NEW FRONTIERS FOR GRID APPLICATIONS

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Abstract

Grid research, rooted in distributed and high performance computing, started in late 90's when scientists around the world acknowledged the need to establish an infrastructure to support their collaborative research on compute and data intensive experiments. Soon afterwards, national and international research and development authorities realised the importance of the grid and gave it a primary position on their R&D agenda. The importance of the Grid was translated into large funding, from various national and international sources, channelled to various grid projects around the world aiming at building the so-called global infrastructure for e-Science. Selected key projects, such as EGEE and Globus, play a key role in developing this infrastructure. This paper reviews the grid as a suite of concept, standards, programming paradigm, and tools intended to support compute and data intensive tasks in various application domains. The future of grid applications is then discussed in light of the major achievements and the future plans of key grid projects. The paper concludes by arguing for a metagrid infrastructure offering a superset of functionalities on the top of existing grid services and placing the user in a privileged position that grants him/her universal accessibility to the grid.

Keywords: grid, applications, infrastructure, middleware.

1 INTRODUCTION

The Grid is aiming at bridging the gap between the demand for technology and the supply of technology by providing a vehicle for on-demand computation and massive storage. No single application domain can be excluded from the potential benefit of the grid, but some will benefit more than others. Serving the wider community is highly dependent on establishing an appropriate match between the grid technology and the application's need. The grid can be conceived as a suite of concept, architecture, programming paradigm, and implementation.

Several definitions describe the grid at a conceptual level. A common definition is given by Foster (2001) who identifies the real and specific objective that underlies the Grid concept as: "coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations. The sharing that we are concerned with is not primarily file exchange but rather direct access to computers, software, data, and other resources, as is required by a range of collaborative problem-solving and resource-brokering strategies emerging in industry, science, and engineering". The rules for sharing resources between the providers and the consumers of these resources are defined within the scope of a virtual organisation (VO). The latter could be a set of individuals and/or institutions with varied purpose, scope, size, duration, structure, community, and sociology (Foster et al, 2001)

The Open Grid Service Architecture (OGSA) (Foster et al, 2005; Foster et al, 2002) is emerging as a standard for a service oriented architecture that can meet the objectives of the high level conceptual definition of the grid. OGSA adopts web services as an infrastructure and framework where service interfaces are defined by the Web Services Description Language (WSDL). However, web services cannot meet all the requirements for grid systems and applications and in particular security requirements and statefulness. Hence the Web Service Resource Framework (WSRF) (Czajkowski et al, 2004) was developed to overcome the limitations of web services.

The grid architecture suggests new programming paradigms that can harness the massively interconnected physical resources of the grid, yielding higher speed, increased power, and larger storage. Parallel programming is a key in this respect. Existing paradigms for parallel programming include Message Passing Interface (MPI) (Karonis et al, 2003) , Distributed Shared Memory (DSM) (Keleher et al, 1994), or a hybrid of the latter two (Speight et al, 1998; Ryan et al, 2004).

The grid middleware is the underlying grid software. Several grid middlewares are being developed within the framework of various grid projects. They differ in architecture, target application domain, and basic constituents. Depending on the architecture, these middlewares can interoperate to a certain extent. Once deployed on a grid site, a middleware will allow grid users to authenticate and use the various grid services. A typical component is the Globus toolkit (Globus-web2) that is part of most of the existing middleware. Basic services offered by the latest release of the Globus toolkit include: security, data management, execution management, information, and common runtime services.

The next section reviews grid achievements and future plans. Following this the paper discusses the future of grid applications in the light of the major developments achieved by key grid projects. Based on this discussion we argue for a metagrid infrastructure on the top of existing grid services to grant universal accessibility to users around the world. The paper concludes with a summary.

2 GRID PROJECTS: ACHIEVEMENTS AND FUTURE PLANS

Realising the importance of the grid for the future of e-Science, research funding authorities around the world supported key large grid projects and smaller related projects:

- With its ambitious goal to transform the European Union (EU-web) into the most competitive knowledge-based economy in the world by the year 2010, the European Commission (EC-web) strongly supported grid development within the fifth and sixth Framework Programs (FP5-web; FP6-web). The key project financed by the EU is the EGEE project, preceded by EDG and succeeded by EGEE-II (EGEE-web).
- Similarly, in the United States the National Science Foundation NSF (NSF-web) and the Department of Energy DOE (DOE-web) financed various grid projects. Globus (Globus-web) is the key grid project in US.
- Besides the EU funding that was channelled to major research institutions in Europe and around the world, national funding authorities in the UK (e-Science programme (eScience-UK-web)), France (Grid-France-web1, Grid-France-web2), Germany (Grid-Germany-web), Ireland (SFI-web, Grid-Ireland-web), and China (Grid-China-web) gave additional funding and support to grid development.

The following sub-sections provide a closer look at the future plans, the infrastructure, and the middleware of the largest EU funded grid project.

2.1 The Future Plans

The EGEE, Enabling Grids for E-sciencE project (EGEE-web), provides the largest production grid infrastructure for applications. The EGEE mission is to manage and operate the production grid for European research, interoperate with e-infrastructure projects around the globe, contribute to grid standardisation efforts, support applications from diverse communities, and forge links with the full spectrum of interested business partners, and to prepare for a sustainable European grid infrastructure (Jones, 2006).

In the first two years of the project an increasing number of diverse user communities have been attracted by the possibilities offered by EGEE and have joined the initial user communities. The first of April 2006, was the starting date of the second two-year phase of the EGEE project, called EGEE-II. This marked the beginning of a new phase in the evolution of scientific grids. According to an IBM Grid strategist[1], the underlying grid infrastructure is now in place, and increasingly, real users (both academic and industrial) will be driving the further development of the technology, with an expanding range of requirements for scientific computing and data processing using grid technology. EGEE-II puts emphasis on providing an infrastructure that increasingly supports applications, interoperates with other infrastructures, and encourages more involvement from industry (Jones, 2006).

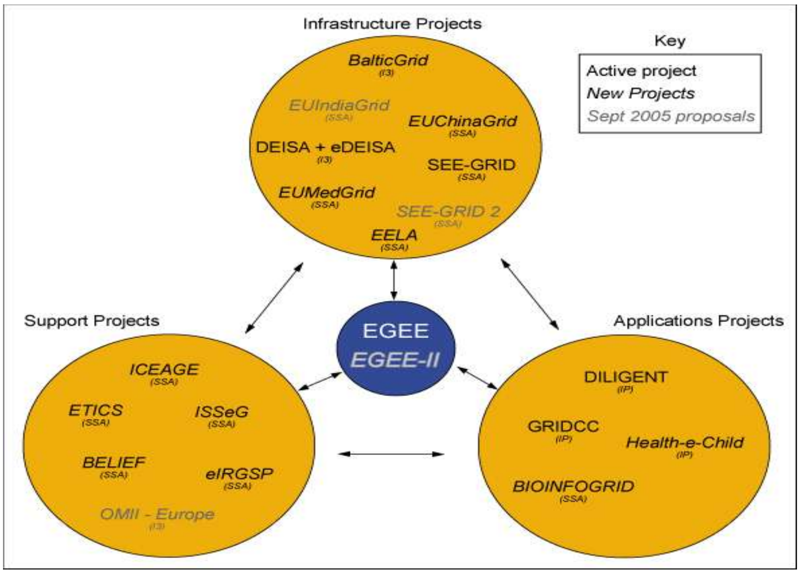

Figure 1. Smaller EU-funded Grid projects related to EGEE and EGEE-II

In the face of a growing user community the EGEE is supporting several related projects (EGEE-News), see Figure 1, aiming at:

- extending the grid infrastructure to new geographic areas such as the Baltic region (Baltic-Grid-web), Latin America (EELA-web), China (EU-ChinaGrid-web), North Africa (SEE-GRID-web), and the Middle East (EUMedGrid-web)

[1] Jean Pierre Prost (IBM Products and Solutions Support Center, Montpellier, France)

- dealing with specific sets of applications and their requirements (DILIGENT-web; GRIDCC-web; Health-e-Child-web; BIOINFOGRID-web).
- contributing to further development of the grid and enhancing the effectiveness of the infrastructure in the area of security and worldwide legislative support (ICEAGE-web; ETICS-web; ISSeG-web; eIRGSP-web; and BELIEF-web)

2.2 The Infrastructure

Bird (2006) describes the EGEE infrastructure as *middleware distributions*, the *process to deployment*, the *time to upgrade, operations,* the *user support model*, and a *VO joining scheme*.

EGEE started in April 2004 with a running grid infrastructure involving 40 sites with a total of 3000 CPU. The infrastructure was built up during 18 months prior to the start of EGEE by the LCG project (LCG-web). The LCG work formed the basic infrastructure of EGEE. It initially conducted basic operations and developed certification and deployment processes. Now the EGEE infrastructure has expanded to 200 sites with greater than 20 000 CPU over 40 countries. Managed operations maintain the stability of sites. The operation volume is approximately 10 000 jobs per day sustained over the last year.

So far the *middleware distribution* retained the name LCG-2.x. Now the middleware distribution will evolve with additional or replacement services coming from gLite (gLite-web) or elsewhere. Middleware providers includes among others: VDT/OSG (VDT-web), OMII Europe (OMII-web), JRA1 (JRA1-web), etc..

The *process for deploying middleware distributions* involves several stages framed into support, analysis, and debugging. These stages are integration, testing and certification, pre-production service, and production services.

A rough estimate of the *time to upgrade an infrastructure* is 2.5 sites/day. The need for full upgrades of a grid infrastructure will be reduced in the future, however, there will be always a necessity to deploy updates, add new tools, and security patches.

Grid operations are described in terms of *services* involving (production and pre-production services, and operational security) and *operation processes* including (problem detection, reporting, problem solving, and escalation procedures).

The goal of a *user support model* is to provide: a single access point for user support; a portal with a well structured information and updated documentation; knowledgeable experts; correct, complete and responsive support; tools to help resolve problems; search engines; monitoring applications; resources status; examples, templates, specific distributions for software of interest; interface with other Grid support systems; connection with developers, deployment, operation teams; and assistance during production use of the grid infrastructure. This model was implemented in the Global Grid User Support System *GGUS (GGUS-web).*

VOs (Virtual Organizations) are formed for pilot applications and applications reviewed and approved by EGAAP (EGAAP-web). A *new VO joining EGEE* with a few sites can benefit from the operations and support, and potentially access to other resources.

The road from EGEE to EGEE-II does not involve a major change in the infrastructure but adjustments based on experience and anticipated evolution. Increased emphasis will be on platform support, interoperability with other grids, consolidation and improvement of existing services, expanded grid operations, achieving reliable production for pilot applications, and bringing new applications.

2.3 The Middleware

Middleware is software and services that sit between the user application and the underlying computing and storage resources, to provide a uniform access to those resources. The Grid middleware services should find convenient places for the application to be run, optimise use of resources, organise efficient access to data, deal with authentication to the different sites that are used, run the job and monitor progress, recover from problems, and transfer the result back to the scientist (Bird, 2006). EGEE deploys a middleware distribution drawn from various middleware products and stacks.

The EGEE middleware consists of various services including:

– Authentication and authorization services. This involves the use of PKI X.509 certificates (GSI-web).

– Basic services. These include *job management* (workload management, Compute Element CE, Logging and Bookkeeping, Local Batch systems, and additional job monitoring tools), *data management* services (File and replica catalogues (LFC), File Transfer Services (FTS), Storage Element, Metadata catalogue, secure keystore, utilities and I/O libraries).

– Other services. These include the Information System and Monitoring and Accounting.

Service challenges set by pilot applications impose new services on grid middleware. For instance the LHC Service challenge 4 (which involves supporting a demonstration of the complete chain of the LHC experiment (LHC-web) motivated the formation of the LCG baseline service working group (LCG-baselineWG-web) whose goal is to provide baseline services to supplement the basic services (e.g. provision of operating system services, local cluster scheduling, compilers, ..). Ganga (Ganga-web) was also designed for data analysis on the Grid to aid users in bookkeeping aspects and keeping track of many individual jobs

3 THE FUTURE OF GRID APPLICATIONS

Two types of classification can be used to describe grid applications:

- *The first type*, widely adopted in the EGEE literature, classifies grid applications in two broad categories (Barbera, 2006):

  - Pilot applications including HEP (High Energy Physics) and Biomed (Biomedical applications). High Energy Physics applications includes ATLAS (ATLAS-web), LHC (LHC-web), and ALICE (ALICE-web). Biomedical applications includes among others GATE (GATE-web) and GPS (GPS-web).

  - Generic applications include the growing number of applications attracted by the grid computational power and storage. These include earth sciences, astrophysics, computational chemistry, fusion, geophysics, finance, multimedia, etc (see EGEE-web).

  Early statistics shows that pilot applications generated approximately 3 million jobs in 2005 and consumed approximately 8.2 M CPU hours.

- *The second type*, classifies grid applications by domain. In a survey of the grid penetration in various application domain, (Maad et al, 2005) considered nine application domains including physics, medicine, astronomy, environment, engineering, media, chemistry, finance, and government. The survey revealed that the cost of developing grid applications is considerable. This was attributed to the adoption of a bottom-up approach for grid middleware development. In fact, most of grid middleware development has evolved in isolation of application domain needs.

On the other hand a top-down approach for grid middleware development may lead to narrow solutions and tend to be less generic. In addressing this dilemma, (Maad et al, 2005) proposed a new software development model to adapt the implementation of the grid anatomy to meet the needs of various application domains, and argued that given the predominance of issues relating to user interactions, data I/O, and workflow, there may be a potential in migrating these functionalities from the traditional bottom-up grid middleware into an independent metagrid environment.

While the design of the grid middleware didn't grow with the user's concerns in mind, the second phase of the EGEE project, EGEE-II, acknowledges the fact that the sustainability of the grid as long term infrastructure depends on the success of its uptake by the wider user community in various application domains. This is not very easy at a stage where the grid middleware is still seeking its stability to deliver productivity ... and with missing concepts such as universal accessibility.

Several efforts are being undertaken to encourage industries to adopt the grid as a “must-implement” technology, optimistically assuming that no single application can be excluded from the potential benefit of the grid in terms of computational power and massive storage. There are definite efforts under way to market grid technology to industry. The Globus Consortium (Globus-Consortium-web) was formed by IBM, Intel, HP and Sun Microsystems to promote the commercial use of Globus. Univa Corp. (Univa-web), a company created by Globus Alliance, provides enterprise-class Globus to users.

4 UNIVERSAL ACCESSIBILITY TO THE GRID

To meet the needs of a wider user community, greater accessibility to the grid is becoming more and more necessary. This is fuelled by cultural differences in the user communities, varying spectrums of requirements, and varying levels of qualifications and abilities of human resources using the grid. Despite the availability of various grid portals (Grid-portal-web1; Grid-portal-web2), none of them address the wider agenda of the universal accessibility to the grid. This has motivated us to espouse a universal access grid layer that would attempt to port the concept of universal accessibility to the grid and to host the existing partial solutions for enhanced grid accessibility. Universal accessibility is rooted in the concept of Design for All in Human Computer Interaction (Stephanidis et al, 2000) and (Stephanidis et al, 1998). It aims at efficiently and effectively addressing the numerous and diverse accessibility problems in human interaction with software applications and telematic services. So far, the key concept of universal accessibility has been supported by various development methodologies and platforms (Stephanidis et al, 1997) and (Akoumianakis et al, 2003). Various application domains benefited from research and development in this area, including among others interactive television and media (Maad, 2003). Currently, porting the concept of universal accessibility to the grid is facing major obstacles attributed to the following (Maad et al, 2006): (a) the lack of an underlying functionality similar to that of a desktop operating system allowing the plug and play of resources and the direct user interaction with these resources; (b) the dilemma between hiding the grid versus making it more transparent; and (c) the software engineering practice adopted in grid middleware development, where the bottom up approach that is predominant conflicts with the ethos of universal accessibility that considers accessibility at design time (Maad et al, 2005).

We propose that the universal access grid layer be implemented as a metagrid infrastructure, hosting solutions to all issues related to universal accessibility to the Grid (see Figure 2 below), and extending the notion of interoperability to embrace grid application interoperability (interactivity and universal accessibility). A prototype metagrid layer is being constructed at Trinity College Dublin. While heavily based on existing grid middleware services and architecture such as EGEE (EGEE-web), Globus (Gobus-web), CrossGrid (Crossgrid-web), GridPP (GridPP-web) and GGF (GGF-web), this metagrid layer hosts one or more target grid techologies (e.g. it has been demonstrated simultaneously hosting WebCom (Morrison et al, 2005), LCG2 (LCG-web) and GT4 (Globus-web-2) while also supporting native services that the target grid technologies do not. By doing so it firmly places the user within the metagrid environment rather than in any one target grid environment. The user obtains a limited form of universal accessibility via the metagrid services, and the target grid technologies are relieved of the need to support direct user and device interactions.

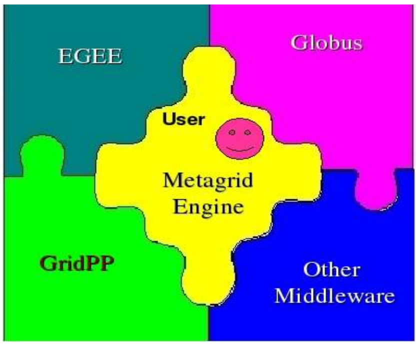

Figure 2. A user centred approach to grant universal accessibility to the grid

Three types of services are offered by the universal access grid layer. These includes: *transparent services*, *metagrid (interoperability) services*, and *value added services*.

Transparent services include a transparent grid filesystem (Maad et al – Journal1; Maad et al – Journal 2) that supplies a vital missing component beneath existing middleware. The grid filesystem can support universal accessibility by supporting all modes of data access in the course of collaborative interaction, by providing a personalised user view of grid data, and by helping locate data in the course of interaction. In so doing it can improve the utility of existing grid middleware.

Metagrid services include services to support secure interoperability (in its broader sense).

Value-added services meet specific domain needs such as data semantics in government applications.

5 CONCLUSION

This paper has reviewed the grid as a suite of concept, standards, programming paradigm, and tools intended to support compute and data intensive tasks in various application domains. The future of grid applications has then been discussed in light of the major achievements and the future plans of key grid projects. A closer examination revealed an urgent need to consider issues of universal accessibility to the grid. This paper argues for a metagrid infrastructure to grant universal accessibility to the grid. While previously not taken into consideration in the development of grid middleware, there is a potential to develop a user-centred grid environment that complements existing grid services. This will open new frontiers for grid applications.

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