across all sub-detectors and sub-systems. The control system will be operational from the installation phase and cover the whole operational period of the experiment. It will therefore have to be flexible enough to accommodate any changes during the lifetime of the experiment; these can be changes in the installed hardware or changes in the operation of the experiment. The control system will have to cater for a wide variety of operational modes, this range from coordinated operation during physics data-taking, to independent and concurrent operation of sub-systems during commissioning or calibration. The operation environment shall be intuitive and user friendly, so that normal operation can be done by non experts. Routine operations and tasks will be automated wherever possible to limit the risk of mistakes and increase efficiency. Operation will need to be synchronized with other online systems, the LHC accelerator and services. The DCS has to ensure safe operation of the experiment and, unlike most of the other online systems of the experiment, the system is supposed to be operational, sometimes even unattended, throughout all operational phases of the experiment, including shutdown periods, putting strong requirements on availability and reliability. The large and world-wide user community of the experiment will require efficient remote access to the control system, with an adequate access control mechanism. Data required for the configuration of the experiment will be available in a database; the data collected by the control system will be archived and available at any time. Any parameter relevant for offline analysis of the physics data will be available in a database.

Methods and strategies

To limit the dispersion of solutions and to reduce the development effort, the obvious overall strategy is to use common tools, common components and common solutions wherever possible. The aim is to achieve this through strong central coordination of all control related activities within the ALICE experiment and through close collaboration with the other LHC experiments.

In the 18 sub-detector groups that are now building and soon installing their detector equipment, many people are contributing to the controls system. These people are usually detector physicists, often non-specialists in the field of controls for large experiments, who work only part-time on the controls of their sub-detector. To coordinate the effort in the various groups a small central team was set up: the ALICE Controls Coordination (ACC). Its major task is to establish strong links with the sub-detector groups and to coordinate their efforts to ensure the uniformity of the control system.

As it was recognized that certain communality exists across the LHC experiments' control systems and in addition the resources for controls, particularly from the CERN side, are very limited, the Joint Controls Project (JCOP) was set up as a collaboration between CERN and the LHC experiments. Acting as a forum to discuss common issues, JCOP has developed a common framework and components[1] for detector control of the LHC experiments.

Within the sub-detectors of the ALICE experiment many similar types of sub-systems need to be controlled, such as high and low voltage systems, cooling systems etc. To identify communalities across the sub-detectors, the requirements for the controls of each of the sub-systems are systematically collected in so called User Requirements Documents (URDs). For each sub-detector an overview drawing captures many of the main parameters of their DCS. These drawings cover mainly hardware aspects of the control system such as location and type of devices and the scale of the system (see figure 1).

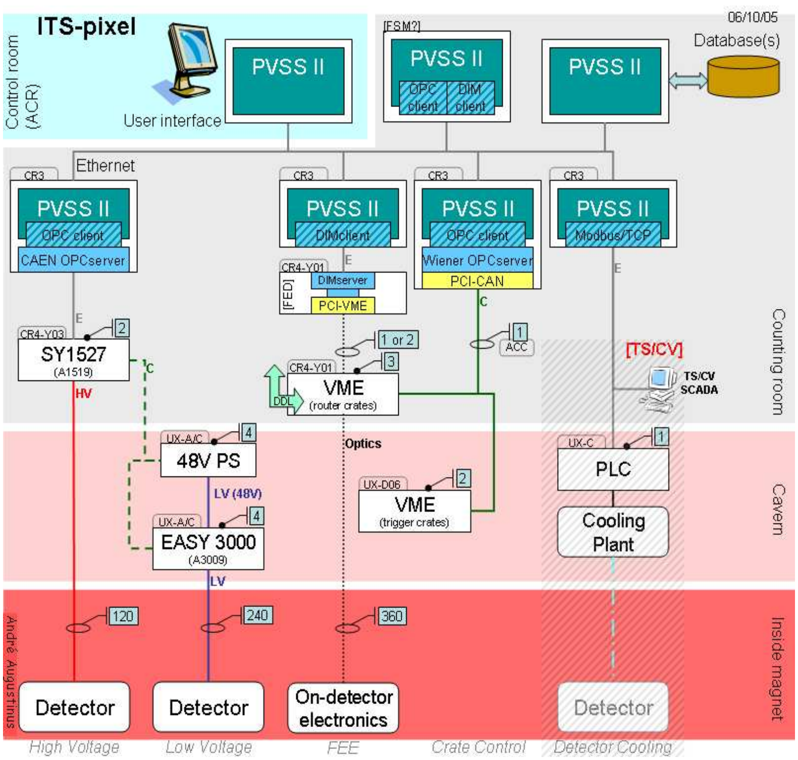

Figure 1: example overview drawing (for SPD sub-detector)

A total of 110 sub-systems have been identified across all sub-detectors. Standardization and the use of common solutions will reduce this to around 10 common sub-systems (applicable to several sub-detectors) and 15 specific sub-systems (applicable to a specific sub-detector only).

SYSTEM ARCHITECTURE

This section describes the hardware and software architectures that were adopted. Some implementation issues are discussed.

Hardware architecture and implementation

The hardware architecture of the control system can be divided in three layers (see figure 2). The supervisory layer consists of a number of PCs that will provide the operator access to the control system and perform most of the operation tasks; the Operator Nodes (ON). It is foreseen to have one of these per sub-detector. In addition this layer comprises a set of servers (SE) that will act as database and file servers for the whole DCS system. An additional set of PCs will be used for system related tasks (network, system management and administration etc.) for the whole DCS.

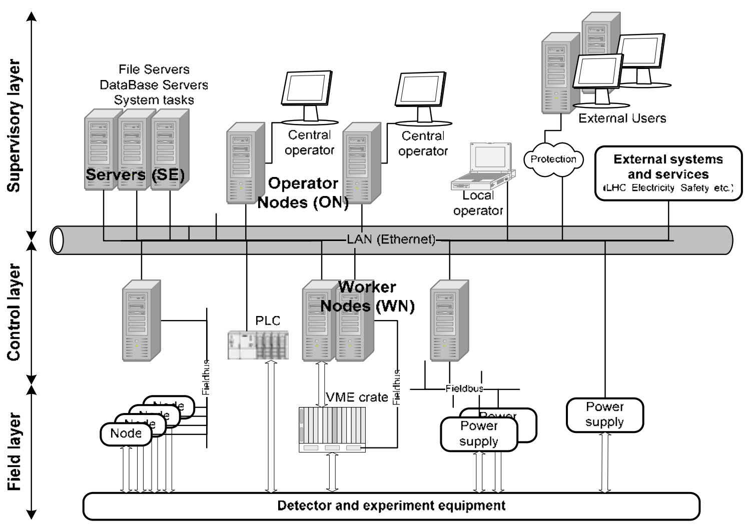

Figure 2: ALICE DCS Hardware architecture

The supervisory layer is, through the DCS LAN, connected to the control layer. The devices in this layer will be mainly PCs, so called Worker Nodes (WN), that interface to the experimental equipment. This layer also contains PLCs or PLC-like devices. The devices in this layer will collect and process information from the field layer, and make it available to the supervisory layer (e.g. for archiving or displaying). At the same time it will process information received from the supervisory layer and distributes it to the field layer.

The control layer is connected through LAN or fieldbuses to the field layer that comprises all field devices such as power supplies, field bus nodes, sensors and actuators.

Across all layers the aim is to avoid sharing of devices amongst sub-detectors (except for the servers in the supervisory layer) in order to ease the independent operation of sub-detectors. This is especially important during commissioning, maintenance and shutdown periods.

In each of the layers common solutions are adopted wherever feasible. In the supervisory and control level all PCs belonging to the same class (SE, ON or WN) will be identical, except for minor variations in the configuration such as amount of memory etc. The number of different computer interfaces (PCI or USB) is kept to a strict minimum. As the devices in the field layer are largely dependent on the sub-detector hardware, there is inevitably a larger variety of devices. However, also here an effort has been made to limit the diversity and to propose common solutions for similar tasks. An example is the General Purpose Monitoring System (GPMS). This system, based on the ATLAS developed ELMB[2], is used wherever temperatures, voltages etc. need to be monitored.

For critical actions, that could endanger the integrity of the experiment, hardwired interlocks are foreseen. These will allow, as an example, to implement a hardwired switch-off of the low voltage to the readout electronics in case of a cooling failure, independently of the software actions implemented in the control system. To protect the experiment from potential harmful external influences, the Detector Safety System (DSS, a safe and reliable part of the DCS) will take protective actions.

Software architecture and implementation

The adopted software architecture is a tree like structure that represents the structure of the sub-detectors, their sub-systems and devices. The structure (see figure 3) is composed of nodes, each (apart from the root node) having a single parent. A node can have zero, one or more children; a node without children is a leaf. The nodes are of two types: a Device Unit (DU) ‘drives’ a device and is a leaf node. A Control Unit (CU) models and controls the sub tree below it. Any sub-tree can be removed from the control tree and be operated independently and concurrently. This mechanism, known as ‘partitioning’, is implemented in each CU and allows sub-detectors to operate their

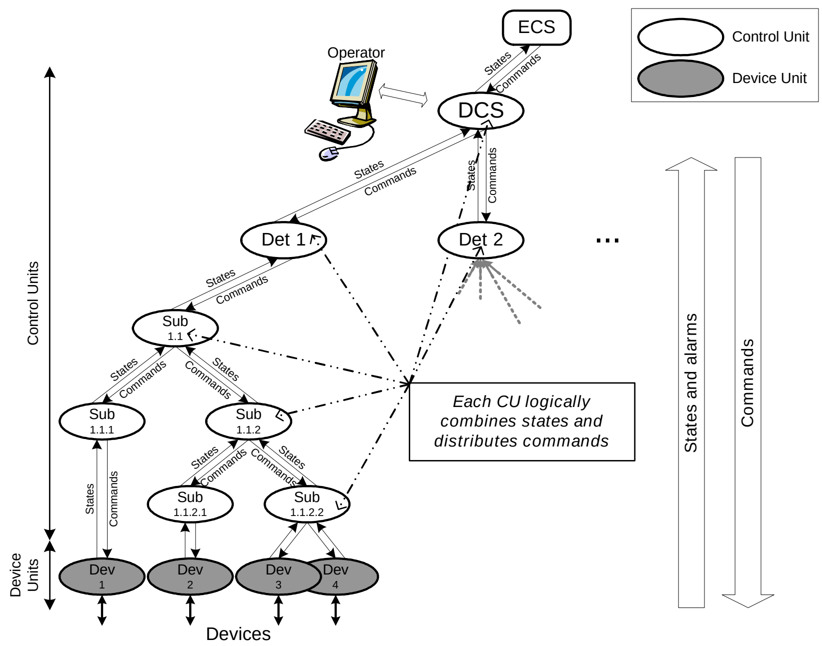

Figure 3: ALICE DCS Software hierarchy

equipment independently for commissioning, debugging or calibration. The behaviour and functionality of each control unit is modelled and implemented as a Finite State Machine (FSM) [3].

The Finite State Machine concept is a fundamental concept in the DCS architecture. It is an intuitive, generic mechanism to model the functionality of a piece of equipment or a sub-system. The entity to be modelled is thought of as having a set of 'states' and can move between these states by executing 'actions' that are triggered by an operator, or by external events.

For the implementation the PVSSII package and the JCOP developed framework is used. The FSM functionality is available in PVSSII through its implementation in the JCOP framework with the SMI++ package.

Based on experience from LEP experiments and refined in lab tests and test beams, standard state diagrams have been defined for most common sub-systems (high voltage, low voltage, etc.), and are implemented with the FSM tool by several sub-detector groups.

To restrict the number of communication protocols to communicate with the hardware two different protocols were identified to cover all the needs. OPC is a widely accepted and an industry standard to communicate with commercially available devices. This is the preferred protocol for this class of devices. PVSSII can act as an OPC client. To communicate with custom build equipment the DIM protocol is recommended; it implements a light weight cross-platform client-server mechanism. Both DIM client and server functionality is implemented in the JCOP framework.

To retrieve information from the various services (magnets, cooling, electricity etc.) an LHC wide standard protocol will be used: Data Interchange Protocol (DIP). This protocol, based on DIM, is implemented in the JCOP framework.

In ALICE most sub-detectors can configure, control or monitor their Front End and Readout (FERO) electronics via the DCS. Due to the large variety of detector technologies and their specific readout electronics, standardization in this area was difficult to achieve. To be able to deal with the multitude of different readout mechanisms and their specific requirements the Front End Device (FED) concept was developed[4]. The FED hides all the implementation details of the front end systems for the control system through a common DIM client-server interface. The interface will recognize commands common to all sub-detectors and will report status and data back to the control system. The FED has the flexibility to also accommodate sub-detector specific functionality.

A large variety of information essential for the operation of the experiment is stored in a collection of databases. The DCS will configure devices through PVSSII from the configuration database through mechanisms implemented in the JCOP framework. The FED will, where required, retrieve configuration data for the front end electronics through a direct access to the configuration database. Any data collected from the field layer can be stored in the archive for later retrieval (trending, post-mortem analysis etc.). A tool, AMANDA, to allow easy retrieval of archived data by non-PVSSII applications has been developed by the ACC. A special case of archiving is the storage of so called conditions data: information needed for the offline analysis of physics data (temperatures, drift velocities etc.).

DCS INFRASTRUCTURE

The detector control system will need an adequate infrastructure (network, computers, etc.) to operate. The infrastructure is procured, installed and maintained by a central team at CERN (part of the ACC), based on the requirements expressed by the detector groups.

Network

The (Ethernet) network as it will be used by the DCS will be a separated, protected network. No direct access to this network will be allowed from outside the experimental area. Remote connections, be it from CERN offices, from the collaborating institutes or any other ISP (e.g. from home) will have to pass through application gateways.

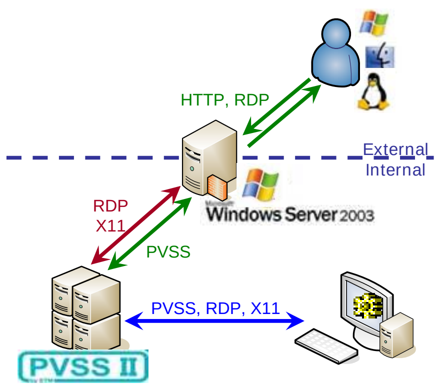

Figure 4: Remote access strategy

Performance tests of this strategy, where remote users connect through a Terminal Server (TS) to a PVSSII project are done. In the tests a remote user visualized continuously varying values (showing a panel with up to 200 values, each of them changing once per second). It was observed that 60 of such remote users could be connected at the same time to a single terminal server without any noticeable performance degradation (see figures 4 and 5). The strategy has also been successfully tested from several places around the world.

The ACC will order the major part of the network hardware with the network group at CERN (IT/CS) to profit from their expertise and ensure compatibility with the rest of the CERN networks. They will take care of the physical installation and maintenance of the network. This part of the network, that will mainly interconnect the DCS computer infrastructure with Ethernet based devices, will have in a first estimation around 350 ports. The whole of this network equipment (switches etc.) will be on non-interruptible power.

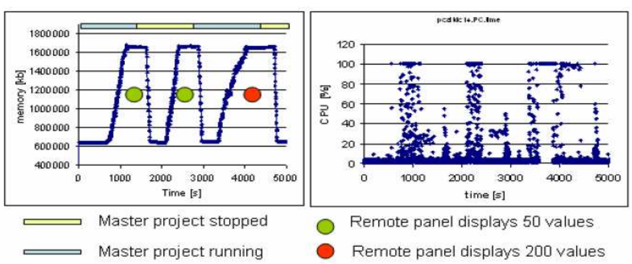

Figure 5: Performance of Terminal Server (60 users)

The part of the network that assures the connectivity with the embedded processors on or close to the detector is considered to be part of the sub-detector equipment. Network switches that will work in the harsh environment of the experimental cavern have been identified and will be installed and maintained by the sub-detector groups. An effort will be made to use the same equipment for all these applications within the experiment.

Computing infrastructure

All DCS computing infrastructure (PCs) will be installed in specially equipped computer racks at the experimental site. These will be 2U high rack mounted computers. The racks will be equipped with an air to water cooling system specially conceived for racks receiving a high density of computer power. All the PCs will be on non-interruptible power.

The baseline operating system for the ALICE DCS is Windows. All system management will follow the architecture and use the tools of a CERN working group: CNIC (Computing and Network Infrastructure for Controls) [5]. Linux will be used in only a few specific cases. All general applications and tools will be installed and maintained by a central team. Any sub-detector specific software (typically PVSSII projects) will need to pass a validation on a reference system, before installation on the production system.

Based on performance tests on larger scale systems a first proposal for the distribution of the sub-systems over the PCs has been made. An effort has been made to combine relatively low resource demanding sub-systems (mainly determined by the number of channels in a sub-system) on the same PC. This distribution has led to a total of about 85 machines to house the 110 sub-systems. Note that this number also includes the PCs that will act as servers or operator nodes. First tests on large distributed systems indicate that the whole DCS system can be operated as a large distributed PVSSII system. More detailed performance tests are being done to refine our knowledge. These tests will study the behaviour of all components in large distributed systems, especially under heavy load.

Further refinement can be expected based on detailed performance tests that have started on various individual components. An example of such a test is the measurement of the time needed to fully configure and switch on a power supply; this is the sum of many different aspects such as speed of FSM, database access and communication protocol performance as well as the reaction of the hardware itself. It is clear that optimisation here is very important to achieve an efficient operation of the experiment. First results of such test have revealed that a fully equipped high voltage crate can be switched on in well under 30 seconds. This overhead has to be compared with typical ramping times in the order of minutes.

DCS ACTIVITIES AT THE EXPERIMENTAL SITE

Over the last year several smaller stand-alone systems have been running at the ALICE experimental site for specific tasks, allowing us to run small prototype systems in a production environment. Examples are temperature surveillance of the TPC installation sites or monitoring of the magnetic field during magnet tests.

A core DCS system consisting of 5 machines has been installed and is operational at the experiment site since July. This system will be used for the installation and testing of several sub-detectors later this year. At that point devices and more worker nodes to interface to these devices will be added. In the first quarter of 2006 about 50% of the final computing power will be installed to cater for the needs of the sub-detector groups during the installation of their detector and associated equipment. The installation of the remaining computers will start the 3rd quarter of the same year, in order to be ready for full scale commissioning at the end of 2006.

The network used currently is the CERN campus network. Discussions with the network group at CERN have started and the definition of the controls network will be finalised this month in order to have the final network infrastructure installed and operational in the first quarter of 2006.

The DSS system is currently being commissioned and the first sensors will be connected. At the same time the interface to the first gas system and the CERN safety system will be implemented. Information from all these systems will be made available to the users via a console in the ALICE control room. As the installation of the services (cooling, electricity, etc.) progress, the control interface to these systems will be gradually put in place and made available to the users.

Coordinated operation of all the online systems (DAQ, Trigger, DCS) will start early 2006, when the TPC and other detectors will start a campaign of cosmics running.

CONCLUSIONS

Many sub-detectors have build, or at least prototyped, parts of their control system, and used them in lab or beam tests. This, combined with our own lab tests, gave us very valuable feedback on the architecture we have chosen for the ALICE DCS. Based on this minor improvements have been made but the basic philosophy proved to be well adapted to the sub-detector needs. Due to the chosen approach of standardization, re-use and common solutions, sub-detector groups are able to build their control systems with only a minimum of resources.

As we are entering the installation phase of the experiment, the DCS is installing its first stage to be used during the commissioning of the equipment that is being installed. Extensive performance tests will continue allowing us to further optimise the system. Results so far make us confident that the ALICE Detector Control System will be fully operational at the beginning of 2007, well in time to allow safe and efficient operation of the ALICE experiment to record the first collisions in the LHC.

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