The DORII Project Test Bed:
Distributed eScience Applications at Work

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Abstract— Much interest has arisen recently on the access to and
management of remote instrumentation and laboratory
equipment in general. The complex of activities related to these
topics can be summarized under the name of Remote
Instrumentation Services, where the term “instrumentation”
includes any kind of experimental equipment, and the term
“services” underlines the general framework whereby the
instrumental resources should be accessed (i.e., the Service
Oriented Architecture). Building on the foundations of previous
European projects, the aim of DORII (Deployment of Remote
Instrumentation Infrastructure) is to build and operate a test bed
addressing different areas of eScience. These include
oceanographic applications, earthquake engineering, and large-
scale physics experiments on synchrotron light. The paper
describes the characteristics and the design of the test bed
stemming from the applications’ requirements, in terms of
networking and middleware, and its current status of
development.

Keywords-eScience Applications, Grid Testbeds, SOA/Web 2.0
Services Testbeds, Next Generation Services Testbeds.

I. INTRODUCTION

Access, configuration, monitoring, control and management of
remote laboratory instrumentation gained growing interest
with the development of the so-called e-Science [1-4].
Remotely controlling a device, sending commands and
acquiring measurements is not new - it has been done and it is
being done in a whole range of different applications.
However, a Remote Instrumentation Service is more than this:
• It should provide a set of standard capabilities to perform
whatever functionality may be required;
• It should construct suitable abstractions of the remote
instrumentation, in order to make it visible as a manageable
resource;
• It should present the user standard interfaces, and allow
browsing the “distributed laboratory space”, choose different
pieces of equipment, configure their interconnection,
orchestrate experiment executions, collect, process and
analyze the results, and make them available to the scientific
community through experiment data repositories, organized as
Digital Libraries.
In order to accomplish such tasks to a full extent, instruments
should become full class members of a Service Oriented
Architecture (SOA), much in the same way as computing and
storage devices are. Test sites should be developed, providing:
i) isolation from and relative independence of the underlying
networking infrastructure; ii) tools for resource allocation and
management; iii) standard user interfaces; iv) non-trivial
Quality of Service (QoS) control and QoS-aware workflows;
v) integration in the Grid. All this can be put in perspective
within the framework of the Open Grid Services Architecture
(OGSA), by enhancing existing service capabilities.
Building on the experience gained in previous European
projects (notably, among others, GRIDCC [5], and RINGrid
[6], on Remote Instrumentation, int.eu.grid [7], on
interactivity, and g-Eclipse [8], on software frameworks for
application developers), the DORII (Deployment of Remote
Instrumentation Infrastructure) project [9] is currently
designing and setting up an extended infrastructure with the
direct involvement and cooperation of users in three main
areas:
• Earthquake community (with various sensor networks);
• Environmental science community;
• Experimental science community (with synchrotron and free
electron lasers).
The goal of the present paper is to highlight the design choices
and the current development status of the DORII
infrastructure, particularly with respect to the specific
application fields, in terms of advanced networking and
middleware solutions. The paper is organized as follows.
Section 2 describes the applications and their requirements.
Section 3 deals with the networking aspects, whereas Section
4 is devoted to the middleware ones. Section 5 contains the
conclusions and directions for future development.
II. DORII APPLICATIONS

DORII applications span a significant range of e-Science domains, each presenting some challenges for the effective exploitation of Grid and networking services. In each of the three groups mentioned in the introduction, there are several differentiated scenarios, which we briefly outline in the following. The goal of DORII is to provide an integrated support environment to such applications, in terms of networking and middleware, by using similar concepts and abstractions, allowing interactivity among scientists and application developers, collaborative working, real-time collection, transfer, manipulation and visualization of data, virtualization and publication of real instrumentation as grid resources.

A. Earthquake Engineering

• Network-Centric Seismic Simulations (NCSS)
  
  This application aims at performing pseudo-dynamic simulations using sub-structuring. This means that a part of the building being simulated is a “virtual” structure, while another part is a physical specimen placed in a laboratory and equipped with actuators (to apply forces or displacements) and sensors (to measure reactions). The simulation server collects the data provided by the sensors and the calculated response of the virtual building components, putting all together in order to represent this set as a unique structure.

• Earthquake Early Warning System (EEWS)
  
  An earthquake early warning system provided with the computational capabilities of a grid infrastructure can be used to speed up the calculation of shake maps. In particular, fast shake maps are very useful for damage assessment in a post-seismic scenario, when it is necessary to coordinate in a safe and quick way rescue team operations. A network of seismic sensors should be deployed and connected by means of a wireless connection to a grid infrastructure. In the presence of an earthquake, all the typical seismic parameters (epicenter, magnitude, ground acceleration, etc.) are estimated and then used to build fragility curves. In the easiest implementation, the application has only to perform an interpolation accessing a database of use cases already calculated (with a non-trivial computing effort, simplified by the grid) in order to fit the current situation. In the other case, the map is calculated immediately after the earthquake parameters are recorded.

B. Environmental Science (Ocean and Coastal Monitoring)

• Oceanographic and coastal observation and modeling
  
  Specific instruments (FLOATS) drift with the current at specific depths and perform temperature and salinity profiles that are transmitted to satellites. The data are received by a ground station in Toulouse through the Argos system on-board polar orbiting satellites and are sent by email to the National Institute of Oceanography and Experimental Geophysics (OGS) in Trieste, Italy, every 8 hours. The OGS processing server starts to update the float files with the positions. Graphics with the positions of the floats are produced and status tables are updated and posted on the web. The entire processing up to this stage is automatically activated every 8 hours. The scientific community may access public and restricted data. OGS developers can also access raw data and update processing software. In the future they will also be able to update floats attributes and parameters.

  This system is complemented with a second kind of (steerable) instrument (GLIDER), programmed to follow a specific route and perform temperature, salinity, oxygen, chlorophyll, and turbidity profiles. The glider transmits its data through a satellite link (Iridium) and the data are received at OGS dock server (as binary files). The processing starts by converting the binary files into ASCII files. Graphics of data are generated and posted on the web. In this application, there is the possibility to interact with the instruments and change the mission parameters.

• Mediterranean Ecosystem Forecasting - weekly Production of Analyses and Forecasts (OPATM-BFM)
  
  The application provides a complete Mediterranean Marine Ecosystem model, which is being considered in a twofold perspective: i) as an automatic procedure (operational chain), which starts weekly and provides 7-day daily analysis and 10-day daily forecasts for the Mediterranean Marine Ecosystem; ii) for long-term climatic simulations of the Mediterranean Marine Ecosystem. The model is a complex one, coupling physical forcing and transport equations with a biogeochemical flux model.

• Coastal Observation and Modeling using Imaging (HORUS Bench)
  
  Digital imaging and remote sensing are used for beach monitoring (user distribution, intertidal profile), as well as river monitoring. A remote station consisting of one or more cameras and a cabinet with a computer inside collects data and sends them to the local network, by using GPRS/UMTS, Wi-Fi or ADSL.

• Simulation and Monitoring System for Inland Waters and Reservoirs (SMIWR)
  
  The application taken into account in the DORII project mainly concerns the surveillance of toxic algae bloom. The instrumentation is installed at a water reservoir in Spain to control water quality (with physical and biological measures). The instrumentation should provide information in near real time about the water quality status. In parallel, a simulation model provides a prediction of the evolution of this quality. Both pieces of information are contrasted in a monitoring system, used by the water management authorities to apply corrective and preventive actions.

C. On-line Data Analysis in Experimental Science (ODAES)

Experimental stations in facilities like Synchrotrons and Free Electron Lasers produce huge quantities of data. These data need to be analyzed on-line, which requires considerable computing power and often teamwork. The problem is even more difficult considering the increased efficiency of the light sources and detectors. Complex calculations are required to take diffraction images and convert them into a 3D protein structure. Similarly, complex calculations are required to
produce tomographies and then perform an analysis of the result. The results of these analyses often need to be visualized by a distributed team and used to modify interactively the data collection strategy. Data from instruments and sensors are saved in distributed repositories, computational models are executed, and finally an interactive data mining process is used to extract useful knowledge.

This kind of application requires both the support of a standard grid computing environment, that is a virtual organization, a set of distributed storage and computing resources and some resource brokering mechanism, a workflow definition and execution environment, and the capability to integrate instruments (the detectors) and interactively collaborate in the data analysis process. A QoS handling mechanism is necessary to use effectively the available network structure. This application can be actually considered as a group of applications, since each beam-line and experimental station represents a completely different data collection process, with specific processing, storage, analysis, sharing, and visualization requirements.

This area concerns three main lines, developed around synchrotron light experiments. Actors involved in this application are software developers, beam-line scientists, and users of the experimental stations. The developers can perform all the activities of the scientists and also deploy software and define the collective behavior (workflows and scripts). The beam-line scientist can perform all the activities of the users, besides controlling the beam-line instrumentation and the detectors. The user can access and visualize data even remotely, collaborate with other users, beam-line scientists and developers, define the data collection strategy, start stop data acquisition, and monitor the acquisition and online processing process. The user can also run scripts and workflows and monitor their execution, and perform offline processing of the available data. This application will be applied to the following beam-lines and experimental stations.

• **SAXS (Small Angle X-ray Scattering)**
  SAXS has become a well known standard method to study the structure of various objects in the spatial range from 1 to 1000 nm, and therefore instruments capable to perform such experiments are installed at most of the synchrotron research centers. The high-flux SAXS beam-line at ELETTRA (Trieste, Italy) is mainly intended for time-resolved studies on fast structural transitions in the sub-millisecond time region in solutions and partly ordered systems with a SAXS-resolution of 1 to 140 nm in real-space.

• **SYRMEP (Synchrotron Radiation for MEdical Physics)**
  The SYRMEP beam-line has been designed by Sincrotrone Trieste, in cooperation with the University of Trieste and the Italian National Institute of Nuclear Physics (INFN), for research in medical diagnostic radiology. The use of monochromatic and laminar-shaped beams allows, in principle, an improvement of the clinical quality of images and a reduction of adsorbed dose (because of both monochromatic and scatter reduction). The available imaging techniques of the SYRMEP beam-line are conventional absorption radiology and tomography, phase contrast imaging, diffraction enhanced imaging.

• **X-Ray Diffraction**
  The X-Ray Diffraction 1 (XRD1) beam-line has been designed primarily for macromolecular crystallography.

The following diagram (Fig. 1) describes how the functional components interact during a typical workflow of the online processing in experimental science. The functional components appearing in the figure are the Virtual Control Room (VCR), the Instrument Element (IE), the Storage Element (SE), and the Computing Element (CE). Whereas SE and CE are “classical” Grid components, the VCR and the IE are a recent addition to Grid middleware, and are currently being further enhanced within DORII.

![Fig. 1. Functional components and workflow in ODAES.](image)

### III. Networking

#### A. Network Application Requirements and Network Infrastructure

The project has conducted an in-depth analysis of applications’ networking requirements [10]. When looking at DORII applications from the network requirements perspective, they can be divided into two major groups: i) applications that process pre-collected data: NCSS, FLOAT, GLIDER, OPAT-BFM and HORUS belong to this category; ii) applications working on data acquired in real-time: these include EEWSS, SMIRW, and the three ODAES cases. Moreover, it is necessary to take into account that in most instances data processed by the applications are acquired in real-time by using a sensor network.

Applications in both classes are characterized by a point-to-point communication paradigm and, in general, do not use data replication. Therefore, multicast or point-to-multipoint LSPs (Label Switched Paths) are not necessary. The main QoS requirements that have been identified are summarized in Table I.

Moreover, the following characteristics can be outlined:
1) Applications that process pre-collected data
   - Bandwidth requirements cover a wide range – from 1 to 100 Mbps, but none needs very large data pipes (in the order of a few Gbps);
   - All applications require low packet loss, but (with the exception of one) they can tolerate some delay and jitter;
   - The nature of the majority of traffic sources is VBR (Variable Bit Rate), i.e., the sources are bursty.

2) Applications working on data acquired in real time
   - Multicast or point-to-multipoint LSPs are not necessary;
   - Again, bandwidth requirements cover a wide range, but no large data pipes are needed;
   - There are variable requirements in terms of packet loss (from very low to high) and jitter (from none to high) that may be tolerated;
   - The nature of the traffic is bursty.

<table>
<thead>
<tr>
<th>QoSs</th>
<th>Bandwidth</th>
<th>Throughput</th>
<th>Max Delay</th>
<th>Jitter</th>
<th>Packet Loss</th>
<th>Path Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLOAT</td>
<td>10 Mbps</td>
<td>1 Mbps</td>
<td>&gt; 50 ms</td>
<td>Low</td>
<td>Very Low</td>
<td>No</td>
</tr>
<tr>
<td>GLOSER</td>
<td>15 Mbps</td>
<td>15 Mbps</td>
<td>&gt; 50 ms</td>
<td>High</td>
<td>Very Low</td>
<td>No</td>
</tr>
<tr>
<td>OPTIM-BM</td>
<td>15 Mbps</td>
<td>15 Mbps</td>
<td>&gt; 50 ms</td>
<td>High</td>
<td>Very Low</td>
<td>No</td>
</tr>
<tr>
<td>FORUS</td>
<td>10-100 Mbps</td>
<td>10-100 Mbps</td>
<td>&gt; 50 ms</td>
<td>High</td>
<td>Very Low</td>
<td>No</td>
</tr>
</tbody>
</table>

Table I. QoS requirements for DORII applications.

In both cases, we observe that bandwidth reservation with book-ahead scheduling may be useful and should indeed be applied in some cases. High reliability is always required. Local access networks (LANs) will be upgraded to the Gigabit level and, wherever possible, traffic priority mechanisms will be introduced. Layer 2 VPNs and, in some cases, point-to-point guaranteed bandwidth connections should be implemented in the backbone. Bandwidth on Demand (BoD) and the adoption of IPv6 are not strictly necessary, but they will be experimented in our test bed for some applications.

A first sketch of DORII connectivity is depicted in Figure 2.

B. Network Monitoring and Management

Network performance monitoring and management within DORII will facilitate the resolution of end-to-end performance problems on paths crossing several networks. Due to the distributed nature of the DORII architecture where the applications will be embedded, special attention has to be given on the proper design of monitoring and management tools. It is important to recall that the DORII network is a multi-domain one; thus, there is the need of the deployment of cross-domain monitoring. Network administrators will be able to access network performance metrics from across multiple domains.

The networking services that are going to be deployed among DORII partners (VPNs, dedicated bandwidth) have specific QoS requirements, rendering their management necessary. In addition, attention has to be paid to the different network access technologies (Gigabit Ethernet, ADSL, WLAN) and the performance metrics that have to be measured in each connectivity link.

As far as the deployed grid applications are concerned, their requirements in computing, storage and network resources are high and require the installation of end-to-end paths. Thus, the provision of QoS to these applications require the establishment of Service Level Agreements (SLAs) and their appropriate monitoring, in order to fulfill their requirements for service availability and performance, by providing guarantees for the delay, inter-packet delay variation, packet loss and capacity.

Taking into consideration the above peculiarities, some of the tools and provided services that are going to be deployed for monitoring and management of the network are the following:

- Network weather-maps that display in a visual way the utilization of the network links;
- MRTG diagrams that monitor SNMP network devices and draw pictures showing how much traffic has passed through each interface;
- Provision of performance metrics of specific links (throughput, delay, lost packets);
- End-to-end path monitoring that is appropriate for Grid-aware applications;
- Monitoring of the deployed services with DORII partners;
- Provision of network statistics and tools for basic commands (ping, traceroute, etc.);
- Notification messages when service or host problems occur and get resolved (via email or other user-defined method);
- SLA monitoring.

In order to provide these services we are examining the installation of monitoring tools, such as perfSONAR [11] or Nagios [12]. PerfSONAR is an infrastructure for network performance monitoring that contains a set of services delivering performance measurements in a federated environment, and it is being used by the NRENs in the DORII partners’ countries. In a similar way, Nagios can monitor performance metrics of specific links and furthermore monitor if specific services are online and collect the appropriate statistics. Finally, it is important to refer that specific instances
of the deployed tools will be created for IPv6 monitoring of the IPv6 enabled part of the DORII network.

IV. Middleware and Infrastructure Services.

The DORII eInfrastructure is mainly based on the EGEE (Enabling Grids for E-scieneCe) [http://www.eu-egee.org] infrastructure and its middleware of choice gLite (http://glite.web.cern.ch/glite). Extensions of the middleware dealing with the management of remote instrumentation are being built by the DORII project (as evolutions of services and concepts developed by the GRIDCC project [5]). Furthermore, to deal with the interactivity requirements of the applications the DORII eInfrastructure deploys a selection of services built by the Interactive European Grid Project [http://www.interactive-grid.eu] (int.eu.grid).

The analysis of requirements of the DORII application presented in Section 2 has resulted in the following architecture (Fig. 3).

![Fig. 3: The DORII middleware architecture.](image)

The gLite middleware offers basic grid services such as Information, Job management, data management and security services. Information about the resources and services of the infrastructure are provided by the Berkeley Database Information Index (BDII), which uses standard LDAP databases populated by an update process. The Workload Management System (WMS) is the service responsible for the distribution and management of tasks across Grid resources, in such a way that applications are conveniently, efficiently and effectively executed. The LCG Computing element (LCG-CE) is responsible for submitting jobs to the underlying local cluster of Worker Nodes (WNs). Storage Elements (SEs) are responsible for data storage and management, while the LCG File catalogue (LFC) offers a hierarchical view of files to users, with a UNIX-like client interface. From the security perspective the Virtual Organization Management Service (VOMS) is a full-fledged Attribute Authority, whose job is to assign attributes like group membership and role ownership to members of a Virtual Organization (VO), so that other Grid services can make informed decisions based on those attributes, with levels of granularity that range from extremely coarse to extremely fine.

The interaction of the users and the instruments is done via the Instrument Element (IE). The Instrument Element [13] is a concept developed initially by the GRIDCC project [5]. It is an abstraction of the instrument (or group of instruments) into a standard interface, which can be used within the rest of the GRIDCC architecture. The term instrument is used in this context to define a piece of equipment that needs to be initialized, configured, operated (start, stop, standby, resume, application specific commands), monitored or reset. The current version of the Instrument Element developed in DORII, (IE2) is set of WS-I compliant web services virtualizing the concept of instrument and sensor and presenting this as a grid component compatible with the EGEE gLite software.

The VCR [14] is a Grid portal that allows registered users interactive access to all the DORII Grid resources, providing them with additional collaboration services like e-Logbook, video and audio conferences, etc. The VCR should support DORII applications with scripts and workflows through an external workflow management system (WF-Man System), a native client application launcher and a tunnelling technology, which can be used to integrate application components and to support interactivity.

g-Eclipse [15] is an access and development platform for the DORII Grid and should be used whenever the application developers need an IDE for their sequential or parallel code. The g-Eclipse framework provides a set of tools for different Grid actors, including tracing and debugging tools for parallel applications [16].

Other services will be added if needed (in Fig. 3 they are represented as “OtherS”). Among these, the services derived from the Interactive European Grid Project provide interactivity capabilities to the applications by the deployment of interactive agents, i.e. i2login.

For accessing all the resources and the services of the DORII e-Infrastructure a common library will be developed. It will be a common access layer between integrated middleware components and the infrastructure.

One of the main goals of the DORII project is to support scientific applications for running on the Grid. Parallel applications using the Message-Passing Interface [17] cover an important class of these applications. In the frame of Int.EU.Grid, the MPI support was significantly improved compared to the general EGEE infrastructure. In this sense, important components of the Int.EU.Grid middleware will be adopted in DORII - Open MPI, PACX-MPI and MPI-Start.

Open MPI [18] is an open-source state-of-the-art implementation of the complete MPI-2 standard. The team developing Open MPI is comprised of research and industrial partners with advanced knowledge of high-performance computing and MPI implementations in particular. Open MPI is actively evolving and cooperating with different hardware and software vendors.
PACX-MPI [19] is an implementation of the MPI-1.2 (and parts of MPI-2) standard, which focuses on running MPI applications on a meta-computer, possibly consisting of different heterogeneous hardware architectures, or in the context of a grid, different clusters. For the local communication, the native MPI is used; for the inter-cluster communication, PACX-MPI handles all the communication details.

MPI-Start [20] was developed as a set of scripts in the frame of Int.EU.Grid. These scripts greatly improve running MPI applications for different MPI libraries, file systems and resource management systems. It is also easy to extend the basic functionality by user routines.

At the time of writing of this paper the DORII eInfrastructure consists of 8 sites distributed among the partners of the project. More specifically there are 6 sites in Greece, 1 site in Poland, and 1 site in Spain that are also part of the EGEE infrastructure, and also 1 site in Spain part of the Interactive Grid infrastructure. In total, those sites provide 2200 non-dedicated CPUs and several Terabytes of storage to the DORII users and their applications.

The deployment of a Catch-all Virtual Organization named vo.dorii.eu was deemed necessary for the initial deployment of the applications. However, several applications will create or have already created their own Virtual Organizations to fulfill their resource or data privacy requirements (e.g., the ihydra and ienvmod VOs).

V. Conclusions

Remote Instrumentation Services are an important part of Grid-based applications, and may well become a significant component of the Future Internet services. The platform and test bed that are being built by the DORII project have a twofold goal: on one hand, they aim at providing further extensions and refinements of the functional components for the virtualization and effective management of real instrumentation; on the other hand, they see the direct involvement of user communities, which will bring their operational experience in the experimental activities to be carried out on the test bed. The paper has examined the main building blocks of this process, and the design choices stemming from the applications’ requirements.

Acknowledgment

This work was supported by the European Commission under the DORII project (contract no. 213110).

References


