GRIDCC Project

D8.3 Project Final Report, with gender issues report appended

Project acronym: GRIDCC

Project full title: GRID ENABLED REMOTE INSTRUMENTATION WITH DISTRIBUTED CONTROL AND COMPUTATION

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Project information

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Section 1. SUMMARY OF GRIDCC ACHIEVEMENTS

1.1 Overall Concept and aims

While remote control and data collection was part of the initial Grid concept, most recent Grid developments have been concentrated on the sharing of distributed computational and storage resources. In this scenario applications that need computational power only have to use these Grid elements in order to access an unlimited amount of computational power and disk storage. However scientific and technical facilities both provide concrete use cases where a strong interaction between the instrumentation and the computational Grid is required.

The GRIDCC project, launched in September 2004 by the European Union, provides a well proven technology that can be deployed on top of existing grid middleware, extending the grid e-infrastructure to the control and monitoring of remote instrumentation. EGEE gLite is the natural reference grid middleware for GRIDCC and the EGEE e-infrastructure is the natural framework where to deploy and integrate the instrument grid technology.

The goal of GRIDCC was to build a geographically distributed system that is able to remotely control and monitor complex instrumentation, ranging over a large number of diverse environments, from a set of sensors used by geophysical stations monitoring the state of the earth to a network of small power generators supplying the European power grid. These applications need real-time and highly interactive operation of GRID computing resources. To achieve this goal the project has pursued three main objectives:

- To develop generic Grid middleware, based on existing building blocks (Grid Services), which will enable the remote control and monitoring of distributed instrumentation.

- To incorporate this new middleware into a few significant applications to validate the software both in terms of functionality and quality of service aspects. These applications include, among others, European Power Grid, Meteorology, Remote Operation of an Accelerator Facility, High Energy Physics Experiment.

- To widely disseminate the new software technology and the results of the application evaluations on the test beds, and to encourage a wide range of stakeholders to evaluate and adopt our Grid-oriented approach to real-time control and monitoring of remote instrumentation.

1.2 GRIDCC Architecture

The core and novel element of the GRIDCC middleware is the Instrument Element (IE), which offers a standard Web service interface to integrate scientific and general purpose instruments and sensors within the Grid. The second key component of GRIDCC is the Virtual Control Room (VCR), which has been introduced to provide to remote users a virtual area from where they can control and monitor the instrumentation and where they can collaborate with each other, even if located in different physical sites. The third main component of GRIDCC is the Execution Service, which provides a workflow engine able to handle BPEL workflows interacting both with the new features of GRIDCC and with traditional computational and storage grid services. Control and monitor of instrumentation devoted to observe phenomena or to control a physical process often require deterministic response times. For this reason

GRIDCC has implemented a software infrastructure able to guarantee (hard and soft) time constraints. Users require that the data produced by the instrumentation be monitored and logged. Data loggers are thus foreseen both locally to the IE (files) and remotely through the built-in SRM (Grid Storage Resource Manager) of the IE that enables worldwide grid publication of the data. Worldwide on-line monitoring is provided with a new and efficient publish/subscribe middleware developed by GRIDCC and compliant with the Java Messaging System (JMS).
Figure 1 depicts the relationship between the GRIDCC components (IE, VCR, Execution Service, Pub/Sub system) and the other Grid components.

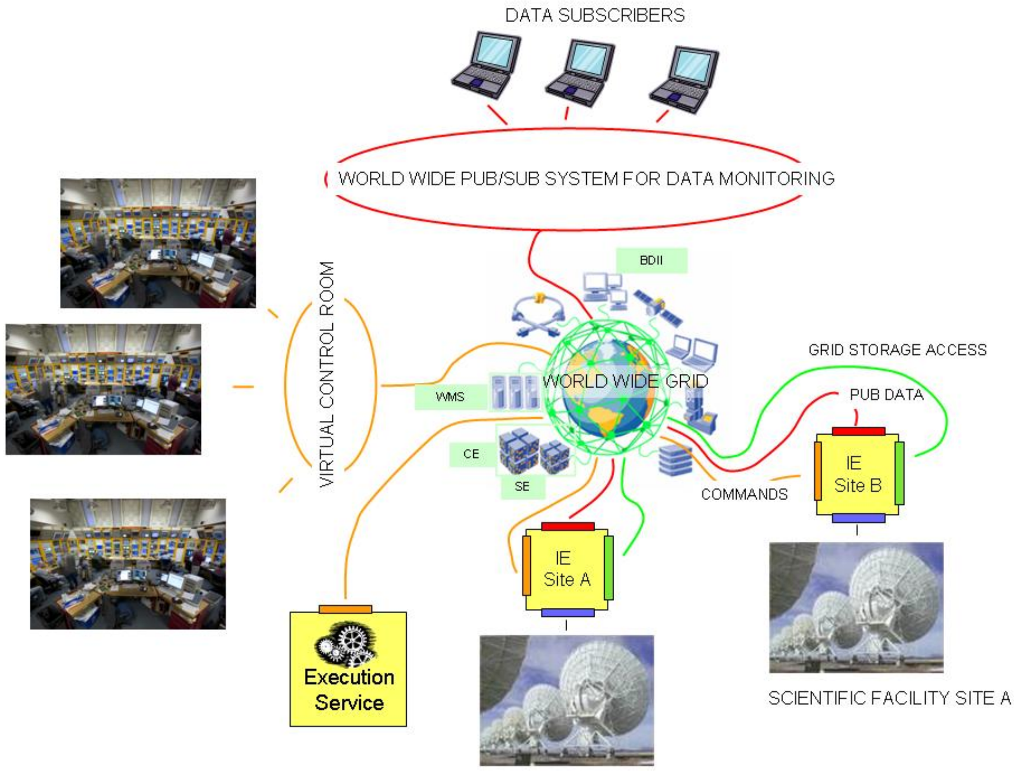


Figure 1 Integration of Instruments into the Grid

Users interact with the remote instruments through the Virtual Control Room (VCR) which provides a prompt and highly interactive environment to control and monitor the instrumentation. Moreover, the VCR provides the users with a cooperative environment (chat, videoconference, electronic log book) to facilitate remote interactions among different operators of the instrumentation.

1.2.1 The Instrument Element

The Instrument Element (IE) is a unique concept to GRIDCC and it consists of a coherent collection of services that provide all the functionalities to configure and control the physical instruments, as well as the interfaces needed to interact and integrate with the rest of the Grid. The four basic interfaces exposed by the IE are: a) the Instrumentation Control, a set of Web service compliant methods that allows the remote control and monitoring of the instruments; b) the Grid Access, a standard SRM interface that makes recently acquired data and information of the IE immediately available to the Grid community; c) the Data/Info

Publishing, a very efficient publish/subscribe and streaming channel based on a multicast implementation of the JMS interfaces (JMS-RMM) that allows the IE to publish both acquired data and information such as errors, status and logs for diagnostic, alarm and monitoring purposes; d) the Instruments Access, an interface to the real instrument(s), customized according to the individual instruments' specifications. Figure 2 depicts these four interfaces of the IE. With the exception of the Instruments Access, all the other interfaces are secure.

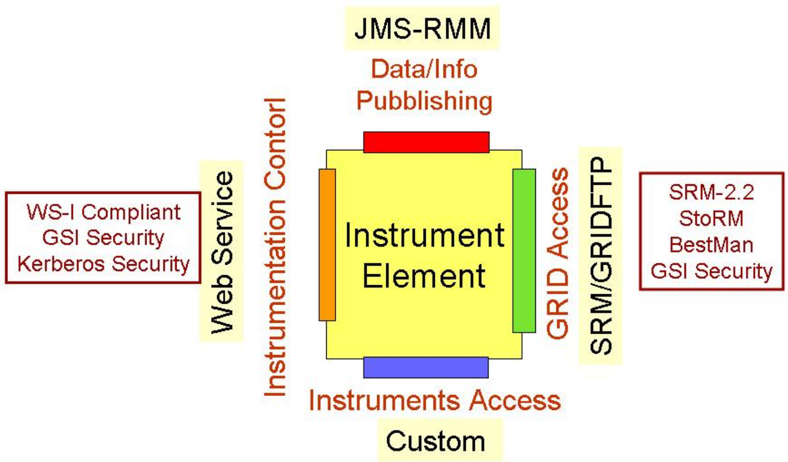


Figure 2 The four basic interfaces of the IE

1.2.2 The Virtual Control Room (VCR)

The Virtual Control Room (VCR) is the application scientists' interface into the GRIDCC system.

The VCR is a Web-based groupware which provides collaboration support tools and the foundation to allow teams of people to control and manage Grid resources (e.g.,job and workflow submission, credential management, file transfer), including remote instrumentation. The VCR has been designed taking into account the fundamental needs of end-users and stakeholders of pilot applications. In particular, the modular and layered architecture supports the common requirements of all pilot applications providing, at the same time, the possibility to easily extend the VCR functionalities with a set of more application-specific plug-ins.

The software we developed can be adopted both as a ready-to-use "virtual collaboratory", and as a framework that can be extended to develop advanced, application-specific collaboratories.

Based on on the Gridsphere portal framework and on top of the CoGRIDCC commodity library the VCR actually is one of the most advanced opensource Grid portals on the market being able to integrate in a really usable interface Grid resources, Non-Grid resources and a full set of other collaboration functionalities (audioconference, videoconference, e-Loogbooks, etc). The VCR is also a development tool for GRIDCC applications via the workflows management environment and CoGRIDCC scripting environment.

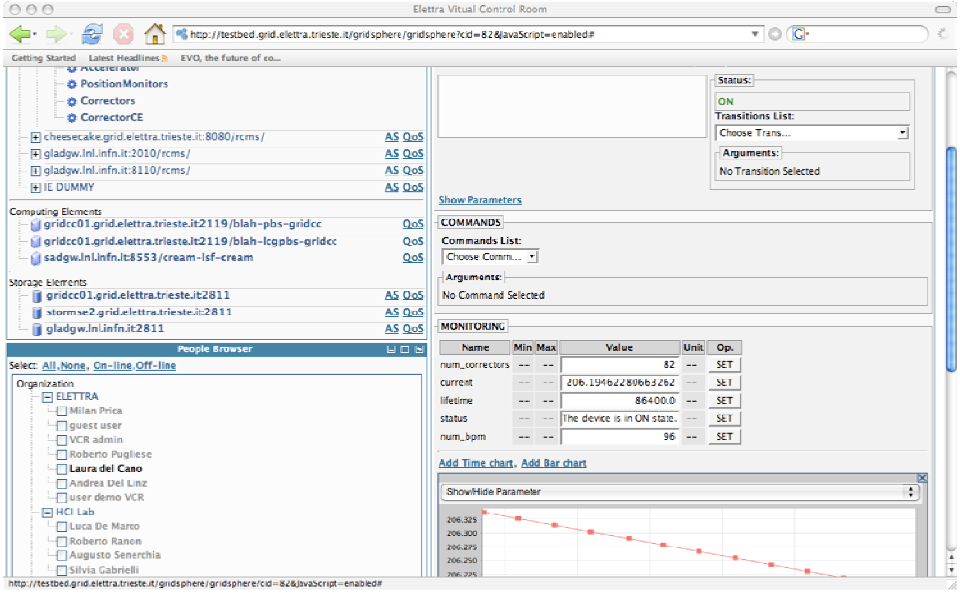


Figure3 : The VCR at work

1.2.3 The Workflow engine

The Workflow engine used within the GRIDCC project is not itself new concept, in fact we adopt the use of a commodity BPEL4WS (Business Process Execution Language for Web Services) engine within this work. The novel concepts brought in within this project are the addition of security delegation through the workflow service and the use of Quality of Service (QoS) requirements over a workflow in order to select which services and resources are most appropriate to meet the requirements of the user.

Most, if not all, workflow engines are developed without security delegation. They are able to securely talk to other services though when talking to a service on behalf of a client they use their own credentials, not the credentials of the client. We have developed a security delegation service which wrappers around a workflow engine. The clients are able to first delegate their credentials to the Workflow Management System (WfMS) which can then use this delegated proxy for communication with other services. This has been implemented for both X509 and Kerberos. In figure 3 the Delegation service is used to provide delegated credentials to the WfMS while the red circles represent adding these credentials into outgoing messages.

In order to better meet the needs of the end user we have incorporated QoS requirements within the Workflow Management System. The user is able to tag those parts of the workflow which must adhere to specific QoS requirements and those where it is desirable though not mission-critical. For these tags the user can specify what the requirements are. The Workflow Management System can then take these into account when planning which resources to use for the workflow. Reservations on resources may be made to increase the chance of adhering to the QoS requirements. In figure 3 the Basic Resolver determines where parts of the workflow should be placed and the Reserver uses the Agreement service to make reservations where appropriate.

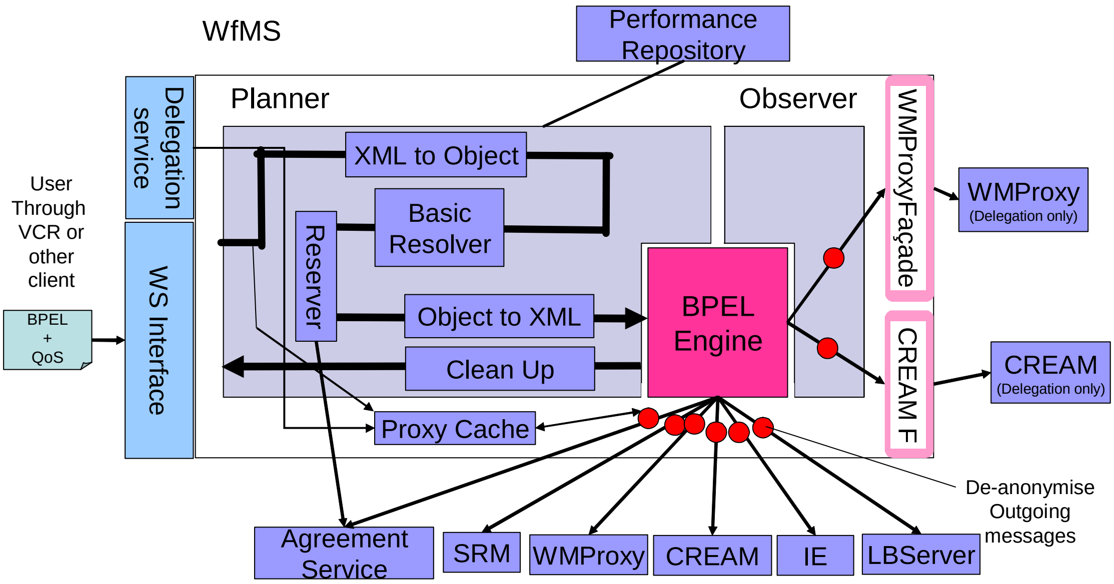
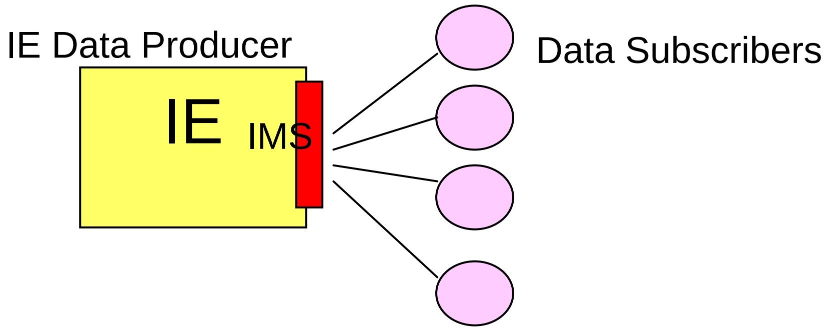


Figure 4 The architecture of the Workflow Management System (WfMS)

1.2.4 The GRIDCC Messaging System

To meet their functional requirements instruments need to exchange and filter the data generated using a connection network with high performance. At the same time, users around the world want to control the entire system and monitor the ongoing activity. Performance and scalable architecture are the most important issues in our use cases in the field of high energy experiments.

To provide a solution for the above requirements and scenario, and to improve performance and usability, we developed RMM-JMS, a publish-subscribe Java Message Service (JMS) based service, on top of our high performance Reliable Multicast Messaging (RMM) layer. This enables the IE to have high-throughput low-latency reliable transport services designed for one-to-many data delivery or many-to-many data exchange in a message oriented middleware publish/subscribe fashion, which is also JMS compliant. RMM-JMS supports peer-to-peer communication in both brokered and brokerless modes. The broker or bridge is used whenever we have more than a single multicast domain (e.g., two LANs).



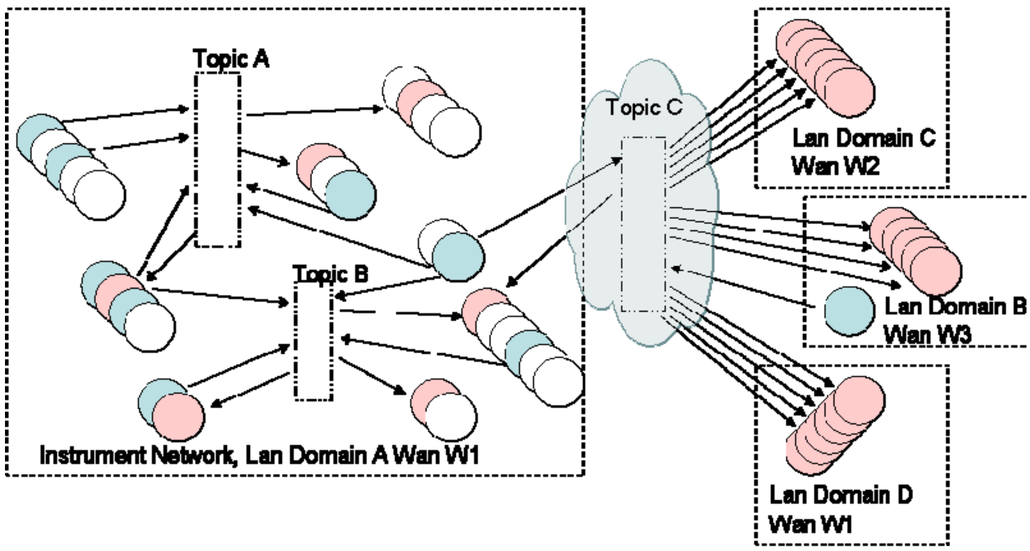


Figure 5 publish/subscribe with RMM-JMS

The RMM-JMS broker/bridge is built on top of the RMM protocol which allows hosts to exchange data messages reliably over the standard IP multicast network. RMM exploits the IP multicast infrastructure to ensure scalable resource conservation and timely information distribution with reliability and traffic control added on top of the standard multicast networking. Its services are built as additional network layers on top of UDP/IP and TCP/IP using a NAK based protocol that employs a fast message to packet mapping. It supports peer-to-peer communication in both brokered and brokered-less modes and is singled out by its high performance capabilities.

1.2.5 Real Time aspects and security

The GRIDCC project use cases raised the need for a deep interaction between users and the virtualization of physical devices, instruments and sensors. In particular, this often requires fast and predictable operations to monitor and control sensors, thus asking for some QoS guarantees in terms of service Response Time (RT). Consider that when the access to a service is performed remotely, e.g., via the Internet using Web Services calls, the correct prediction of the service invocation time becomes critical in order to understand whether an instrument can be controlled properly, or the delays introduced by the wire and the serialization/deserialization process are unacceptable.

To fulfill the mentioned requirements, we developed two different types of access with different Quality of Service:

• Strict (hard) guarantees: The response to a requested service is reliable; in this case the Agreement Service performs advanced reservation and can negotiate QoS parameters between components.

• Loose (soft) guarantees: The response to a requested service is unreliable. Therefore QoS is provided on top on a best-effort infrastructure. In this case a prediction method based on a statistical approach has been provided.

Talking about the RT we need to point out that no real time Web Service engine has been so far produced. Therefore a Service Requester, even in the presence of an Agreement Service cannot negotiate a particular remote method execution. Anyway, the requester can still try to estimate the execution time of a remote method. This estimation is not trivial and quite more important in real-time, near-real-time, as well as in interactive distributes application like ours.

The Security Architecture is Kerberos based and it was designed to minimize the performance penalty that the security operations cause at server and client side, thus offering improved responsiveness when controlling a real instrument. The involved operations are message encryption, where confidentiality is required, or message signature, where only integrity is considered sufficient. The choice between the previous ones is left to each application. In addition, in use cases that do not require a really coupled interaction between user and Instrument a GSI-based security is provided.

Even if all the issues and solutions presented and discussed have been exploited during the design and implementation of our IE any application based on Web and Grid Services that exhibits the same requirements can benefit from them.

1.3 Technology demonstrators

GRIDCC has validated its middleware, integrating it into three pilot applications. A brief description of these applications is reported here below.

1.3.1 Power GRID

At Brunel University there exist a number of small renewable energy generators, currently two 1kW photovoltaic (PV) arrays and a 150 kW combined heat & power (CHP) of which 80 kW is electrical. A 6 kW wind turbine is planned and we have a local weather station for environmental monitoring. In addition to the real generators we have sophisticated computer models of large-scale electrical generators which we run on Grid cluster worker nodes in order to evaluate the scalability of the GRIDCC control and monitoring system to potentially thousands of generator instances.

Currently we have customized Instrument Managers for the three classes of power generator and the weather station. Each of the generators has a different interface to the Instrument Element via individual Instrument

Managers. The generators have finite state machines to enable them to be controlled from the VCR or the WfMS.

Figure 6 shows the VCR monitoring of the electrical power output of one of the PV arrays on a sunny day. The data is updated every 5 seconds.

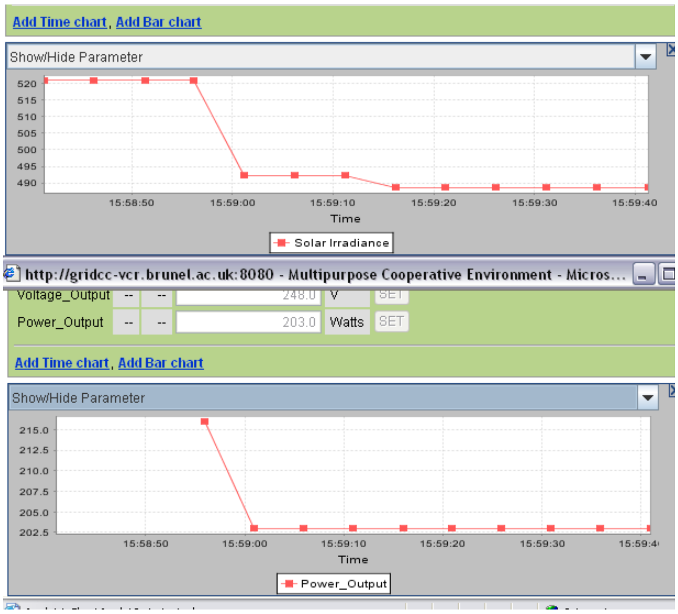


Figure 6. The VCR monitored data from one of the PV arrays. The solar irradiance (W.m^{-2}) is shown on the upper time chart and the simultaneously measured instantaneous electrical power in Watts is shown on the lower trace. The correlated drop at 15:58:56 is clearly seen.

The ability of a remote operator (or multiple remote experts) to see the dynamic behavior of any of the generators at any time is a principle goal of this project. A problem solver framework that operates at the level of the Instrument Element has been implemented. This allows any appropriate problem solving system, for example a neural network or a decision tree, to be used to determine automatically what the likely problem is when a generator ceases to behave normally (for example sudden loss of power).

1.3.2 High-Energy Physics: control and monitoring of experiments

The GRIDCC middleware has been deployed to control and monitor the run of the Compact Muon Solenoid (CMS) experiment, one of the two larger general-purpose particle physics detector of the Large Hadron Collider (LHC) at CERN in Switzerland. It will be located in an underground cavern at Cessy in France, close to Geneva. The completed detector will be cylindrical, 21 meters long and 16 meters diameter and weigh approximately 12,500 tons. The figure 7 reports a recent image (as of January 2008) of the CMS detector already installed in the cavern.

Figure 7: Insertion of the tracker in the heart of the CMS detector

CMS consists of various sub-systems (the tracker, the electromagnetic calorimeter, hadron calorimeter, the muon detectors and the magnet) to measure the different types of particles produced in the highly energetic collisions of protons and heavy ions. The Run Control and Monitor System (RCMS) controls the collection of event data from the detector elements and it is based on the GRIDCC middleware. RCMS manages, configures and monitors a few thousands of PC where globally some ten-thousand online objects are running.

First collisions are expected by the end of 2008, but since autumn 2006 a subset of the CMS detector including the solenoid magnet with a 4 T magnetic field has been operated to detect cosmic muons. The operation was called Magnet Test and Cosmic Challenge (MTCC). The good results obtained in the MTCC allowed validation of architectural choices made for the GRIDCC-based Run Control system. The main areas to improve the system both in performance and functionality were even identified. During 2007 commissioning and integration runs are performed every month to check the status of the detector after the several components are lowered into the cavern. These operations are called Global Runs (GR). GRs make use of the latest software versions to verify the status and the integration of all the software components involved in the CMS operation. The CMS Run Control system has been updated to the latest GRIDCC versions.

Work is still in progress to scale all the sub-systems and the run control to the final size.

1.3.3 Far Remote Operation of Accelerator Facility

Far remote operations of the ELETTRA Accelerator is the most complete demonstration of the GRIDCC middleware. This application gives the user a flavour of the real potentiality of a Grid of instruments. This 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.
The 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 is now in production at the Synchrotron Radiation Facility and currently used also for operator training. GRIDCC is using agreement service layer between the workflow management system and the grid resources providing the resource reservation service. An integrated problem solver is monitoring the running tasks in order to identify error conditions and provide support for fault-tolerant operation. Experience gained in this application will be reused in the new accelerator Fermi@ELETTRA which is currently under construction.

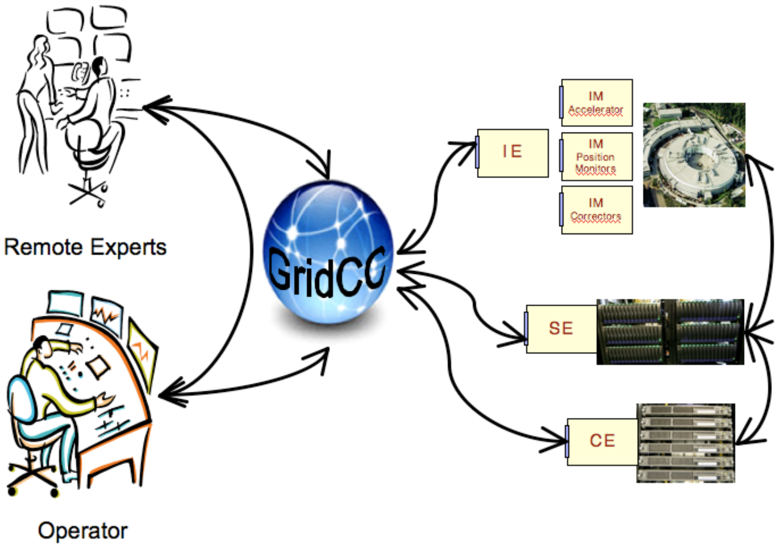


Figure 8: Remote operations of ELETTRA.

Figure 9: The operator in the ELETTRA control room

1.3.4 Other applications using the GRIDCC middleware

Other significant applications have used the new middleware to control and monitor their own apparatus. The list includes:

- Meteorology
    - It is the application that has produced the Skiron system, which provides weather forecasts for Greece and the Eastern Mediterranenan region. The Meteorology application introduced the requirement for high computational resources and the requirement for producing the forecasts in a specific time window, requirements that were addressed by the GRIDCC software and application development guidelines. This Skiron System uses the following GRIDCC components
        - The Virtual Control Room. The VCR is the interface through which it is possible to discover resources, execute the meteorology model, monitor its execution and retrieve the results.
        - The Skiron/Eta model is installed and appropriately configured at a HELLASGRID cluster at IASA's site.
        - GRIDCC Virtual Organization. The resources that belong in the GRIDCC VO support MPI execution in the GRID environment, which is a prerequisite of the meteorology Skiron/Eta forecasting model**.**
    - The Skiron system is now operating daily on deterministic mode. Short-range forecasts are available through a site dedicated for the project (http://forecast.uoa.gr/nowcasting.html). The meteorological application in its final form has expanded functionality and it is utilizing as a weather now casting system, as well as an early warning and analysis system in cases of hazardous weather detection.
- Device Farm control

- The Device Farm application is devoted to the remote control of telecommunication measurement systems. A pool of instruments (e.g., channel simulator, noise and signal generators, oscilloscope, spectrum analyzer, signal switching matrix), forming a “measurement chain” can be remotely accessed and configured, in order to perform a specific measurement experiment and visualize the results on the virtualized instrument panel. The latter may be integrated in the VCR or, if a more sophisticated 3D representation of the instruments is desired, be generated on the local client through a tunnel from the VCR. The other main GRIDCC architectural component used is the Instrument Element (IE), one for each physical device. Visualization data (e.g., the trace of a spectrum analyzer) are best collected via the Java Messaging System that implements the publish/subscribe functionality of the IE.

- Geo-hazards monitor
    - The IMAA's contribution on GRIDCC project has been the possible integration of a sensors' network, installed on a selected landslide in Basilicata region, planning a possible technology and developing applications on behalf of GRIDCC improved middleware; all this on geophysical techniques and geo-hazard monitoring, one of the main activities of the Institute.
    - According to the use case and to the logical model of geo-network activity, a Java management library has been developed to run control (remote run control) and to maintain the Data-Logger Keithley Instruments Model 2701 that collects all data from sensors; on this library, after accurate tests, an improved prototype integrated on GRIDCC middleware has been planned and developed.
    - The future purposes are to extend the same approach to other IMAA principal activities involving the study and the analysis of satellite data received at the IMAA satellite station in the framework of advanced Environmental Monitoring and Civil Protection dedicated systems.

- Intrusion Detection System (IDS)
    - It is a Distributed Anomaly Detection System. Each separate node, an Instrument Element called Local Detector (LD), analyzes Netflow data received from a router, extracts the values of specific heuristics (metrics) and stores them in a local database. Each LD may perform local detection based on the extracted heuristics and supports two different states: the normal State and the Anomaly State. However, the purpose of importing an Anomaly Detection System in the GRIDCC middleware is to perform global detection in a large scale network comprising of many different domains. This is achieved by applying a data fusion algorithm that combines multi-link, multi-metric data from different network locations (Instrument Elements) to produce a view of the network state. The fusion is based on a methodology that uses Principal Component Analysis (PCA). The central node that performs global detection is another IE called Global Detector (GD). GD collects network data by communicating via GRIDCC Web Services with the LDs and supports two different states: the normal State and the Anomaly State.

1.4 Dissemination

The dissemination of GRIDCC results has been active throughout the project duration. Besides a number of papers (41 conference papers, 2 contributions to an edited book, and 8 journal papers), posters (5), invited talks (16) online contributions (3), and live demos (6), GRIDCC took an active part in the organization of some major dissemination events:

- In 2005, partner CNIT organized the Tyrrhenian International Workshop on Digital Communications (**TIWDC05**), in Sorrento, Italy, from July 4 to July 6, 2005 (see **http://www.ingrid.cnit.it** for this and two other successive events), under the theme "Distributed Coordinated Laboratories: Issues in Networking, Instrumentation and Measurements". Two papers from the GRIDCC project were presented as invited contributions, specifically describing the project, and are included in the edited book: *Distributed Cooperative Laboratories: Networking, Instrumentation, and Measurements*, by Franco Davoli, Sergio Palazzo, Sandro Zappatore (Eds.), Springer, New York, NY, 2006 (ISBN: 0-387-29811-8).
- A live demonstration of Power Grid was made at the **"London Technology Network" Meeting** on "Grid-Computing and Web Services: Real world successes from academic insights" of November 23, 2005, held at Imperial College. The demonstration attracted interest from a number of industries, including Fujitsu-Siemens, IBM (UK), and BT.
- A demonstration of the Elettra application (*Using GRIDCC for Remote Operations of an Accelerator*) was given by Roberto Pugliese in conjunction with the Related Projects session at the **EGEE Conference 2006**, Geneva, Switzerland, Sept. 25-29, 2006. GRIDCC appears in the list of projects present at the Conference.
- In the framework of the **IST 2006 Event** in Helsinki, Finland, *IST 2006 - Strategies for Leadership*, a Workshop featuring GRIDCC was proposed and held on Nov. 21, 2006. The session was called "Further Steps and Requirements for True and Effective Instrumentation Grids" and it underlined the strategic importance of the theme of the GRIDCC Project. Comments and expressions of interest appear on the web page **http://ec.europa.eu/information_society/istevent/2006/cf/network-detail.cfm?id=845**. All presentations given at the session can be found at: **https://ulisse.elettra.trieste.it/agenda//fullAgenda.php?ida=a06273**. The Workshop proposal received 27 expressions of interest, and the overall number of attendees (including speakers) was 44.
- A booth was shared at the **OGF20/EGEE User Forum** in Manchester, UK, May 7-11, 2007, with the projects RINGrid, int.eu.grid, and g-Eclipse. People from GRIDCC were present at the booth with brochures and posters, and a movie of the Elettra demo was shown.
- GRIDCC established collaboration with the **EGEE-II** project, in order to test the Service Level Agreement (SLA) installation and monitoring procedures described in EGEE-II/SA2. GRIDCC partner IASA has coordinated an effort to set up a test case. The progress of this collaboration and the results from the application testing were presented at the EGEE'07 conference, Budapest, Hungary, in the Technical Network Liaison Committee session.
- The GRIDCC project has organized the **2nd International Workshop on Distributed Cooperative Laboratories – Instrumenting the Grid (INGRID 2007)**, in cooperation with the projects RINGrid, VLAB and CRIMSON. The Workshop was held in S. Margherita Ligure, Italy, from April 16 to 18, 2008, and has seen the presence of outstanding keynote speakers, high-quality presentations and live demos, with about 70 attendees. There have been a total of 9 presentations from GRIDCC. As with the first edition, revised and extended versions of the papers will be published in book form by Springer (edited by F. Davoli, N. Meyer, R. Pugliese, and S. Zappatore).
- GRIDCC organized a Tutorial Workshop on Scientific Instruments and Sensors on the Grid at ICTP (the Abdus Salam International Centre for Theoretical Physics), Trieste, Italy. ICTP is well known for the quality and relevance of the events it organizes. The School was held from the 23rd to the 28th of April, 2007, and it gathered 37 participants - 23 students from developing countries, and 14 among lecturers, speakers and tutors, all highly qualified experts from Italy, Poland, USA and Australia (**http://cdsagenda5.ictp.trieste.it/full_display.php?smr=0&ida=a06290**).

Section 2. GRIDCC FAQ

- ***What is GRIDCC?***
  - ***What is Grid Computing?***
    - There is no universally agreed definition of Grid Computing, except that it is a type of distributed computing, a useful and reasonably detailed descriptive article is available from the Wikipedia (http://en.wikipedia.org/wiki/Grid_computing) To quote from an on-line article in 2005 written by John Moore (http://www.fcw.com/print/11_25/news/89311-1.html) "Different definitions and interpretations of grids exist, some of them conflicting. Ian Foster, head of the Distributed Systems Laboratory at Argonne National Laboratory, defines a grid as a system that coordinates resources that are not subject to centralized control and live in different domains — for example, different groups within the same organization. Foster also defines grids as employing a mix of standard and open protocols and interfaces. In this view, a grid is an open-source system that lets users in one group tap into computers and applications residing in other, possibly far-flung groups."
  - ***What is special about GRIDCC?***
    - GRIDCC integrates geographically distributed instruments, of arbitrary complexity, with existing computational grid computing resources. It provides a Virtual Collaborative Environment for the remote control and operation of these resources, a workflow management system for implementing one's specific use cases and provides highly optimised and flexible methods for accessing data, logging errors and messages. Also provided are a generic problem solving capability, Kerberos and X509 certificated security and authentication. It extends traditional computing into the world of sensors, electronic instruments and complete experimental apparatus and facilities using standard interfaces.
  - ***What is a Virtual Organisation ?***
    - In grid computing, a Virtual Organization is a group of a geographically independent set of individuals or institutions with a common goal who share the resources of a computational grid. The management of user access to grid resources is via the Virtual Organisation Management Service (VOMS) which keeps track of individual users (identified by their X509 certificates) and their roles.

- ***Why do I need GRIDCC?***
  - If you need real-time computing over a grid, if you want to encapsulate instruments and experiments (both real and virtual) so that they appear like existing grid resources, if you want to use a multi-user/multi-site interactive monitoring and control environment then GRIDCC software may be what you are looking for.
  -
- ***What do I get when I download GRIDCC software?***
  - ***How do I download it?***
    - Go to the GRIDCC home page (http://www.gridcc.org/). From this page you can download the software. You will be asked to provide a few details and to agree to the terms of our licence.
  - ***How do I test it? Where can I find examples***

- When you down load the software you receive the instructions to install it and how to run few significative examples.

  - ***How do I create/join a Virtual Organisation?***
    - Once you have obtained a Grid Certificate, you will need to become a member of a Virtual Organisation (VO). VOs are usually associated with a particular collaboration or group of companies with common interests, but as the Grid grows so will the number of VOs, so providing a list here would be impractical.
    - VOs will generally have their own web sites which are likely to have some Grid-related information, so you should look at these for more information. Your local site may also have its own relevant web pages.
    - If you need to create a virtual organisation then there are a number of orgnisations, research, public and private than can assist you. Purely as an example we refer you to a relevant page of the Enabling Grids for E-sciencE (EGEE) consortium here (http://swevo.ific.uv.es/vo/index.html).

- ***Has GRIDCC been successfully tested and deployed?***
  - Yes it has. A number of different deployments of the GRIDCC middleware have been deployed, tested and evaluated within the GRIDCC project. A brief description of each of them can be found in this document in section 1.3. A number of demonstrations are available from our GRIDCC home page (http://www.gridcc.org/). As of the date of this document you can find demonstrations of remotely operating an experimental facility, a demo showing the discovery of distributed instruments, and a demo showing a number of real electronic instruments (e.g. a spectrum analyser) being used via a Virtual Control Room.

- ***What are the restrictions on using GRIDCC software?***
  - The GRIDCC License is a Berkeley Software Distribution (BSD) style Open Source License. The text of which is at http://www.gridcc.org/LICENSE.
  - The GNU General Public License (GPL) is not compatible with the GRIDCC License, in the sense that GRIDCC software cannot be linked with GNU software, but GNU software can be used and depended upon.
  - The GNU Lesser General Public License (LGPL) is compatible with the GRIDCC License.

- ***How is GRIDCC connected with EGEE?***
  - GRIDCC is a “related project” (Application Project) of Enabling Grids for E-sciencE (EGEE). Their website can be found here http://www.eu-egee.org/ .

- ***Where can I get more information?***
  - Most of the information that you might need, or just find interesting such as conference papers, is available from the public part of the GRIDCC home page (http://www.gridcc.org/).

- ***Where can I get support?***
  - None of the software has any formal support, however members of the GRIDCC consortium can be approached regarding the negotiation of a contract for the support and further development of the software for your particular application.

Section 3. PARTNER EXPLOITATION PLANS

3.1 INFN

INFN has been the coordinator of this project and has provided specific efforts in the original concepts, design and implementation of the Instrument Element. Important contributions are even given in the areas of real time instrumentation access (QoS) and of the fast messaging systems. These are crucial subjects to the main research themes of INFN that mainly operates in the field of experimental physics.

One of the major outcomes of the project driven by INFN has been the adoption of the GRIDCC middleware for the run control of the CMS experiment (see paragraph 1.3.2), one of the four LHC experiments at CERN. INFN will continue the development and the maintenance of this middleware within the experiment to provide an adequate support both in the commissioning of the detector and along the years of data taken that are foreseen.

Exploiting this successfully story, the same approach has been adopted by a nuclear physics experiment called Agata that is in the building phase at the National Laboratory of Legnaro (INFN-Italy), but will be even operated at Spiral 2 accelerator (Ganil, France) and at GSI Darmstadt. At the end of 2007 Agata experiment has decided to use the GRIDCC middleware to control the detector.

More in general INFN is interested in exploiting GRIDCC outcomes and to continue the development of the middleware in all the cases where a remote control of large scientific experiments or facilities is needed introducing the ability to control and monitor interactively their remote instrumentation, enabling data generation, distributed storage and visualisation and collaboration of the users operating the facilities.

A natural target of this exploitation are big scientific apparatus either located at a single site with the need for access by numerous researchers or distributed over different sites.

INFN is involved in several experimental facilities that fit these requirements with one of the most interesting cases related to the deep-sea neutrinos telescopes: the ESFRI project KM3Net. This scientific community has expressed a strong interest in using GRIDCC for controlling and monitoring the experiment.

The highly synergic community of the European seafloor observatories leaded by the ESFRI project EMSO has expressed the same strong interest to adopt the GRIDCC software.

3.2 Iasa

The Security Infrastructure specified for GRIDCC offered a security layer for Authentication-Authorization of the users (through the VCR) and IEs in a transparent or semi-transparent way. The standard security mechanisms i.e. GSI employ Public Key Cryptography for all the main cryptographic functions, something that the security architecture needed to avoid due to the performance penalties of its security overhead. Experience from GRIDCC has shown that the bottleneck of performance is located within the IE, as it provides services to numerous clients simultaneously. Thus, the emphasis of the security infrastructure was placed on minimizing the security overhead, offering at the same time interoperability with legacy Grid infrastructure, i.e. X.509 and VOMS certificates that identify the users in the grid world. The security functions provided the required protection at the SOAP message level (i.e. message authentication, authorization, integrity and confidentiality) as this not only allowed better interoperability in the web service based communication between the IEs but also had less impact in the performance of the IE than the alternatives. A security architecture that covered the above needs was designed and pilot software was implemented in the framework of GRIDCC. From the performance measurements that we conducted, important improvements over the standard GSI mechanisms in SOAP level security performance (Web Service Security) were demonstrated. The security architecture was based on the client-server paradigm and used standard Grid credentials (X.509 proxy certificates, VOMS proxy Certificates) for the initial user login and mapped these credentials to Kerberos (RFC1510) ones. Therefore, the mapped identity was used to acquire access to the distributed IEs, and symmetric cryptography was utilized for the encryption functions. The whole security functionality was provided for the secure communication between the VCR and the IE. More specifically:

- The VCR utilized a client security component that performed all the security functionality and hided its complexity from the end user.
- The IE utilized a server security component i.e. the Access Control Manager (ACM) that transparently authenticated and authorized user requests from the VCR.

IASA aims at extending and applying this security architecture within other projects to further improve the performance by providing a new design based on new real time requirements. Additionally, IASA intends to implement supplementary security mechanisms that supply the required security flexibility and scalability essential for the Web Service based communication of the IEs and authorization of the users' requests, thus allowing more complex security schemes, instructed by the applications requirements, to be implemented.

IASA considering the IDS application and work that has been done for this application aims to improve further the detection algorithm. The detection algorithm currently detects the anomaly and returns the network path. IASA plans to enhance it so as to enable it to return more information concerning the nature of the detected anomaly. We are interested in making a classification network attacks including mainly different types of Denial of Service attacks and worm propagation. Another goal is to test the algorithm effectiveness when utilizing sampled data (with different sample ratios). Finally, IASA's goal is to deploy it in a large-scale production environment.

3.3 Brunel University

As an outcome of the GRIDCC project, Brunel University has exploitable intellectual property in the use of grid computing for monitoring and control of massively distributed systems, particularly for distributed electricity generation and loads. This intellectual property includes the expertise and experience needed to apply the Open Source software that was developed in collaboration with our project partners.

Our plan is to seek one or more industrial partners who are interested to build an industrial-scale demonstration of the GRIDCC approach to instrument and sensor control and monitoring. It is envisaged that this may require some sharing of risk and perhaps further sponsorship of a demonstrator project (e.g. from the new Energy Technologies Institute in the UK). A successful demonstrator implementation would be intended to lead to further take-up by a range of UK, EU and worldwide power industry companies.

The research team at Brunel already has contacts with many companies who may be interested to participate in such a trial implementation, including: National Grid plc, EDF Energy, Converteam Group SAS, Siemens plc and Econnect Group Ltd.

The UK Energy Research Centre (UKERC) may be approached to organise a forum, under their 'Research Hotel' scheme, to present the possibilities to these and other potential users. Brunel is also closely involved in the London Technology Network (LTN), which seeks to match new technologies arising from university work with potential industrial applications.

Brunel University has a well-established commercialisation arm, the Brunel Enterprise Centre, which has the necessary expertise to manage the commercialisation of any future exploitation.

3.4 CNIT

The pre-GRIDCC middleware adopted by CNIT to perform remote control of telecommunication measurement instrumentation was based on a proprietary solution (the Labnet Server). After successfully completing the the development and installation of the needed elements of the GRIDCC architecture, CNIT has acquired the experience to make all its telecommunication measurement instrumentation, distributed in a number of Laboratories, GRIDCC- and, consequently, EGEE-compliant.

The access to and control of remote laboratory instrumentation is one of the Consortium thematic research priorities, which have been elaborated during 2006, and presented to the Italian ICT industry and to the Italian National Research Council (CNR), during a meeting organized by CNIT in Florence in October 2006. Following this presentation, a joint CNIT/CNR/Industrial initiative has been launched, named TERIT (TElecommunication Research in ITaly), which has been presented and discussed with the Ministry of University and Research (MUR) and is being extended to other interested Ministries, with the aim of raising funding in the order of 100 MEuros/year for 5 years.

In case of success of the TERIT initiative, CNIT has the necessary Intellectual Rights and experience to lead the part related with Remote Instrumentation, on the basis of the activity carried out within GRIDCC.

Moreover, a non-negligible exploitation action has been the participation of CNIT as one of the major actors within the European projects RINGrid (SSA in FP6) and DORII (I3C in FP7), which base much of their action on the premises of GRIDCC.

3.5 Elettra

During the course of GRIDCC implementation, Sincrotrone Trieste SCpA (ELETTRA) has been involved mainly in the following parts of the project:

1. **System Architecture:** ELETTRA has participated in designing an overall architecture for the GRIDCC services ecosystem, with emphasis on User Interaction Collaboration Services.
2. **Instrument Element:** ELETTRA has contributed in the design of the Instrument Element (IE) interface and has worked at the development of a version of the middleware, which can run in embedded platforms. Moreover ELETTRA has provided the IE with the gLite security model.
3. **Integration with the eInfrastructure:** ELETTRA has studied the integration of GRIDCC with the Grid information system (BDII) in order to let the Grid recognise it as an available resource. Moreover ELETTRA developed the CoGRIDCC (Commodity of the GRIDCC) library to make

easier the development of applications using collectively traditional Grid resources and Instrument Elements.

4. **Virtual Control Room:** ELETTRA has implemented the Virtual Control Room (VCR), a portal based on advanced web technologies. The VCR allows the user a simplified interaction with all GRIDCC resources: this includes traditional Grid (gLite) resources like Storage Elements and Computing Elements their brokers and the Instrument Element. The VCR is also a collaboration framework providing all the tools needed for computer supported collaborative work (audioconference, videoconference, eLogbooks). The VCR provides a system to develop GRIDCC applications via the workflows management environment and CoGRIDCC scripts development environment.
5. **Applications:** ELETTRA has developed and put in production the most complete demonstration of the GRIDCC middleware. The remote operations of an accelerator with the feedback via Grid to correct the orbit gives the user a flavour of the real potentiality of a Grid of instruments.

ELETTRA is a large producer of scientific data that have to be processed in order to produce scientific results. ELETTRA thus began to provide solutions to help this process in order to let researchers operate remotely the experimental station and do science collaboratively and then to connect their detectors, instruments and sensors to the Grid trying to virtualize and hide all the details of information technology in order to let scientist concentrate and focus on their job: do science.

Based on this experience, ELETTRA wishes to deploy GRIDCC middleware to their experimental stations in order to enhance the scientific productivity of the laboratory.

ELETTRA is part of IGI (Italian Grid Infrastructure) and as such will promote the GRIDCC middleware inside this JRU (Joint Research Unit) and in all the projects in which the JRU is involved.

ELETTRA is also planning to apply GRIDCC in the field of environmental monitoring where it will integrate in the Grid a set of new generation PM10 sensors capable of not only to weight but also to analyze the composition of PM10. A regional project has been just submitted in collaboration with the Friuli Venezia Giulia civil protection and with the environmental protection agency.

Many other projects have shown interest in some components of the GRIDCC. The CYCLOPS project for example is interested in using the VCR in the field of Civil Protection. ELETTRA through its Industrial Liason Office will try to evaluate the market potential of the GRIDCC middleware. ELETTRA can at first apply the open source business model and in case of strong market potential can even support a spin-off.

Last but not least, ELETTRA wishes to put the acquired know-how to use, in order to help scientists integrate their apparatus with the Grid. ELETTRA's involvement in the DORII EU projects ensures the continuity that can guarantee the success of this venture.

3.6 IBM

In the course of the GRIDCC project, which was concluded successfully in September 2007, IBM Research Lab in Haifa created a JMS compatible messaging system based on our very efficient reliable multicast middleware. Although the system itself is not subject to further development, various ideas which were build into it are now used for further research, such as high throughput and low latency JMS compatible systems, bridging of multicast domains, authentication and authorization of publications and subscriptions.

- High throughput and low latency JMS compatible systems: In the course of the GRIDCC project, we have compared our implementation with other JMS implementations, and the comparison turned to be much in our favour. By enhancing the underlying multicast middleware, and tuning some of its features to JMS requirements, such as message selectors, wildcard topics, and others, we hope to get even a much better JMS compatible messaging systems
- Bridging of multicast domains: In the course of the GRIDCC project, we implemented a very efficient method of forwarding publications and subscriptions between multicast domains, where the forwarding link had two separate implementations, one using our very efficient reliable unicast messaging, and another one based on standard HTTP link, which is important in WAN links which pass through firewalls and proxies. We continue now the research in these directions, hoping to make the latter more efficient.
- Authentication and authorization: One of the JMS features we implemented in the GRIDCC project was the possibility to open an authenticated connection and to use it only for authorized publications and subscriptions. This is also a direction for further research, e.g., by integrating these security features in the transport level.

3.7 Imperial College

The effort within the GRIDCC project from Imperial College London has been in the areas of real time integration with existing Grid infrastructure, Grid Security, workflow enactment, performance analysis and extrapolation of this information for the more optimal use of resources in the Grid. These are core themes to the research efforts of both the High Energy Physics group and the London e-Science Centre. As such the Intellectual property developed within this project will feed into a wide range of future projects to come out of both of these groups.

Most future exploitation of the efforts at Imperial College London is at an early stage of development. We envisage a number of new projects both internal to Imperial College London and collaborative work with partners from the GRIDCC project. Outlined below are a number of projects that we are currently working on:

The Victoria University of Wellington, New Zealand, is undertaking a project similar to the efforts carried out as part of the GRIDCC project. We have been asked to participate in this project as they wish to see if elements of GRIDCC can be used for their work. This project (KAREN) is currently with the New Zealand funding council for evaluation.

Workflow editor as an OMII-UK developed project. We have discussed with OMII-UK the prospect of developing further the workflow editor as part of a workflow tooling kit for OMII-UK. The initial reception to this has been favorable.

Workflow security delegation as an OMII-UK developed project. We have discussed with OMII-UK the prospect of developing further the workflow security delegation service as part of the OMII software stack. This would provide the ability to use workflow delegation but also provide delegation to other parts of the OMII software. The initial reception to this has been favorable.

A UK funding council (EPSRC) bid is currently being developed which will take the security and workflow work from GRIDCC along with new ideas based around Cloud computing, allowing for execution of workflows on arbitrary resources.

3.8 IMAA/CNR

General: Integration of a network of sensors, installed on a selected landslide in Basilicata region, planning a possible strategy (technique, technology) and developing applications on behalf of GRIDCC improved (progressive, in progress) middleware; all this on geophysical techniques and geo-hazard monitoring, one of the main activities of the IMAA.

Particular:

Analysis, development, planning, implementation of Java management library to run control (remote run control) and maintenance of Data-Logger Keithley Instruments Model 2701 that collect all data.

Improvement and optimisation on Linux Operating System.

Development and planning of a prototype integrated on GRIDCC middleware.

Improvement and optimisation of self-reconfiguration automated task, according to the use case and logical model of geo-network activity.

Take advantage of GRIDCC middleware principal features.

The intention to extend the initial purposes described on which the prototype has been developed, and to involve in the other Institute’s principal activities as that based on the study and the analysis of data received by satellite.

3.9 Udine University

During the course of the GRIDCC project, the Human-Computer Interaction (HCI) Lab at the University of Udine has been mainly involved in the design, development and evaluation of the Virtual Control Room (VCR).

Our plan is to find ways to exploit and extend the VCR in other domains and projects. For example, one of our current researches is about innovative user interfaces for the management of emergency situations, such as natural and man-made disasters. In this context, the VCR could evolve into a groupware tool able to support teams of emergency workers during management and on-field operations (e.g., by using mobile devices).

The involvement of the HCI Lab (or its spin-off company Mobile3D) in future GRID and e-Science projects using the VCR is another possibility for exploitation, given the interest towards the GRIDCC software that has arisen towards the end of the project.

Finally, the general knowledge acquired in designing, developing and evaluation Web-based groupware interfaces will be exploited in university courses, researches and industrial applications in which the Lab will be involved.

3.10 GrNet

During the course of GRIDCC implementation, the Greek Research and Technology Network (GRNET S.A.) has been involved mainly in the following parts of the project:

- System Architecture**:** GRNET has participated in designing an overall architecture for the GRIDCC services ecosystem, with an emphasis on the Execution Services.
- Web Services QoS**:** GRNET has studied the QoS-relevant parameters of Web Services invocation, documented in D2.2. Based on that, GRNET designed the methodology to follow for evaluating the overall QoS of a WS invocation, which was later materialised by INFN as a statistical approach and a software implementation.
- Agreement Service**:** GRNET has implemented the Agreement Service, which establishes reservations on CEs, SEs and IEs on behalf of other system components, thus acting as a reservation proxy. Using reservations, the system can provide strict guarantees with regard to resource usage.

Based on this experience, GRNET wishes to get a better understanding of how to integrate its networking infrastructure (already providing QoS facilities) with its distributed computing infrastructure implemented as the HellasGrid National Grid Initiative. GRNET is aiming towards a unified e-Infrastructure for Greece and Europe, which would bring together all kinds of resources for e-Science and will allow collaboration of Greek scientists among them as well as with other scientists from Europe and the rest of the world. Enabling this infrastructure with overall QoS will be instrumental for its successful use and efficient utilization. Furthermore, extensions of the Agreement Service for reserving networking resources is also a goal of GRNET, thus making the upcoming GRNET-3 optical (dark-fibre) network accessible in an even more dynamic manner. Last but not least, GRNET wishes to put the acquired know-how to use, in order to help scientists integrate their apparatus with the Grid. GRNET's involvement in the RINGrid and DORII EU projects ensures the continuity that can guarantee the success of this venture.

Section 4. GENDER ISSUES

The GRIDCC project proposed a Gender Equality Action Plan since its inception. Such plan was designed with the intent to promote the recruiting of female researchers at all levels of the project. This action has only been partially helpful as, at the end of the project, only about 10% of the recruited staff is female, although during recruitment most positions had female applicants on their interviewed short-lists..

Nevertheless female staff were appointed to key positions in our project. The first line of the project management, composed by 6 managers, sees a woman as Quality Manager. Furthermore, one of the most important working packages of the eight composing the project, the “Integration and Pilot Applications”, is led by a woman. Finally, a woman is leading the role of Project Administrator.

In the formal review meetings female members of the project team made a significant number of the presentations to the EU project officer and reviewers.