

REMOTE OPERATIONS OF AN ACCELERATOR USING THE GRID

R. Pugliese, M. Prica, Sincrotrone Trieste S.C.p.A., Trieste, Italy

Abstract

The Grid enabled Remote Instrumentation with Distributed Control and Computation (GRIDCC) [1] project is a three-year project funded by the European Commission (FP6 IST-511382). Its goal is integrating instruments and sensors with the traditional Grid resources. The GRIDCC middleware is being designed bearing in mind use cases from a very diverse set of applications, and as the result, the GRIDCC architecture provides access to the instruments in as generic a way as possible. GRIDCC is also developing an adaptable user interface and a mechanism for executing complex workflows in order to increase both the usability and the usefulness of the system. The new middleware is incorporated into significant applications that will allow the software validation in terms both of functionality and quality of service. The pilot application this paper focuses on is applying GRIDCC to support Remote Operations of the ELETTRA synchrotron radiation facility. We describe the results of implementing via GRIDCC complex workflows involved in the both routine operations and troubleshooting scenarios. In particular, the implementation of an orbit-correction feedback shows the level of integration of instruments and traditional Grid resources that can be reached using the GRIDCC middleware.

INTRODUCTION

Grid research has concentrated mainly on the marshaling of computation and data, and their interactions at hubs of analysis and synthesis. This focus has spawned the notion of computational and data Grids, respectively. As the technology for these has matured, increasing attention is being directed towards the actual sources of data: instruments and sensors. Scientific instruments and sensors provide the raw observations used to develop, falsify, and verify scientific theories and thus drive the scientific progress. The scientific process begins not with the data, but rather with the preceding data collection.

This collection interacts profoundly with interpretation and analysis, whether by human or by machine. Another important trend is the increasing use of *in silico* experiments, and the integration of model-based simulation with physical sensors. These projects further couple the data collection with analysis and simulation. In these scenarios, a unified paradigm for Grid-enabling both physical instruments and virtual instruments will result in flexible, extensible systems for exploiting the tremendous potential of information technology. The above considerations suggest that we seek to push the Grid to the edges of the practice of science: to the point where data is collected, and to the point where the scientist use data; and thus create an end-to-end Grid environment for scientific activity. Many instruments and sensors are

already digitally accessible, but they are poorly integrated into the Grid. In this paper we define an instrument to be any piece of equipment controlled through a computer interface such as telescopes, particle accelerators or power stations. Instruments work in real-time and their successful operation often requires rapid interaction with conventional computing and storage resources as well as with other instruments. The control of instruments is often an interactive process. The real-time and interactive nature of instrument control provides a critical requirement for the definition of acceptable Quality of Service (QoS) constraints for interactions between the different Grid components. In order to meet these defined QoS constraints it is often necessary to provide mechanisms for reserving the instruments [9], the required computing and storage elements and network bandwidth. While running an experiment, an application scientist will inevitably need to perform more than one task. A common scenario involves running an experiment using a piece of equipment, analyzing the obtained results and then in light of this analysis eventually conducting further experiments. Thus the need to provide the best possible support for workflows, defined as the execution and management of sets of dependent and potentially heterogeneous tasks. (In this paper, the term "task" is used to indicate a general piece of work while the term "job" refers specifically to a computational task.) Workflow support must be powerful enough to deal with a myriad of possible workflows that the application scientist may wish to describe, but also presented in simple and intuitive manner. It should not be assumed that application scientists are competent software engineers, nor should they be forced to act as such. Application scientists should be presented with a similar interface to the Grid and to the instruments to that which they are already familiar. For this purpose, the GRIDCC project is developing a Virtual Control Room (VCR) [12] environment that presents to its users a tailored interface both to the Grid and the instruments. One of the barriers to placing instruments onto the Grid in the past has been the risk of damage to the instruments caused by (unintentional) miss-use from the inexperienced users. Protection of the instruments through appropriate checks and measures becomes thus an essential requirement. These checks and measures include local problem solvers which are capable of diagnosing situations which would cause damage to an instrument; e.g. by monitoring the temperature of the positioning motors on a telescope and shutting them down in the case of overheating. Likewise, there is a need for global problem solvers required to identify problems that cannot be detected or remedied by a single instrument.

Considerable effort has already been made within the e-science community to develop Grid middleware through a number of projects [3], [5], [6], [7]. Whenever possible,

GRIDCC builds on these projects and the community standards and extends them with the added functionality. The GRIDCC architecture implementation is being developed within the gLite [4], a Grid middleware built within the EGEE [3] project. Among the many workflow description languages available for use within the Grid, BPEL [13] has been selected having a number of commercial and open source engines becoming available.

THE GRIDCC ARCHITECTURE

In this section we present the overall architecture [10] for the GRIDCC project. The project is composed of several service groups (Figure 1), each of which may be decomposed into a number of individual services.

Virtual Control Room (VCR): The VCR is the application scientists' interface into the GRIDCC system. VCR offers a customizable, user-friendly interface to the interactive real-time control of instruments and a complete collaborative environment for support of the group work.

Information Service (IS): The IS provides a repository for information collected within the architecture. It may be queried to discover information.

Global Problem Solver (PS): The PS uses information from the IS in order to diagnose potential situations which may lead to damage of the instrument or other elements. It is also responsible for taking whatever actions are appropriate to remedy these situations.

Security Services (SS): These services are omnipresent throughout the GRIDCC architecture and provide the mechanisms for performing authentication and authorization of users.

Execution Service (ES): The ES is responsible for taking a workflow defining a sequence of tasks to be performed and ensuring that it is executed with all existing QoS requirements.

Instrument Element (IE): The IE [8] is an abstraction of an instrument (or a group of instruments) into a standard interface that can be used within the rest of the GRIDCC architecture.

Compute Element (CE) and Storage Element (SE): The CE and SE are usual Grid abstractions of a computational resource(s) and storage resource(s).

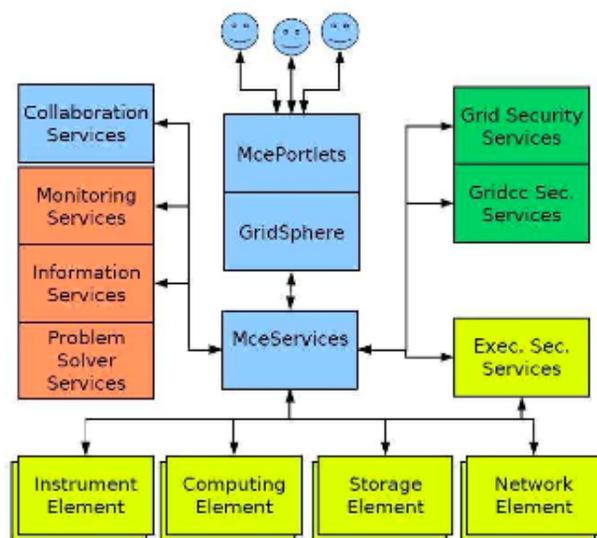


Figure 1: GRIDCC architecture.

APPLYING GRIDCC TO REMOTE OPERATIONS OF AN ACCELERATOR

Remote operations of an accelerator (e.g. ELETTRA) involve: planning of the accelerator operations, maintenance of the accelerator and its troubleshooting, repair of delicate equipment; understanding and pushing performance limitations; performing commissioning and set ups and various routine operations.

All these activities are based on large amounts of information, which are at present accessible only at the accelerator site. All the High Level Software (HLS) of ELETTRA, a third generation synchrotron radiation facility located in Trieste (Italy), is suitable to be implemented using the GRIDCC testbed Figure 2). ELETTRA HLS consists of application programs like OneBM (One-Button Machine) and OrbitFB (Orbit Feedback). The implementation of the OrbitFB application via a GRIDCC workflow, a real feedback via Grid, shows the level of integration of instruments and traditional Grid resources, which can be reached using the GRIDCC middleware. The machine operators and remote experts in a Virtual Control Room can collaboratively operate the accelerator in a routine and in a troubleshooting scenario. In the OrbitFB application, beam positions are sent via Grid to a remote computing center where orbit correction code is running and the corrections are feedback to the corrector elements thus improving the orbit of the storage ring. Remote control of an accelerator facility has the potential of revolutionizing the mode of operation and the degree of exploitation of large experimental physics facilities. Grid technologies facilitate the sharing of these resources across a distributed computing environment.

In particular, the Grid handles issues of authentication, authorization, resource description and location, data transfer and resource accounting, all of which makes Grid technologies extremely useful for implementing highly distributed control systems such as those of an

accelerator. Grid technologies can also be used to integrate operations with computing farms where complex machine physics models can run.

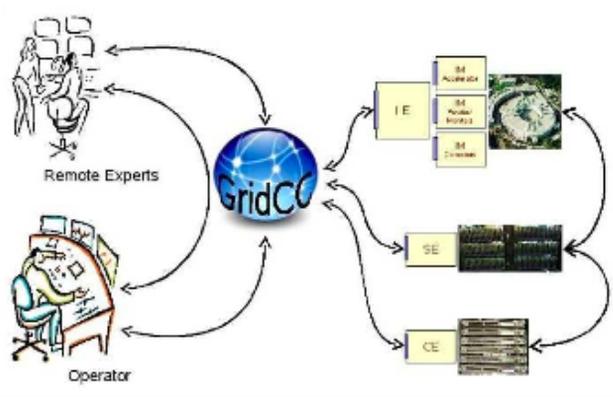


Figure 2: GRIDCC for remote operations of ELETTRA.

The implementation of the OneBM and the OrbitFB programs using the GRIDCC middleware and the involved complex workflows is a demanding task. The OneBM application controls different parts of the accelerator and turns them on gradually executing a set of tasks, monitoring the outcome of each task and taking corrective actions in case of malfunctions in order to have the machine up and running at the desired working parameters.

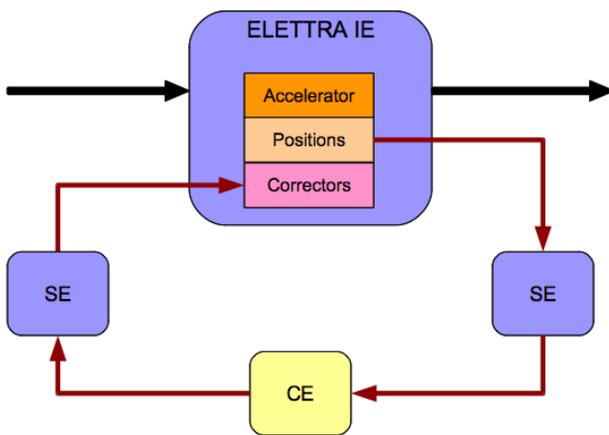


Figure 3: OneBM workflow.

In this case, different components of the GRIDCC architecture are involved and interact frequently, in particular the Instrument Elements and the Execution Services. In the OrbitFB (Figure 3) application the data coming from the machine is fed to a simulator to correct and optimize machine parameters in a loop. Implementing this challenging application required the development of a new machine simulator that can be controlled via Tango [11], the control system used at ELETTRA. As we are developing a generic bridge between the IE middleware and the Tango control system it will be very simple to move from a simulated environment to the real accelerator. The simulator may thus be effectively used to develop the pilot application. Moreover, the OneBM and Software Technology

the OrbitFB have to be coded as GRIDCC workflows and the corrector algorithm has to be coded as a separate program to be executed on a computing resource.

A very useful side effect of porting the HLS to the GRIDCC testbed is the possibility for ELETTRA to setup a powerful training tool by which a user can learn to control the accelerator using the simulator without affecting the status of the real machine. We have implemented an IE with three Instrument Manager (IMs). The first IM is the Accelerator, which allows controlling the general parameters of the machine and implements commands to initialize, start and stop the machine and inject current into the storage ring. Also, it allows injection of the beam orbit distortions used in simulations. The Position-Monitors IM allows the acquisition of the beam orbit in the storage ring of the accelerator through beam position sensors and saving the obtained data either locally or on a remote Grid storage element. The Correctors IM allows the correction of the beam orbit acting on a set of corrector magnets distributed along the storage ring. The values applied to the corrector magnets are the result of the orbit correction calculation and may be uploaded from the local file system or from a remote Grid storage. The IMs are all interfaced with a set of Tango devices that implement the machine simulator and in the future they could be connected to the Tango devices that control the real machine. An additional IM, the Orbit-Corrector has been developed to interact with a local computing resource that executes the orbit correction code.



Figure 4: An operator in the ELETTRA control room.

RESULTS

In the current setup a remote operator can log in the Virtual Control Room and launch the OneBM workflow that starts the machine simulator and gradually injects current into the storage ring of the accelerator reaching the normal operating conditions. The operator may then interact with the machine modifying the orbit by injecting a random distortion and thus simulating a problem. VCR offers the operator a set of collaboration tools such as

Skype [14] and VRVS [15] that allow him to contact remote experts and discuss operating procedures or seek advice in case of eventual malfunctions. To deal with an orbit distortion, an expert would likely suggest launching the OrbitFB workflow. The operator (Figure 4) can monitor the workflow execution from the VCR and at the same time interact with the Position-Monitors IM to visualize the orbit and evaluate the quality of the beam. The OrbitFB has been tested in three different setups: The first one uses an IE to interact with a local CE, an approach similar to the one used by NEESgrid [16] project. With this configuration we managed to run the OrbitFB loop at 1 Hz. The second setup uses CREAM [17] as a web service interface to the specific remote CE. We managed to run the OrbitFB loop every 5 seconds with this setup. In the final setup we used the WMProxy [18] as a web service interface to the gLite broker. As expected, it turned up to be the slowest setup, with OrbitFB loops running every 20 seconds.

CONCLUSIONS

Far remote operations of the ELETTRA accelerator pilot application shows the potential of the GRIDCC middleware in accessing and controlling distributed instrumentation in a large experimental physics facility. It also demonstrates how Grid technologies can be used to integrate operations with computing farms where complex machine physics models can run. VCR, the GRIDCC user interface, provides operators and experts with a set of tools that allow collaborative efforts in coping with everyday tasks as well as handling exceptional events. This pilot application will evolve with the further development of the GRIDCC middleware. GRIDCC will use agreement service layer between the workflow management system and the grid resources providing the resource reservation service. An integrated problem solver will monitor the running tasks in order to identify error conditions and provide support for fault-tolerant operation.

ACKNOWLEDGEMENTS

We would like to thank the GRIDCC team and the ELETTRA machine physic and machine operators

groups. The GRIDCC project would not be possible without the contribution of the European Commission (FP6, IST-511382).

REFERENCES

- [1] GRIDCC Grid Enabled Remote Instrumentation with Distributed Control and Computation, <http://www.gridcc.org/>
- [2] ELETTRA Sincrotrone Trieste, <http://www.elettra.trieste.it/>
- [3] Enabling Grids for E-science, <http://public.euegee.org/>
- [4] GLite: Lightweight Middleware for Grid Computing, <http://glite.web.cern.ch/glite/>
- [5] The Globus Alliance, <http://www.globus.org/>
- [6] The Condor Project, <http://www.cs.wisc.edu/condor/>
- [7] Platform LSF, <http://www.platform.com/products/LSF>
- [8] Frizziero, Gulmini, Lelli, Maron, Oh, Orlando, Petrucci, Squizzato, Traldi, Instrument Element: a new Grid component that enables the control of remote instrumentation, <http://www.gridcc.org/getfile.php?id=1496>
- [9] T. Ferrari, E. Ronchieri, gLite Advance Reservation Architecture, <http://edms.cern.ch/document/508055>
- [10] The GRIDCC Architecture Document, <http://www.gridcc.org/getfile.php?id=1382>
- [11] Tango Control System, <http://www.tango-controls.org/>
- [12] Pugliese, Asnicar, Del Cano, Chittaro, Ranon, De Marco, Senerchia, Collaborative Environment for the Grid - Multipurpose Collaborative Environment, Distributed Cooperative Laboratories, Springer 2006
- [13] BPEL4WS, <ftp://www6.software.ibm.com/software/developer/library/wsbpel.pdf>
- [14] Skype communication tool, <http://www.skype.com>
- [15] VRVS Virtual Room Videoconferencing System, <http://www.vrvs.org/>
- [16] NEESgrid project, <http://it.nees.org/>
- [17] CREAM, <http://grid.pd.infn.it/cream/>
- [18] WMProxy, <http://egee-jra1-wm.mi.infn.it/egee-jra1-wm/wms.shtml>