Controls for the LHC Experiments

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Abstract

We describe the plans and activities at CERN to develop a common approach and solutions for the Detector Control Systems needed by the LHC experiments. Emphasis is put on the Joint Controls Project (JCOP), the systems architecture, as well as the selected standards and technologies.

I. INTRODUCTION

The Detector Control Systems for the LHC experiments have requirements in terms of size, complexity and availability exceeding by far whatever has been put into operation in this domain in the HEP community. Some of the experiments envisage to extend controls to cover data acquisition to build an integrated system.

The size of the collaborations requires distributed development, which brings in additional needs for standardisation and support of tools and methods to ensure a smooth integration when the detector components arrive at CERN. All systems will have to communicate as well with the LHC machine and CERN's technical infrastructure.

At the same time we witness a significant reduction of CERN's personnel, which makes an in-house development and long-term maintenance impossible. Fortunately, industry has made enormous progress in controls and has come up with open standards and new products, both in hardware and software, which allow us to build our systems largely with such items.

To address these issues a Joint Controls Project (JCOP) [1] was set up as a collaboration between all four LHC experiments and the CERN IT Division. This talk will present the chosen technologies and the approach chosen by JCOP to provide a common Framework to build detector control systems.

II. THE JOINT CONTROLS PROJECT

The LHC experiments will have to monitor and control an enormous number of items, the order is about one million per experiment. A large fraction of the equipment will be inaccessible during beam time, which means that high reliability is needed. Due to the distributed collaborations, the development will be distributed as well. Finally, the reduction of CERN's manpower combined with the need for long-term maintenance require solutions based upon industrial products. Taking these considerations into account, CERN's management decided together with the experiments to set up a Joint Controls Project (JCOP) to address these problems.

JCOP was established in January 1998. The partners are the four LHC experiments and the Controls Group of the CERN Research Sector (IT-CO). At the beginning of this year, additional help was made available from the EP-ESS group, which will provide solution for commonly used equipment such as racks and power supplies.

The JCOP mandate is "To develop a common framework and components for the detector controls of the LHC experiments and to define the required long-term support"[2].

A. Project Organisation

The project is organised around three bodies:

- The Project Team is the forum where technical matters are discussed, solutions proposed and reports presented. It meets bi-weekly and is open to everyone interested. We have regular participation also by non-LHC experiments and people from the accelerator and technical sectors.
- The Executive Board consists of the four Controls co-ordinators, the Project Leader (chair) and the IT-CO Group Leader, with occasional participation of the Deputy Division Leader of the EP Division. It is responsible for the day-to-day project management and meets bi-weekly as well.
- The Steering Board is composed of the members of the Executive Board plus the DAQ Co-ordinators and the Technical Co-ordinators of the experiments, as well as the Division Leaders of EP and IT or their Deputies (chair). It meets quarterly, gives high level direction and allocates resources. Reporting is to the CERN Technical Director for host-lab issues and to the LHCC for the Experimental Programme.

B. Main Project Goals

The project mandate defines a list of deliverables under the heading "common framework", which addresses all aspects of a basic system which should allow the experiments to implement their specific control systems.

The starting point was the collection of user requirements, which was a long and incomplete process, because most people building the sub-detectors have "more important" things to worry about than controls. While this is understandable, there is a risk that some of their needs might not be covered.

The second step is to establish a common controls architecture which will serve as the fundamental input for the development of a framework. After good initial work done about two to three years ago, JCOP established towards the end of 1999 the Architecture Working Group (AWG) [3], which started to become really active in the spring of this year with the arrival of an associate with experience in architectural design of data acquisition systems. The AWG started by defining a glossary of terms, it addresses all questions dealing with an overall controls hierarchy, partitioning to allow distributed and concurrent set-ups and debugging, command and alarm handling, access control and communication with external systems, just to mention the main topics.

The third step is the design and implementation of the Framework [4], which will produce the "products" that will be used by the developers of the final control systems. It provides in addition to the basic functionality of the SCADA system and the front-end components, implementation guidelines, pre-configured panels to build a controls hierarchy, to configure standard components, alarms, data logging, etc. It also provides hooks to add experiment-specific extensions.

C. *JCOP Information*

A comprehensive Web site [2] contains a lot of information both on general controls topics and on the JCOP project. Papers are published very early already during the discussion phase to allow everyone to inject their thoughts and to give feedback to the various sub-projects. It also contains links to the corresponding sites of the experiments.

III. CONTROLS ARCHITECTURE

The basic controls architecture will be the same for all experiments and resembles the classical industrial multi-level approach. Figure 1 shows the LHCb architecture [5] as an example with the different functional levels and with the typical technologies foreseen to be used.

At the Field Management level, the experimental equipment (sensors, actuators, devices) will be connected to a variety of front-end units based on the following technologies:

- Programmable Logic Controllers (PLC) for equipment and devices requiring either a high level of reliability or closed loop control and regulation, typically gas system, cooling regulation or similar. The channel density is low in such applications.
- Industrial I/O units for standard measurements and controls of temperatures, voltages, contacts, status bits. Examples are rack control, experiment infrastructure and units delivering only basic signals.
- VME based sub-systems for special purposes and where interfacing with readout electronics is required.
- Custom-designed embedded I/O such as the ATLAS Local Monitoring Box which aims at high density analogue measurements requiring radiation and magnetic field tolerant components.

Above this layer follows what we call the Process Management level, where we find again PLCs, probably VME, but mainly PCs dealing with fieldbuses and/or intelligent sub-units. Many of these units will incorporate

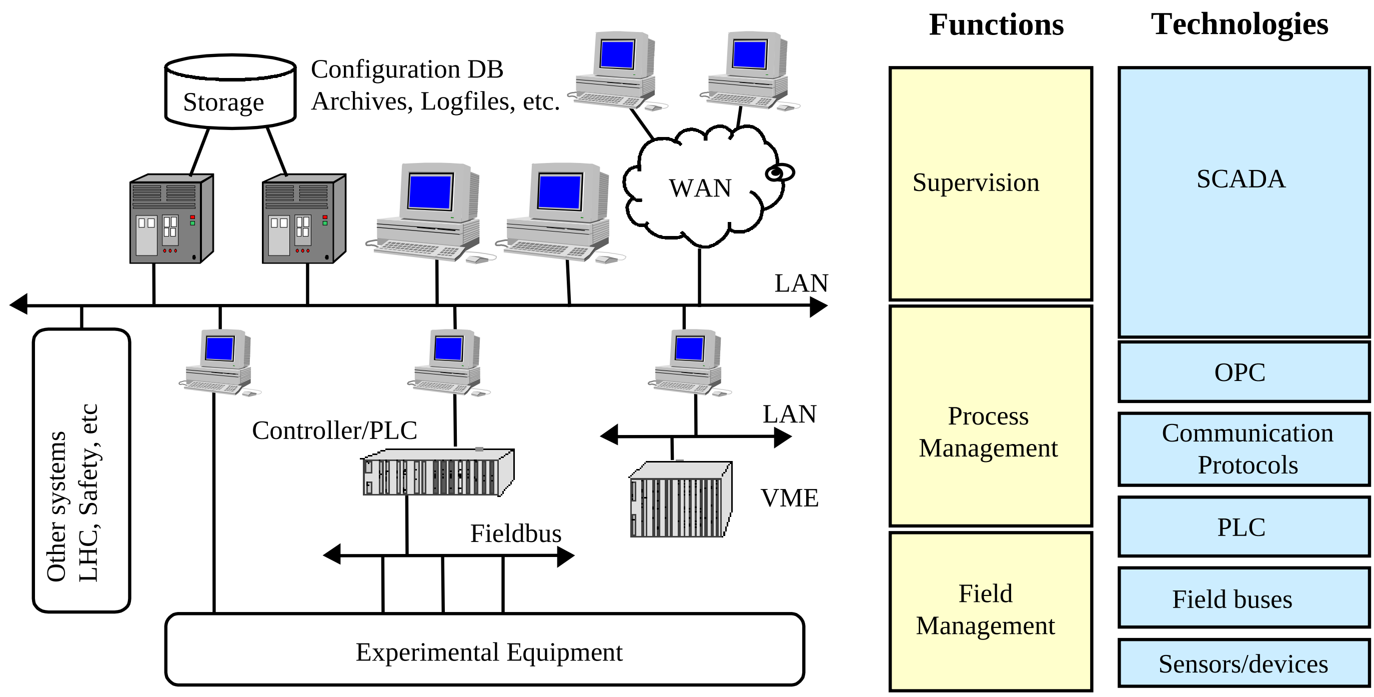

Figure 1: Example LHCb Architecture

OPC servers, a standard method to interface to the supervisory layer in a manufacturer-independent way.

Finally, the supervision level will be implemented using a commercial SCADA system which offers most of the functionality required to complete the system. This level deals with the human-machine-interface, access control, data logging, alarm handling, configuration management, just to mention the most important functions.

IV. New Technologies

During the recent years we witness a clear trend away from custom-developed control systems to systems based on industrial components. The two major technologies in our environment are OPC and SCADA.

A. *Object Linking and Embedding (OLE) for Process Control (OPC)*

OPC [6] addresses the problem of connecting a variety of PLCs from different manufacturers to the supervisory level, which itself is provided by different companies. This led in the past to the need for drivers for all types of PLCs (or other front-ends) in all supervisory systems.

The OPC concept introduces a unified layer between these two levels with OPC Servers towards the lower end and OPC Clients towards the supervision. In this way, a system with an OPC Client can connect to any front-end providing an OPC server. The OPC data model, shown in Figure 2, allows multiple clients to connect to the same server as well as a client being able to talk to several servers.

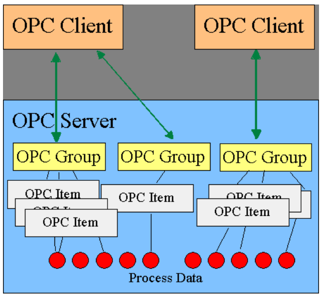

Figure 2: OPC Data Model

The individual data elements to be read or written are called OPC items, they are defined via the server configuration. Items are then put into groups defined by the client, i. e. each client can set up its own group with items of interest. OPC supports a variety of data access protocols which allows to optimise the exchange depending on the needs of the application.

OPC is well supported by PLC manufacturers as well as by third parties providing development packages. Most of them are members of the OPC Foundation which issues the standards. IT-CO represents CERN in the foundation. To promote the usage of OPC in experiments, OPC support is provided by helping newcomers to become familiar with the technology through training and consulting. We also work with suppliers of HEP-specific equipment the help them get started with OPC.

B. *Supervisory Control And Data Acquisition (SCADA) Systems*

SCADA systems have been introduced at CERN more than ten years ago, but initially only in the domain of industrial controls such as cryogenic plants. Initially, all these systems were proprietary without an open interface, which made it almost impossible to integrate them into a more complex environment.

Today's systems follow open standards for communications (TCP/IP), database access (ODBC, SQL), Web interfacing and run on NT and/or Linux. Most of them support OPC.

A few years ago it was nevertheless not clear at all if such a product would be adequate for the needs of the LHC experiments. JCOP therefore started an extensive evaluation project to search for products on the market and to evaluate them against the requirements. It began with Technology Survey in 1998 to understand the general capabilities of SCADA. Detailed discussions with companies, visits to reference sites and product demos followed. Then, six products were selected for in-depth evaluation, which concluded with recommendation to the community in September 1999. All four experiments agreed shortly after leading to a Market Survey and Tendering procedure. CERN's Finance Committee gave the green light in September 2000 to purchase PVSS-II [7] from ETM in Austria.

The contract negotiations are converging and we are pleased to announce that we can offer world-wide unlimited usage of the product for the LHC experiments. This marks a major milestone in the preparation of the detector control systems.

The benefits of SCADA are:

- Standard development environment leading to a homogeneous system
- Support for large distributed applications
- Buffering against technology changes such as operating systems, platforms, etc.
- Follows market evolution
- Provides maturity and stability
- Saves huge development effort (50-100 person-years)
- Company builds its experience into the product and provides documentation, support, maintenance and training

The drawbacks of SCADA are:

- Not tailored exactly to the end application
- Risk of company going out of business
- Company may develop unwanted features
- One has to pay

We believe, however, that the advantages outweigh the drawbacks by far and that our project will profit enormously from this strategic choice.

V. The Framework

Using a SCADA tool and other standard building blocks (OPC, PLCs, Fieldbuses) is a necessary but not a sufficient condition to ensure that a detector controls system can be developed in a distributed fashion and be integrated afterwards. These components leave too many choices to the developer which may lead to chaos unless a global architecture and the corresponding interfaces have been defined in advance. Furthermore, very similar functionality is needed by the various sub-systems and should therefore be provided centrally.

The JCOP Framework Project [4] is an attempt to overcome this problem. It will define a common architecture, define a set of guidelines and conventions, and develop a comprehensive set of tools and facilities.

At present, the architectural design is well underway (controls hierarchy, partitioning, alarm handling, persistency, …), prototyping of concepts has started, first components are being developed.

According to the project plan, a largely complete set of components and recommendations should become available in June 2001, following several intermediate releases.

VI. Conclusions

Controls for High Energy Physics experiments has evolved from home-made solutions to largely industry based solutions within a rather short time scale. Both the availability of components offering high performance and the decrease in numbers of development staff have been contributing factors.

The Joint Controls Project is considered a success today as it has brought the four LHC experiments together and led to the choice of a common set of tools and methods to allow each experiment to build its detector control system.

The major technology choices have been made and intensive development is starting. The next major milestone will be the release of the Framework.

VII. Acknowledgements

What I presented is the result of the work of many people from the experiments and IT-CO, who spent numerous hours in discussions to define the requirements, to find consensus on common solutions, to evaluate components and products and to converge on a limited number of choices. Special thanks go to David Myers who got the project off the ground and run it successfully during past three years. I also would like to commend the experiments for having made a big effort and compromises in the interest of common solutions. This is a real breakthrough. Last, but not least, the continuous support of CERN's management helped a lot to achieve our goals.

VIII. References

[1] see http://itcowww.cern.ch/jcop

[2] http://itcowww.cern.ch/jcop/revisedmandate4.pdf

[3] http://itcowww.cern.ch/jcop/subprojects/Architecture/

[4] http://itcowww.cern.ch/jcop/subprojects/Framework/welcome.html

[5] P. Mato, private communication

[6] http://itcowww.cern.ch/jcop/subprojects/OPC/welcome.html

[7] http://itcowww.cern.ch/pvss2/index.htm