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Centralized Monitoring of the Microsoft Windows-based computers of the LHC Experiment Control Systems

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Abstract. The control system of each of the four major Experiments at the CERN Large Hadron Collider (LHC) is distributed over up to 160 computers running either Linux or Microsoft Windows. A quick response to abnormal situations of the computer infrastructure is crucial to maximize the physics usage. For this reason, a tool was developed to supervise, identify errors and troubleshoot such a large system. Although the monitoring of the performance of the Linux computers and their processes was available since the first versions of the tool, it is only recently that the software package has been extended to provide similar functionality for the nodes running Microsoft Windows as this platform is the most commonly used in the LHC detector control systems. In this paper, the architecture and the functionality of the Windows Management Instrumentation (WMI) client developed to provide centralized monitoring of the nodes running different flavour of the Microsoft platform, as well as the interface to the SCADA software of the control systems are presented. The tool is currently being commissioned by the Experiments and it has already proven to be very efficient optimize the running systems and to detect misbehaving processes or nodes.

1. Introduction
The back-end software of the control systems of the LHC Experiments consists of a large variety of applications which monitor and control the order of a million I/O parameters per experiment. These applications are based on the commercial package PVSS [1] and the Joint Controls Project (JCOP) Framework (FW) [2] and are distributed over up to 160 computers that are geographically spread around the Experiments’ facilities. Efficient detector data-taking requires the concurrent and coherent operation of all these control applications. However, the unprecedented size and complexity of the Experiments make very difficult to understand the operational state of the control system itself and to diagnose problems. These necessities motivated the development of the System Overview Tool [3] of the JCOP FW, which provides monitoring of the various components of the control system and of their connectivity at all levels, as well as an efficient troubleshooting strategy.

2. The System Overview Tool of the JCOP Framework
The System Overview Tool provides centralized monitoring of the integrity of the control systems and assists experts diagnosing eventual problems. Figure 1 shows the logical organization of the System Overview Tool, which assumes an arrangement of the components of the control system into four different layers:

- **Hardware Layer**, which covers basis monitoring of various parameters, like fan speeds, voltage and current levels and temperatures.
• **Operating System Layer**, which comprises the monitoring of the CPU load, memory charge, network status and traffic, file system usage and process monitoring.

• **PVSS Infrastructure Layer**, which covers the detailed supervision and control of the PVSS processes running on the remote nodes.

• **Application Layer**, which involves the internal operation of the control application including its relation to external services, e.g. connection to the front-end equipment or to external database servers.

Given the different requirements of the LHC Experiments in terms of supervision, a modular concept was adopted for the implementation of the tool. Each of the subcomponents of the tool exploits different technologies to access the information from each of the layers listed above. This layered approach, together with the independent data paths used, allow for unambiguous isolation of the root of the problems.

Farm and process monitoring are performed by the Farm Monitoring and Control (FMC) sub-component of the System Overview Tool and is described in the next section.

![Figure 1. Logical arrangement of the JCOP System Overview Tool](image)

3. Farm Monitoring and Control
The Farm Monitoring and Control sub-component of the JCOP System Overview Tool covers the supervision of the hardware and operating system layers of the control systems. Due to the heterogeneous environment of the Experiments, where the Microsoft Windows and Linux platforms are used, the FMC package supports both operating systems. Moreover, a significant effort was made to homogenise the information handled for both sets of computers, thus largely simplifying the integration the monitoring within the JCOP System Overview Tool and providing a coherent picture of the farm to the operators.

For the supervision of the Linux nodes, the FMC agents originally developed to monitor the computers in the LHCb Event Filter Farms were re-used [4]. These agents are well-proven lightweight servers running on the remote nodes, which communicate with an arbitrary number of clients running on different PCs using the CERN Distributed Information Management (DIM) middleware [5]. Moreover, given the increasing constraints on manpower, the reutilization of the LHCb monitoring agents allowed to minimize the code development and permitted an easy integration of the supervision of Linux computers into the JCOP System Overview Tool. However, the unavailability of a suitable solution for the Windows computers offering similar functionality to the LHCb monitoring agents motivated the development of a dedicated monitoring agent. The design, implementation and functionality of this component are explained in the next section.

6. FMC of the Microsoft Windows-based Computers
Although the usage of Linux in the control system of the LHC Experiments is still increasing, the unavailability of some drivers and industrial technologies such as OLE for Process Control (OPC) [6]...
under this platform, led to a strong usage of Microsoft Windows for controls. Presently around 90% of the control computers run different flavours of Microsoft Windows. For this reason, a dedicated monitoring agent was developed to provide a coherent overview of the operational parameters of all nodes in the production system.

6.1. Design and Implementation

The Windows FMC server exploits the Windows Machine Instrumentation (WMI) technology [7] from Microsoft to access a number of parameters from different components and publishes the information via DIM such that the information can be visualized in the System Overview Tool. The following are some of the reasons that justify the election of WMI for the implementation of the monitoring agent:

- The WMI technology allows to access computers resources over the network, thus allowing the development of a centralized monitoring agent.
- WMI provides a common interface to different instrumented components of the operating system like processes, networking components or disks, thus enabling an eventual extension of the functionality of the monitoring agent in an easy way. These objects are represented by classes, which expose information through properties and allow the execution of some actions via methods.
- WMI features a SQL-like language called WMI Query Language (WQL) to access management information.
- WMI provides a transparent way to handle security, which is based on the Microsoft Distributed Component Object Model (DCOM) [8].

Unlike the LHCb Linux FMC agents, the usage of WMI enabled the development of a centralized monitoring process. This approach simplifies significantly the management of new versions over the life-time of the application and is less intrusive for the controls PCs. Figure 2 shows the layout of the different processes of the FMC subcomponent of the JCOP System Overview Tool.

![Figure 2. Process layout of the JCOP System Overview Tool.](image)

In order to cope efficiently with the number of hosts in the control systems, ~160 per experiment, the Windows FMC Agent is a multithreaded application where the monitoring of the target PCs is decoupled into separated threads. This results of special relevance to minimize the latency due to temporary unavailability of remote hosts. Furthermore, special care was taken to minimize the impact of the monitoring application onto the production machines, which run control processes and are substantially loaded.
6.2. Functionality

Figure 3 shows one of the main graphical interfaces of the System Overview Tool displaying the information gathered by the Windows FMC agent for a host. Table 2 shows the current list of parameters monitored by the Windows FMC. The information made available by the Windows FMC Agent can then be used to calculate summaries and generate reports per groups of hosts. Figure 4 shows as an example of the 30 top memory demanding processes in a set of computers. The tool also allows system managers to selectively set alerts, archive and trend the performance counter of particular processes, e.g. to detect possible memory leaks in processes or to fire an alert when a process crashes. This type of information is very valuable to optimize the control systems and identify misbehaving nodes or processes.

| Component          | General Information                                                                 | Performance Counters                              |
|--------------------|-------------------------------------------------------------------------------------|----------------------------------------------------|
| Operating System   | Type, service pack level, release version, last boot up time, local date time        | No                                                 |
| CPU                | Type, family, manufacturer, number of cores                                         | User%, Idle%                                       |
| Memory             | Total visible memory size, size stored in paging files                               | Free Physical Memory, Free Space In Paging Files    |
| Filesystems        | Name, mount point                                                                    | Total, % used                                      |
| Network Interfaces | Name, PIC bus, MAC and IP addresses                                                 | Tx and Rx bit rates                                |
| Processes          | Name, PID, user, command line, start date                                           | Memory used, CPU load                              |
| Services           | Name, type, start mode, desktop interact                                            | Status                                             |

7. Conclusions

The Windows Monitoring Agent enabled the extension of the farm and process monitoring to include also the computers running Microsoft Windows in the control systems of the LHC Experiments into the JCOP System Overview Tool. The selection of WMI as underlying technology allows centralized and homogeneous access to a vast number of system resources. On the other hand, the usage of DIM allowed a simple and elegant integration within the System Overview Tool of the JCOP FW. Although this agent is still in an early stage of development, its functionality has already proven to be very valuable to understand the behaviour of systems and to assist developers optimizing their performance across machines by identifying the most resource demanding processes.
Figure 3. One of the main panels of the JCOP System Overview Tool showing the information gathered by the Windows FMC agent for a remote host.

Figure 4. An example of the search capabilities of the tool showing the 30 top resource consuming processes in the farm.
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