GATE simulation for medical physics with genius Web portal

C.O. Thiam, L. Maigne, Vincent Breton, D. Donnarieix, R. Barbera, A. Falzone

GATE SIMULATION FOR MEDICAL PHYSICS WITH GENIUS WEB PORTAL

C.O. Thiam[1], L.Maigne[1], V. Breton[1], D. Donnarieix[1+2], R. Barbera[3], A. Falzone[4]

[1]*Laboratoire de Physique Corpusculaire, 24 avenue des Landais, 63177 Aubière cedex, France*
[2]*Unité de Physique Médicale, Département de Radiothérapie-Curiethérapie, Centre Jean Perrin, BP 392 63011, Clermont-Ferrand cedex, France*
[3]*University of Catania and INFN via S. Sofia 64, I-95 123 Catania, Italy*
[3]*NICE srl, via Marchesi di Roero, 1, I-14020 Cortanze(AT), Italy*

1. Introduction

PCSV team of the LPC laboratory in Clermont-Ferrand is involved in the deployment of biomedical applications on the grid architecture. One of these applications deals with the deployment of GATE (Geant4 Application for Tomographic Emission) for medical physics application. The aim of the developments actually performed is to enable the usage of the GATE platform in clinical routine. However, this perspective is only possible if the computing time is highly reduced as Monte Carlo GATE simulations applied to doses calculation in radiotherapy per example require several hours of calculations in order to achieve a precise result. The new grid architecture, developed within the framework of the European project Enabling Grid for E-sciencE (EGEE)[1] is there to answer this requirement. The use of the grid resources must be transparent easy and rapid for the medical physicists. For this purpose, we adapted the GENIUS web portal in order to facilitate the GATE simulations planning on the grid. The GENIUS development project started in 2002 was initiated by the Italian INFN Grid Project [4]. Its goal was to create a web portal that would overcome all the difficulties related to the complex command lines interfaces (CLI) and the job description language (JDL) that a user encounters when he has to submit his application in a grid environment. We describe first the architecture and implementation of the portal, the services offered and to finish the work realized (since April 2004) to customize the portal in order to allow transparent GATE jobs submission and management on the EGEE-LCG2 infrastructure. We present some results on the computing time demonstrating the impact of grid resources for the optimization of GATE.

2. GATE: Monte Carlo simulation

GATE is a generic Monte Carlo platform based on GEANT4 (current version 4.7.0.p01) [2]. Specific modules are added on top of GEANT4 for (Single Photon Emission Computed Tomography) and PET (Positron Emission Tomography) requirements and facilitate the usage of the code. GATE can also be applied to model brachytherapy-radiotherapy applications. In this paper GATE platform is used to calculate the relevant dosimetric quantities for treatment planning in brachytherapy-radiotherapy.

3. The parallelization method

Each MC simulation uses a sequence of random numbers to generate the physical interactions in matter. The more numerous the interactions in a medium are, the longer the sequence of random numbers generated for the simulation is. A simple way to reduce the execution time of a simulation used in physical experiments is to sub-divide a long or a very long simulation into little ones by indexing to each simulation a sub-sequence of random numbers obtained by partitioning a long sequence of random numbers. Sub-sequences have to be independent; this method is valid only because the particles emitted in simulations are independent. An obvious way to get parallel random numbers streams is to partition a sequence of a given generator into suitable independent sub-sequences, such as the Sequence Splitting Method [3].

4. GENIUS and GENIUSphere

4.1. Description

The GENIUS [5] web portal is carried out on the top of the middleware services of the EGEE infrastructure. The layout of the portal can be described by a three-tier architecture model (figure 1). On the user workstation, a web browser running Internet Explorer and Mozilla is used to access to the EGEE grid infrastructure through the User Interface. The EGEE User interface (UI) machine runs the Apache web server, the Java/XML framework EngineFrame developed by NICE and GENIUS itself. From the User interface via the portal the user has access to the remote Grid resources.

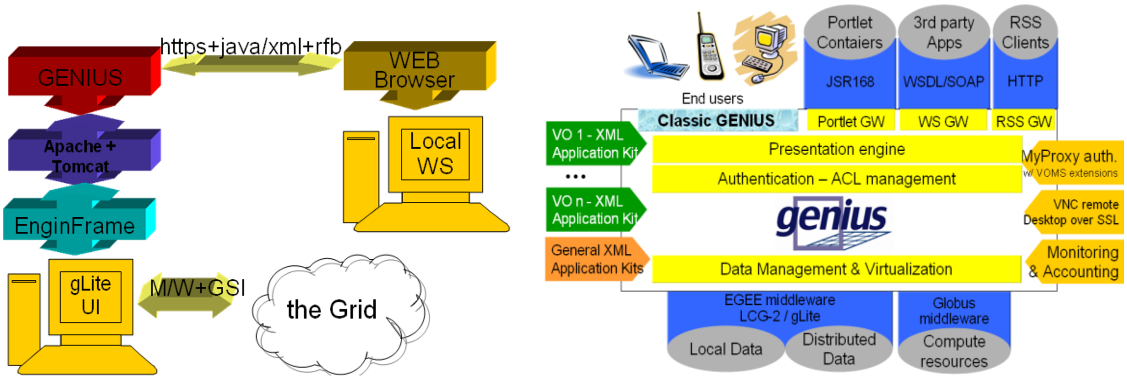

Figure 1: Three-tier architecture of the GENIUS portal

Using those services, the user can interact with files on the UI and from there the user can launch jobs to the grid and manage the data of the Virtual Organisation to which he belongs.
In order to guarantee a secured access to the grid, GENIUS has been implemented with a multi-layered security infrastructure:

- All web transactions are executed under the Secure Socket Layer (SSL) via HTTPS
- The user has to obtain an account on a UI machine of the grid and be part of a VO.
- At each time a user wants to interact with files on the UI machine, he is prompted for the username and password he obtained on that machine.

To increase the security, usernames and passwords typed on the browser are not saved anywhere; they are streamed under the https protocol and then destroyed. The GENIUS portal logs out automatically if no actions have been done on the web browser for more than 30 minutes to avoid undesired accesses (Figure 2).
As the user is authenticated and authorized to use the portal, he can have access to more than 100 functionalities. All the GENIUS services are described in the User's manual that can be browsed from the official site.

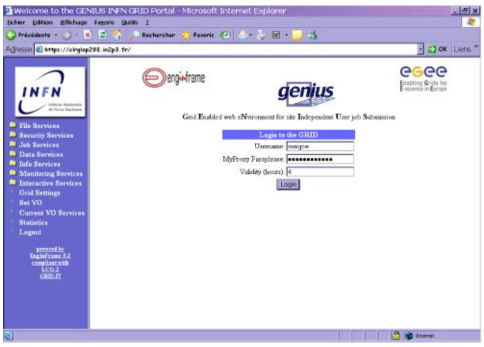

Figure 2: Screenshot of the web portal Genius.

Figure 3: GENIUS new version and GENIUSphere

A new version of GENIUS (Figure 3) is under validation to bring a larger flexibility in the use of grid resources by the web portal. This GENIUS version benefiting services of new technologies of data-processing programming, gives a large improvement the ways to write the code for grid integrations. The grid machines will be able to communicate easily and the files browsing for GATE application will be able to transparently with an easy files downloading.

4.2. Encoded functionalites for GATE applications on the Genius web portal

In order to enable a transparent and interactive use of GATE applications on the grid, we have developed, in joint collaboration with the department of Physics and Astronomy of the Catania University, all the functionalities to run GATE simulations on distributed resources (Figure 4). Those developments are intended to researchers of the GATE collaboration willing to have access to large computing resources to run long simulations but has been designed also to answer the needs of physician and medical physicists in a clinical

structure (typically the Centre Jean Perrin) to compute dosimetric studies using Monte Carlo high precision for specific applications for instance ocular brachytherapy treatments using ophthalmic applicators of radioactive sources. We will explain in the following the current developments done on the GENIUS portal and GENIUSphere to enable a transparent and convenient access to the grid for GATE applications.
Many informatic languages are used to implement functionalities on the portal:

- Bash coded files enable to define and call all the command lines interface needed for the application, the creation of files such like scripts, jdls and the interactions with the grid (submission, monitoring)
- XML coded files enable the creation of the buttons and functionalities appearing on the portal screen.
- JAVA scripts allow interfacing other application automatically.

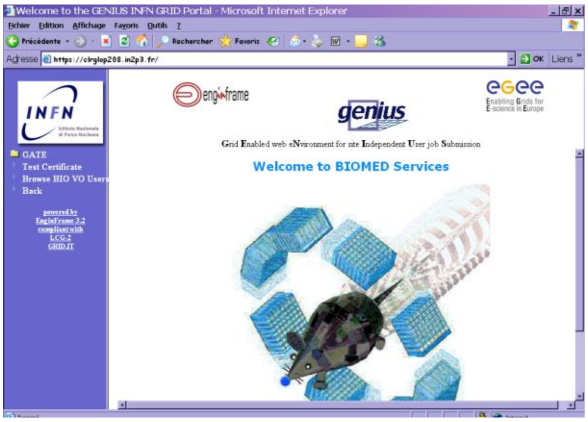

Figure 4: Screenshot of the GATE application on GENIUS

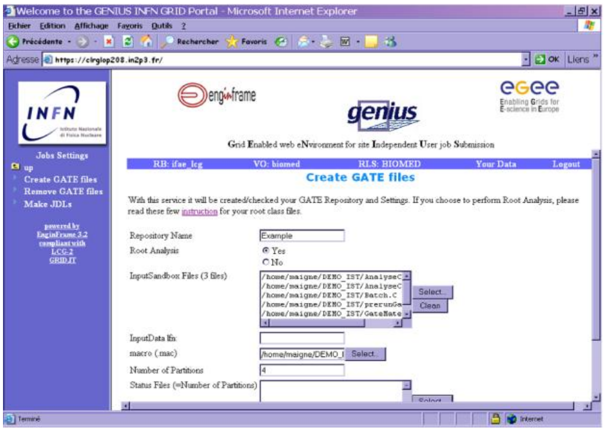

Figure 5: Screenshot of the web portal Genius related to the creation of GATE files

The GATE service on the web portal is made of two parts essentially: “Jobs Services” for submission and monitoring jobs and “Data Services” for registration and management of medical data files. In the “Jobs Services” part, the Job Settings folder provides to the user a web page enabling the creation of the GATE files (Figure 5), their removal from the UI and the creation of the jdl files (Job Description Language) to launch them on the grid. From this Web page, user also uploads all the information reliant to the GATE macro, and to fix a number of partitions for its job. Once that the jobs are submitted, you have the possibility to monitored your jobs by checking their status. At the end of the execution, when all jobs are done, spooler directory is created with the outputs of the jobs available in it.

5. Computing times test

GATE being available on several EGEE sites, with a combined capacity of 3000 CPUs approximately, we carried out tests in order to estimate gains in computing times. The tests were done using a radiotherapy treatment simulation generating several million events (20.000.000 particles). This simulation is divided successively into series of ten, twenty, fifty and hundred jobs which are then deployed on the grid. We evaluated time spent in different states from the moment the job is submitted to the output retrieval.

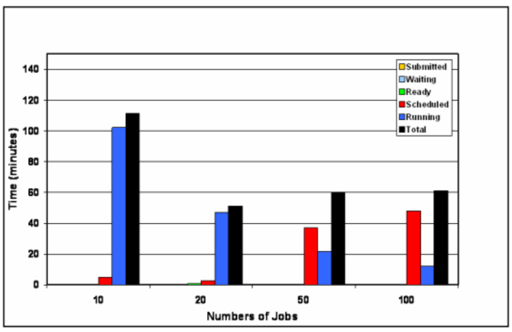

Figure 6: Times comparison in relation to jobs states

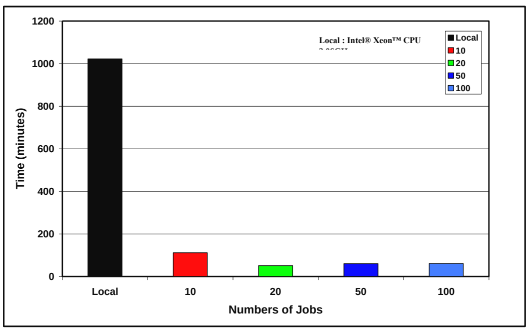

Figure 7: Comparison between local time and the grid computing time

The values represented on figure 6, describe the job states during its life on the grid. Once that the request is addressed to the Resource Broker (RB) job state is “submitted”. Job state is “waiting” on standby while RB questions the information system to find Computing Element (CE) adapted to accommodate your job. Job state is “Ready” if the request is prepared to be subjected to Computing Element. Job state is “Scheduled” if is a batch queue on the Computing Element. Job state is “Running” while it is executed. Job state is “Done” if the execution is finished successfully and preceded well. Result can be repatriated with the user.
Time corresponding to Scheduled state can be important (Figure 6) and depends directly on the load of Computing Element load and the computing performance of the nodes. The other times are almost negligible compared to the total time a job spends on the grid. Figure 7 represents a comparison of computing time on a local machine compared to times obtained for each series in the test.
Within the framework of our application, we obtain a very significant result splitting a simulation GATE on the grid architecture with a crunching factor which can reach 20 (Figure 7). The computing time is not necessarily proportional to the number of jobs running in parallel. This is in part due to three parameters like launching time, numbers of free CPUs, load and performance of Computing Element. It is important to take into account of the parameters. Also, submission and retrieval times can be very important using a large sequential submission or multithreaded submission.

6. Conclusion

GENIUS web portal will allow in a long term to use GATE application in brachytherapy and radiotherapy treatment planning using medical data (medical images, DICOM, binary data dose calculation in the heterogeneous mediums) and to analyze the results obtained in visual form. Other functionalities are under development and will make possible and easy to register medical data on grid storages elements and to manage them. Work carried out so as to split the simulation reduces considerably the computing time. The figures obtained are very good know in a that the clusters used for these tests are significantly loaded. The computing grid gives promising results and meets a definite need: reach acceptable computing time for a future use of Monte Carlo simulations for treatment planning in brachytherapy and radiotherapy. Our GATE activities for dosimetry application entered in to direct phase of evaluation by the cancer treatment center of Clermont Ferrand (Centre Jean Perrin).A work station is currently available in this center to test the use of GATE application on the grid through GENIUS and GENIUSphere.

References:

[1]. EGEE Project: http://public.eu-egee.org/
[2]. GATE: “a simulation toolkit for PET and SPECT”, Jan S., Santin G., Strul D., Staelens S. and al, *Phys. Med. Biol.*, 49 (2004) 4543-4561.
[3]. Parallelization of Monte Carlo Simulations and Submission to a Grid Environment, L. Maigne, D. Hill, P. Calvat, V. Breton, R. Reuillon, D.Lazaro, Y. Legré, D. Donnarieix,., Parallel Processing Letters journal, Vol. 14, No. 2 (June 2004), p 177-196.
[4]. GENIUS: “a simple and easy way to access computational and data grids”, A. Adronico, R. Barbera, A. Falzone, P. Kunszt, G. Lo Re, A. Pulvirenti, A. Rodolico, Future Generation Computer Systems, volume 19, Issue 6, pages 805-813, 2003.
[5]. Visit the GENIUS web site: http://genius.ct.infn.it