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# Scheduling Interactivity Using Grid Computing

[1]V.Vijayalakshmi and [2]V.Sathya
[1,2]Assistant Professor,
[1]Department of Computer Science, [2]Department of Computer Applications,
[1,2]MGR College, Hosur, Tamil Nadu, India

***Abstract:*** Grids are facing the challenge of moving from batch systems to interactive computing. In the 70s, standalone computer systems have met this challenge, and this was the starting point of pervasive computing. Meeting this challenge will allow grids to be the infrastructure for ambient intelligence and ubiquitous computing. This paper shows that EGEE, the largest world grid, does not yet provide the services required for interactive computing, but that it is amenable to this evolution through relatively modest middleware evolution. A case study on medical image analysis exemplifies the particular needs of ultra-short jobs.

## I. INTRODUCTION

In the 70s, the transition from batch systems to interactive computing has been the enabling for the widespread diffusion of advances in IC technology. Grids are facing the same challenge. The exponential coefficients in network performance [7] enable the virtualization and pooling of processors and storage. In the field of biomedical application, widespread diffusion of grid technology might require seamless integration of the grid power into everyday use.
In the more specific area of medical image processing, algorithms often involve a visual evaluation or exploration of the results. In some cases (e.g. rigid registration of multimodal images of the same patient), algorithms are sufficiently automatic to be executed remotely without interaction and the results sent for visualization to the user. In other cases, such as inter-subject registration, it may be necessary to use the anatomical knowledge of the user to better define the expected result (anatomical correspondences between cortical areas in the brain are loosely defined). In such a case, the interaction may be limited to an alternation of independent distant computations and user correction requests, but a soft real-time interaction would be much more interesting. A last class of image processing algorithm, like pre-operative planning, deeply involves the user and requires at least soft real-time to be really useful.

However, the need for fast turnaround time on the grid is not limited to medical image analysis, but encompasses all situations of display-action loop, ranging from a test and debug process on the oration of databases, to computational steering through virtual/augmented reality interfaces, as well as portal access to grid resources, or complex and partially local workflows. A critical system requirement is thus the need to move Grids from exclusive batch-oriented processing to general purpose processing, including iterative tasks. Section 2 of this paper will provide experimental evidence about the reality of the need, from the analysis of the activity of a segment of the EGEE grid heavily used by its biomedical community, the biomed VO.

## II. EGEE USAGE

The current use of EGEE makes a strong case for a specific support for short jobs. Through the analysis of the LB log of a broker, we can propose quantitative data to support this affirmation. The broker logged is grid09.lal.in2p3.fr, running successive versions of LCG; the trace covers one year (October 2004 to October 2005), with 66 distinct users and more than 90000 successful jobs, all production. This trace provides both the job intrinsic execution time t (evaluated as the timestamp of event 10/LRMS minus the timestamp of event 8/LRMS), and the makespan m, that is the time from submission to completion (evaluated as the timestamp of event 10/LogMonitor minus the timestamp of event 17/UI).

## III. SCHEDULING FOR INTERACTIVITY

A Scheduling Policy for SDJ Deadline scheduling usually relies on the concept of breaking the allocation of resources into quanta, of time for a processor, or through packet slots for network routing. For job scheduling, the problem is a priori much more difficult, because jobs are not partition able: except for check point able jobs, a job that has started running cannot be suspended and restarted later. Condor [6] has pioneered migration-based environments, which pro-vide such a feature transparently, but deploying constrained suspension in EGEE would be much too invasive, with respect to existing middleware. Thus, SDJ should not be queued at all, which seems to be incompatible with the most basic mechanism of grid scheduling policies.

The EGEE scheduling policy is largely decentralized: all queues are located on the sites, and the actual time scheduling is enacted by the local schedulers. Most often, these schedulers do not allow time-sharing (except for monitoring). The key for servicing SDJ is to allow controlled time-sharing, which transparently leverages the kernel multiplexing to jobs, through a combination of processor virtualization and slot permanent reservation. The SDJ scheduling system has two components.

• A local component, composed of dedicated queues and a configuration of the localscheduler. Technical details for MAUI can be found at [11]. It ensures that:

- Immediate execution of SDJ if resource are available.
- The delay incurred by batch jobs has a fixed multiplicative bound.
- The policy is work-conserving, implying that the resource usage is not degraded, eg by idling processors.
- The policies governing resource sharing (VOs, EGEE and non EGEE users,...) are not impacted.

• A global component, composed of job typing and mapping policy at the broker level. For the local component, the first question is to prove correctness. Extensive experiments have been conducted on the EGEE cluster at LAL. shows a case where three kind of jobs are allowed to run concurrently: batch, SDJ, and dteam. On a dual-processor, only two of each kind actually runs, which ensures bounded delay. Fig 3(b) gives the overall site view; the fraction intended limitation of SDJ-dedicated resources (10 running jobs maximum) is achieved.

## IV. GPTM3D

Interactive Volume Reconstruction

PTM3D [9] is a fully featured DICOM images analyzer developed at LIMSI. PTM3D transfers, archives and visualizes DICOM-encoded data; besides moving independently along the usual three axes, the user is able to view the cross-section of the DICOM image along an arbitrary plane and to move it. PTM3D provides computer-aided generation of three-dimensional representations from CT, MRI, PET-scan, or echography 3D data. A reconstructed volume (organ, tumor) is displayed inside the 3D view.

The first step in grid-enabling PTM3D (gPTM3D) is to speedup compute-intensive tasks, such as the volume reconstruction of the whole body used in percutaneous nephrolithotomy planning. The volume reconstruction module has been coupled with EGEE with the following results:

• the overall response time is compatible with user requirements (less than 2 minutes), while the sequential time on a 3GHz, 2MB memory PC is typically 20 minutes.

• the local interaction scheme (stop, restart, improve the segmentation) remains strictly unmodified.

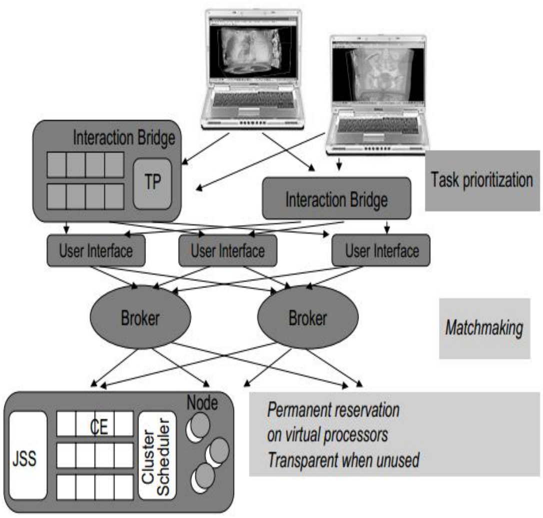
This first step has implemented fine grain parallelism and data-flow execution on top on a large scale and file-oriented grid system. The architecture based on Application Level Scheduler/Worker agents shown in fig 4 is fully functional on EGEE. The Interaction Bridge (IB) acts as a proxy in-between the PTM3D workstation, which is not EGEE-enabled, and the EGEE world. When opening an interactive session, the PTM3D workstation connects to the IB; in turn, the IB launches a scheduler and a set of workers on an EGEE node, through fully standard requests to an EGEE User Interface; a stream is established between the scheduler and the PTM3D front-end through the IB. When the actual volume reconstruction is required, the scheduler receives contours; the Scheduler/Worker agents follow a pull model, each worker computing one slice of the reconstructed volume at a time, and sending it back to the scheduler, which forwards them to IB from where they finally reach the front-end. The next step will be to implement a scheme where the IB and the scheduler cooperate to respectively define and enforce a soft real-time schedule.
User-level scheduling has been proposed in many other contexts, and a case for it has been made in the AppleS [1] project. In a production grid framework, the Dirac [10] project has proposed a permanent grid overlay where scheduling agents pull work from a central dispatching component. Our work differs from Dirac in two respects: first, the scheduling and execution agents are launched just as any EGEE job, and are thus subject to all regulations related to sharing: typically, they are SDJ, thus will be aborted if they exceed the limits of this type of jobs.Moreover, they work in connected mode, more like login-based applications [8].

## V. GRID-ENABLING IMAGE EXPLORATION

In the previous section, the grid was used only as a provider of computing power, while the data were located on the front-end. Sharing data is a well-known need for algorithmic research, but this is true for clinical research as well. We have started the process of extending PTM3D toward accepting remote data access. The integration of gPTM3D with the Medical Data Management scheme presented in another paper is the final goal. However, at the present time, we consider a most restrictive scheme, which uses the internal format of PTM3D images, where the slices are bundled in a 3D file (bdi and bdg formats). In this context, the main issues are the access latency. The ongoing work targets adaptation to the user activity, mainly trough interactive selection of the image resolution and the region of interest.

## VI. AN ARCHITECTURE FOR GRID INTERACTIVITY

The scheme described in the previous sections virtualizes the resources at the coarse grain of batch versus short deadline jobs. An open issue is scheduling across SDJ. Consider for instance a portal, where many users ask for a continuous stream of execution of SDJ. This situation can be modelled with the so-called (period, slice) model used in soft real-time scheduling, where a fraction (slice) of each period of time should be allocated to each user in order to keep happy. To be coherent with a software architecture based on VOs, global regulation of SDJ should be left to the implementation of sharing policies (ultimately implemented by site schedulers). However, it is the responsibility of the provider of a particular service to arbitrate between its users. The Interaction Bridge described in the previous section is the adequate location for this arbitration. Figure 5 describes the resulting architecture.



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