MONITORING CONTROL APPLICATIONS AT CERN

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Abstract

The Industrial Controls and Engineering (EN-ICE) group [1] of the Engineering Department at CERN has produced, and is responsible for the operation of around 60 applications, which control critical processes in the domains of cryogenics, quench protection systems, power interlocks for the Large Hadron Collider and other sub-systems of the accelerator complex. These applications require 24/7 operation and a quick reaction to problems. For this reason the EN-ICE group is presently developing the Monitoring Operation of cOntrols Networks (MOON) tool to detect, anticipate and inform of possible anomalies in the integrity of the applications. The tool builds on top of Simatic WinCC Open Architecture (WinCC OA) [2] SCADA and makes usage of the Joint COntrols Project (JCOP) [3] and the UNified INdustrial COntrol System (UNICOS) [4] Frameworks developed at CERN. The tool provides centralized monitoring and software management of the different elements integrating the control systems like Windows and Linux servers, PLCs, applications, etc. Although the primary aim of the monitoring tool is to assist the members of the EN-ICE Standby Service, the tool may offer different levels of detail, which also enables experts to diagnose and troubleshoot problems. In this paper, the scope, functionality and architecture of the tool are presented and some initial results on its performance are summarized.

INTRODUCTION

The LHC accelerator complex and its associated Experiments rely on many critical auxiliary systems for their safe operation. The EN-ICE group at CERN develops solutions and provides support in the domain of medium and large control systems covering the Experiments, as well as the technical infrastructure and accelerator systems. The group was born in 2009 following a major reorganization of the controls groups at CERN, which aimed at centralizing in a single group the experts and the knowledge on industrial control systems existing at CERN. EN-ICE currently provides an ample portfolio of solutions and actively participates in the development of two successful controls frameworks at CERN that build on top of the WinCC OA (formerly PVSS): the JCOP and the UNICOS frameworks. The utilization of these two frameworks is promoted by the group in all WINCC OA-based applications in order to reduce the development and maintenance efforts.

Moreover, the group also develops and maintains a large variety of turn-key applications in various fields like cryogenics, power interlock systems and safety. These applications are wide-spread around the CERN facilities and although many of them are operated by separated groups, EN-ICE is the ultimate responsible for their correct operation and maintenance over the lifetime of the LHC.

A quick response to abnormal situations or misconfiguration of the systems is crucial to maximize the physics usage of the LHC. Two main actions were taken by EN-ICE to ensure the maximum availability of these control applications, namely:

- A standby service was put in place to guarantee the availability of an expert 24/7.
- A tool was developed to centrally manage software upgrades and to monitor the integrity of the applications, which provides an efficient troubleshooting strategy to both, members of the standby service and application developers. This is the Monitoring Operation of cOntrols Network (MOON) tool and it is described in the rest of this contribution.

MOON

Why Yet Another Monitoring Tool at CERN?

In the last few years, a wide spectrum of monitoring tools has flourished at CERN. Although these tools provide many similar functionalities, this variety is, to some extent, justified by the peculiarities of the applications that are imposed by the technologies used, and the operational environment. Prior to deciding on the development of a new tool, an evaluation of various existing monitoring applications was carried out. The following were some of the main criteria that could not be satisfied by the tools evaluated and that led to the development of MOON:

- Integrated software configuration management and application monitoring allowing for quick correlation between mis-configuration of the monitored applications (e.g. wrong versioning of a component or configuration parameters) and run-time anomalies.
- Centralized deployment of software components on sets of WinCC OA-based applications.
- Detailed light-weight access to the run-time databases of the remote WINCC OA-based applications exploiting the native interfaces and protocols of the product.
- Need to combine in a single tool the monitoring of all elements integrating control applications, namely: hosts, WINCC OA-based applications and their associated front-end devices, like PLCs and FIP [5] buses, as well as the supervision of the technical infrastructure, e.g. electrical distribution, status of the network devices, etc.
- Graphical representation of the components of the control application and of their interconnections and dependencies.

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- Support of multiple views presenting different levels of detail of the applications depending on the role of the user, e.g. a standby-service user with a limited knowledge of the applications as opposed to an expert or a developer.
- Multiplatform: given the extensive usage of Microsoft Windows and Linux for the control applications at CERN, detailed monitoring of hosts running these operating systems is required.
- Minimization of the development and maintenance efforts.
- Alarm system to list the current faults affecting the monitored systems. In addition the fault history to detect the recurrent problems.
- Long term storage of alarms and monitored parameters.
- Trending of online and historical values.

Moreover, it is very important to underline that MOON is not a complete new development as it is largely based on existing tool and reuses many components of the EN-ICE Frameworks as it is explained in the next section.

Architecture

MOON is an integrated monitoring and software management tool based on WINCC OA which exploits the following two main components of the JCOP Framework, which were originally developed for the control systems of the LHC Experiments:

- The Component Installation Tool [6] for centralized deployment of software components onto sets of WINCC OA-based applications.
- System Overview Tool [7] for farm and application monitoring.

The main building blocks of the application are shown in Figure 1. MOON extends the functionality of the JCOP System Overview Tool to also provide the monitoring of the PLCs and FIP agents. In addition, the demanding requirements of MOON in some specific areas like alarm handling and nightly reports called for a number of enhancements to the original functionality of the components that were successfully ported back to the base utilities. Moreover, the utilization of the UNICOS tools and concepts for the graphical interfaces provides an intuitive and powerful navigation schema for users with different technical backgrounds.

Functionality

The main graphical interface of MOON is shown in Figure 2. The panel is organized into multiple tabs that containing tree-like views of the applications and monitored equipment. These trees are implemented using the JCOP Finite State Machine (FSM) [8], which models each monitored component according to a well-defined set of states and possible transitions amongst them. Moreover, the FSM toolkit organizes these applications in a hierarchical fashion where the state of a node is calculated based on the state of its children where the leaves of the tree represent the actual monitored equipment, i.e. the PLCs, the hosts, the WINCC OA projects, etc.

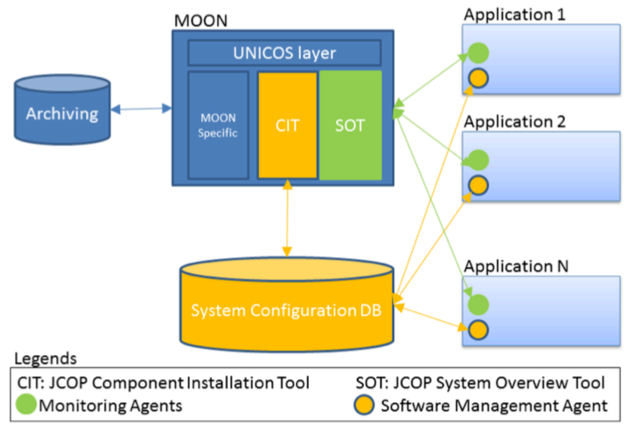

Figure 1: MOON main building blocks.

The state of each node in the tree is characterized by an associated colour. The propagation of the states and associated colours upwards in the FSM hierarchy summarizes the overall state of all monitored applications in a view and provides an intuitive method to locate the components of the control systems experiencing anomalies.

The selection of a node in a tree causes a dedicated panel to be displayed on the right-hand side of the graphical interface. The information displayed in those panels depends on the mode of operation of the tool: run-time monitoring or configuration management. Figure 4 shows an example panel in the former mode where a synoptic view providing a graphical representation of the monitored components, as well as their dependencies and connectivity is shown. In the configuration management mode, the panels display and allow modifying the configuration of the remote applications in a centralized fashion (Figure 5). This mode is restricted to experts by means of a strict access control policy and it is heavily used during technical stop periods of the LHC to upgrade sets of components in groups of applications. The arrangement of the applications in the FSM tree is preserved when toggling between the two modes of operation of the tool.

Each FSM view shows a different level of detail and logical organization of the equipment. As an example, the main view presented to the members of the standby service contains a coarse and simplistic representation of the control applications (e.g. current state and basic information of a device) whereas the expert view holds all required information for an expert to understand the behaviour of the application (e.g. statistics, performance counters).

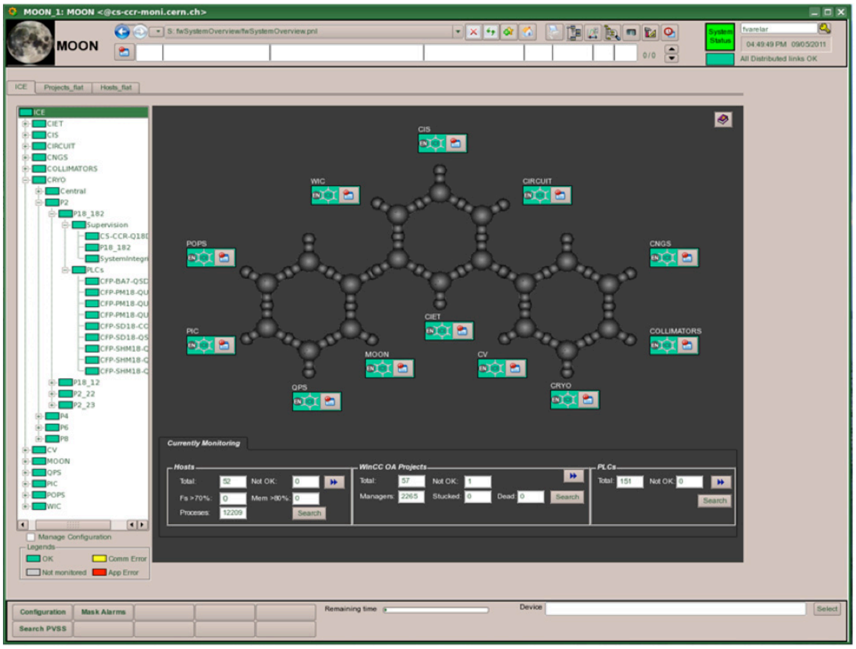

Figure 2: Main graphical interface of MOON showing a summary of the states of the EN-ICE controls applications.

At each level of the trees corrective actions on the remote applications can be taken by experts, e.g. to restart a process or reboot a host.

Problem identification is also complemented by the powerful alarm-handling schema featured by the tool. Besides an overall alarm screen, at each level of a FSM tree, the user can access a preconfigured alarm panel that restricts the alarms displayed to those raised by the equipment and applications in the local FSM sub-tree. Data gathered and alarms raised by MOON are archived to an ORACLE database for offline analysis. Alarms triggered by misbehaving sensors or problems in the readout can be masked by experts. This feature can also be used to prevent alarms from a particular set of applications during planned interventions. In this case, experts may define an expiration date for the masking such that the tool automatically unmasks these alarms at the due date.

MOON also provides a direct link from its alarm screen to the web help procedures written by experts that are associated with an alarm. Moreover, the tool also provides users with access to an electronics logbook to report an incident.

Web reports are generated daily for each application. These reports contain detailed information of the state of the different components integrating the control applications during the last 24 hours. In order to help analysing errors and predicting possible faults, the reports also include statistical data, like the number of occurrences of particular alarm.

System Size and Performance

The system which is currently in production has a considerable size and it is expected that it will grow in the near future (see Table 1). Currently, the parameters monitored by MOON are refreshed every few tens of seconds. However, this interval may be increased as system grows in size. Figure 3 shows the distribution of incidents per application domain over a week. Despite of the high number of incidents detected by the tool, an intelligent filtering schema is applied so that the standby service is notified only in the event of major faults.

Table 1: Monitored Items

Item	Current number	Estimated number	Refresh interval
Application Domains	12	20	N/A
Hosts (cores)	52 (544)	100	30s
PLCs	151	400	30s
WinCC OA applications	57	300	30s
Processes	12177	25000	30s

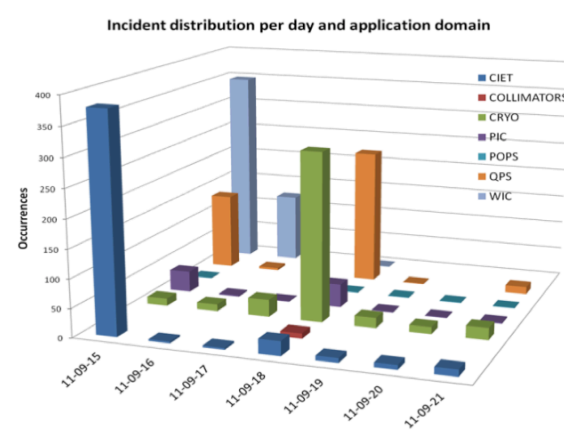

Figure 3: Incidents distribution.

NEXT STEPS

Currently, MOON monitors and provides views for the standby service for most of the EN-ICE WINCC OA applications in the accelerator and technical infrastructure domains. The development plan foresees a continuous upgrade of the tool with an incremental addition of new functionality whilst avoiding any interference with the monitored applications. In particular, a major milestone has been set for the unusually long stop scheduled at the end of 2011 beginning of 2012. During this period, it is planned to complete most of the functionality envisaged for the tool and to extend the range of monitored applications to Experiments. Specific actions include the completion of the expert views, enabling email notifications in the event of alarms, as well as the monitoring of devices and peripheral technical infrastructure, such as network equipment and electrical distribution that, although they are not a direct responsibility of EN-ICE, are vital for the correct operation of the control applications. Moreover, an effort will be made to extend the monitoring to the LabVIEW - based applications developed by the group. Finally, EN-ICE also foresees to offer the tool as a service to other groups at CERN having similar requirements in terms of application monitoring.

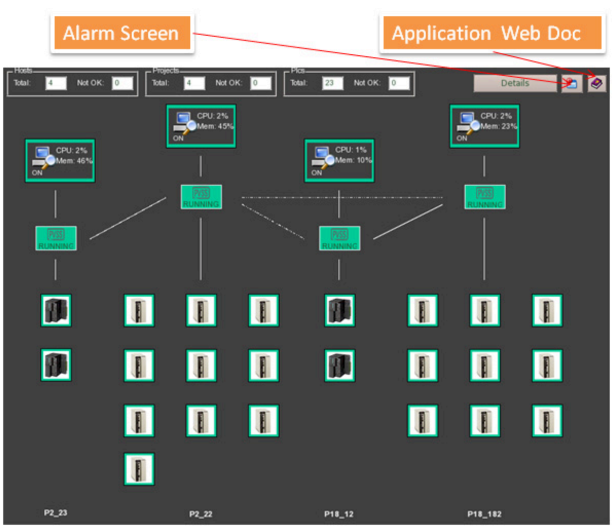

Figure 4: MOON user interface showing the layout of the cryogenics control applications for Point 2 of the LHC.

CONCLUSIONS

The modular design approach of the EN-ICE Frameworks, the clear definition of the user requirements gathered at the initial phase of the project, as well as the consistent model of abstraction the control applications has enabled a rapid development of MOON with limited resources. Although the tool has only recently entered the production phase, it has already shown its power to assist experts and members of the standby service in their daily work. A number of centralized upgrades have been successfully performed using the tool leading to a significant reduction of the time required for these interventions thus increasing work efficiency. Moreover, MOON has now become the primary tool for the members of the standby service to understand the behaviour of the control applications. The tool has successfully operated with no interference on the monitored applications since its initial deployment. For these reasons, MOON is already contributing its grain to maximize the Physics usage of the LHC by reducing the reaction time in the event of problems in the EN-ICE applications that control critical processes for the operation of the machine and the experiments.

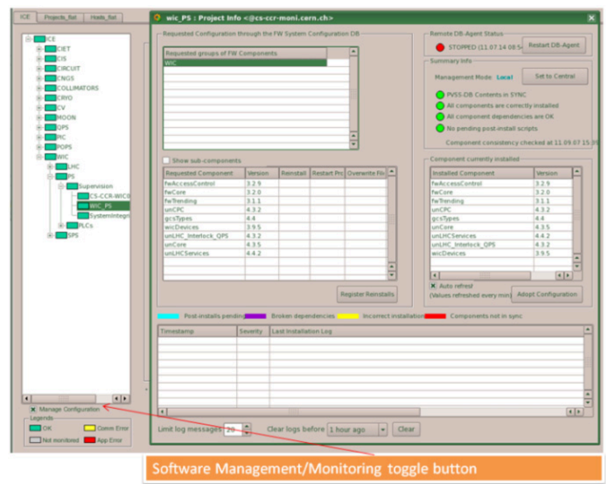

Figure 5: MOON software management panels showing the requested and current configurations of a WINCC OA project.

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