CODES

Contract COOP-CT-2005-018122

CODES

Computing On Demand for Electromagnetic Software and applications

HORIZONTAL RESEARCH ACTIVITIES INVOLVING SME
Instrument: Co-operative research project

Final Activity Report

Period covered: from 1/05/2005 to 31/10/2007 Date of preparation: 12/12/2007

Start date of project: 1/05/2005 Duration: 30 months

Project coordinator name: Bruno Casali
Project coordinator Organisation name: IDS Ingegneria dei Sistemi Spa

Revision: 1.0

Abstract

This report covers the accomplishments and the achievements CODES project.

In the beginning, the CODES Project was planned in a timeframe of 24 months; during the first year of the project some delays occurred and the CODES Consortium asked and obtained a project extension of 6 months.

This extension led the CODES project to be concluded on October 2007, instead of April 2007, with a full achievements of the results planned in the beginning.

The details of the results and achievements for the whole projects are contained in the delivered Reports.

Institution	**Authors**
IDS - Ingegneria dei Sistemi Spa	Bruno Casali
Compass Ingeniería y Sistemas, SA	Ramon Ribo
IMST Gmbh	Rens Baggen
TICRA Fond	Poul Eric Fransen
THALES	Jean Paul Martinaud
Grid Systems	Joan Masso
Information Technology Link srl	Sabino Titomanlio
International Centre for Numerical Methods in Engineering	Javier Mora
Italian Research National Council - Information Science and Technologies Institute	Domenico Laforenza
Università degli Studi di Lecce	Luciano Tarricone

Keyword List

GRID, ELECTROMAGNETIC, SOFTWARE

Document Evolution

Revision	Date	Reason of change
Rev. 1.0	15/12/2007	First Edition

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1. Introduction

1.1 Project Objectives

The CODES project has multiple objectives that belong to the following areas:

1. **Knowledge creation and management**
2. **Software development and improvement**
3. **Dissemination and Exploitation**

1.1.1 Knowledge creation and management

It is quite natural that a considerable amount of knowledge has be created and transferred in the frame of CODES project. This is one of the objectives of the project and among the main knowledge topics that will be addressed:

- Assessment of future demands on EM simulation based on current user profiles and state-of-the art EM-developments.
- Specification of the different parallelization and distribution schemes customised for the different algorithms. Software requirements about the parallelization and distribution techniques
- Definition of benchmark models, based on different problem profiles, simulation goals and post processing of final results. Emphasis on performance enhancements standards.
- Assessment of existing GC technologies and toolkits. Criteria to select and adapt toolkits
- Specification of programming patterns to use GC in the parallelization of em software
- Specification of suitable architecture to develop em design environment using *Service Oriented Architecture* (**SOA**) based on GC

Knowledge has been organized into the document delivered for each WP.

1.1.2 Project achievements

In line with the CODES Description of the Work, the main achievements are described in the following.

1.1.2.1 CODES COMPUTE GRID

The configuration of a working geographical computational Grid, *CODES Compute Grid* (**CCG**) with at least one node for each participant.

This Grid, has been used as a laboratory to test the result of the development activities and for dissemination purposes.

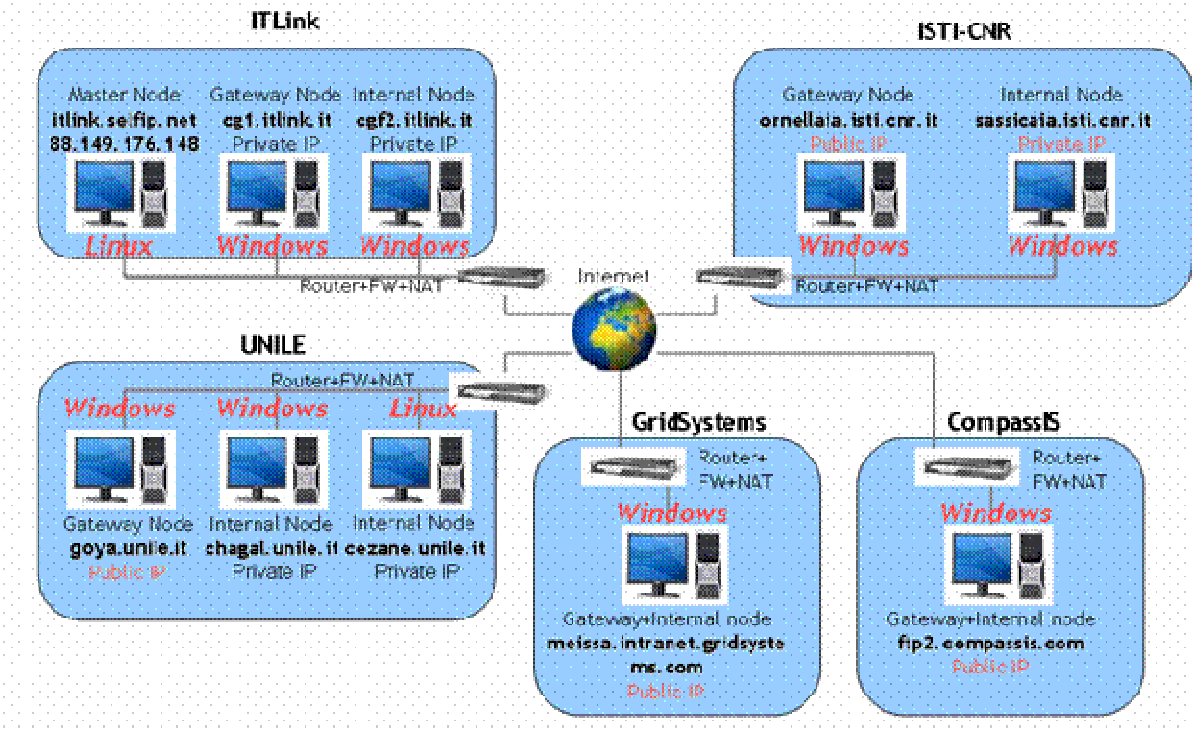

Fig. 1.1 - CODES geographical Grid

1.1.2.2 CODES GRID FRAMEWORK

CODES Grid Framework (**CGF**) is a multiplatform middleware based on existing GC toolkits, but specifically designed and developed to address the problems related to the distribution of computation of heterogeneous em software tools over a computational Grid and the aspects related to the integration (command and control, data exchange, accounting, security) in a geographical distributed, multi-company computing environment.

The main CGF features are listed below:

- Use Globus Toolkit 4 (GT4) – all remote interfaces are Web Services (GT4 WSRF)
- Support Linux & Windows platforms
- Replaced GT4 components unavailable on Windows (WS-GRAM and GridFTP) with CoG Gatekeeper and GASS server
- Developed abstraction layers and higher-level services on top of GT4 including Grid configuration db, workflow manager, scheduler
- Grid configuration with immediate propagation of Grid configuration changes
- Secure and distributes remote logging
- Planned Grid-aware system configuration and monitoring GUIs (Admin Services)
- Full encapsulation of local execution with transparent move of input/output files from local execution context to a global shared file area
- Allows interface to existing application frameworks (Legacy Interface)

- Simple adaptation layers for program activation (Execution Agent)

The CGF has been based on the following main topics:

- **Divide-et-impera approach**

  Split each computation (Procedure) in sub-blocks (Operations) that can be executed separately, possibly on different machines

- **Task dispatching**

  Procedures and Operations exploit task-dispatching: each sub-block can separately solve a portion of the initial problem.

- **Procedure & Operations**
  - CGF manages complex computations specified as procedures
  - A Procedure is a directed, acyclic graph of ***Operations***
  - A single Operation correspond to a single sub-computation
  - CGF procedures have an XML specification
  - A procedure describes ONLY the execution logic needed for a computation
  - The business logic related to the computation is specified into dedicated DataService providing
    - Input data conversion
    - Input files creation
    - Output data checks

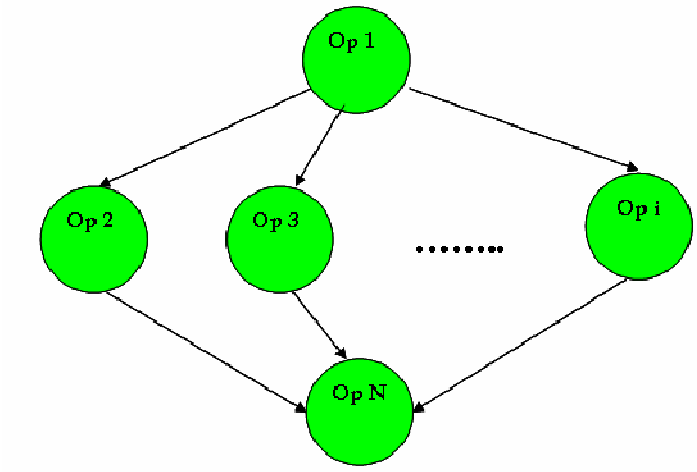

Fig. 1.2 - Procedure example

- **CGF Technical features**
  - Use Globus Toolkit 4 (GT4) – all remote interfaces are Web Services (GT4 WSRF)
  - Support Linux & Windows platforms

- Replaced GT4 components unavailable on Windows (WS-GRAM and GridFTP) with CoG Gatekeeper and GASS server
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- Allows interface to existing application frameworks (Legacy Interface)
- Simple adaptation layers for program activation (Execution Agent)

1.1.2.3 UPDATED EM SOFTWARE TOOLS

The SMEs intend to upgrade those software that, after the thorough requirements analysis conducted in the early stage of the project, will demonstrate to be the most suitable and promising for the application of GC techniques.

The obtained results will depend on how the GC can actually fit into the existing software architecture, leading to proof of concepts, pilots, prototypes or possibly finite products that will be tested on the CCG.

It is quite obvious that update of existing software code will be necessary in order to make it ready to use GC as well as newly developed EM methods and techniques for obtaining the best possible accuracy. Further, the performance prediction tools for enabling performance prediction shall be updated

1.1.2.4 CODES DESIGN ENVIRONMENT

The CCG will be itself the core of the design environment.

Main objectives are:

- Obtain a clear specification of what a Grid-based electromagnetic design environment should be, in particular addressing the aspects related on data communication and security, license and accounting, service model (i.e. fully ASP, data centered/compute distributed, etc.)
- Develop a prototype of *CODES Design Environment* (**CDE**), layering a design infrastructure on top of the existing CCG by means of the selected Service Oriented Architecture (SOA) that will be customised for the purpose. The infrastructure will provide shared design service including authentication, security, project database, licensing, accounting, etc.
- Realize the *CODES Dissemination Grid* (**CDG**), by means of the integration of the *CODES Virtual Centre* with the *CODES Design Environment*. The CDG will be the final output of the project: a virtual centre where it will be possible to access to the results of the project as well as use a pilot design environment (the CDG) based on an underlying pan-european compute Grid.

As described in the following Figure 1.3, where the interdependences between the above mentioned components are showed.

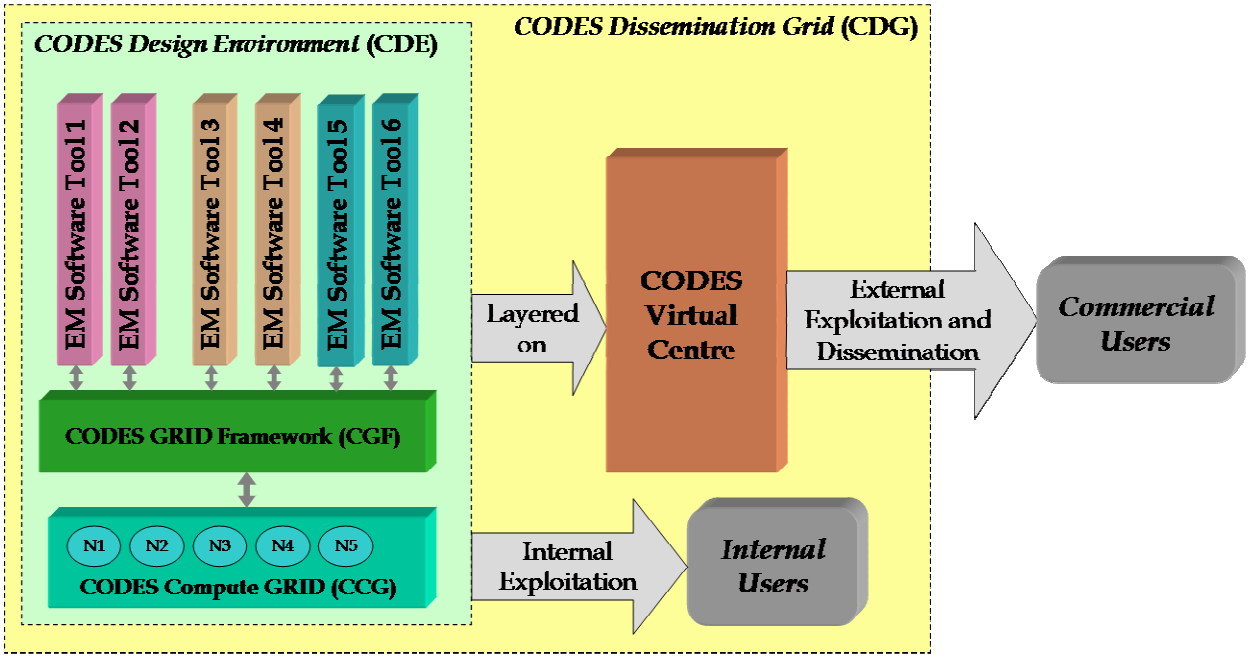

Fig. 1.3 – The CODES Software/Hardware Components

1.1.3 Support to Knowledge Management and Dissemination

The CODES Project will use a robust approach for the management of the Project, the sharing of knowledge and results, the Exploitation and Dissemination of the project results.

In Particular, a dedicated Internet Portal, the *CODES Virtual Centre* (**CVC**) has been developed in order to provide:

a) CODES P*rivate Area Services,* to support the technical and Contractual matters;

b) CODES *Public Area Services*, where citizens will be able to raise their awareness about the GRID projects

The **CVC** has been developed thanks to the requirements given by the CODES Participants and the support of an external Company, with specific competences in Web Services development.

The **CVC** has been online since the 4th month of project activity for Project Management purposes and has been fully operative at To+12.

The **CVC** also play a key role in our planning for using and dissemination the knowledge since it will act as the hub to allow the distribution of the knowledge produced and for the full use of the results produced by the project by the CODES Participants.

All the CODES project delivered reports have been uploaded in a dedicated area on the CVC.

2. Workpackage description

2.1 WP1 – User requirements analysis

2.1.1 Objectives

The objectives of WP1 for were:

1. to define the user requirements for the CODES Grid Framework (CGF)

   The main objective has been to identify a baseline specification for a common platform that could be adopted by all the participant SMEs.

   The CODES platform will be mainly constituted of a dedicated framework that will use standard Grid middleware in order to make existing EM software applications able to run in a Grid environment.

2. to identify the EM software relevant to run into a concurrent/distributed fashion

   IDS, CompassIS and IMST selected some EM software tools that have to run into the CODES Grid. IDS, CompassIS and IMST choose task dispatching as the most suitable distribution approach for their EM software tools; TICRA selected the parallelisation approach.

2.1.2 Progress towards objectives

Period	**Activity**
May-September 2005	The SMEs defined their user requirements. The result of the work has been consolidated into the deliverable D1.1. The SMEs identified the EM software tools to run into a Grid environment. The result of the work has been consolidated into deliverable D1.2.
September-December 2005	The unavailability of two critical GT4 services on Windows – GridFTP and GRAM – emerged and compelled the RTDs to perform a further analysis to identify the possible technical solution, to be matched with the the CODES User Requirements.
January-April 2006	A critical review of the User Requirements started, involving close cooperation among IDS, ITLINK, UNILE, ISTI-CNR in order to find and agree on a technical solution feasible within the project and useful for the SMEs.
April 2006 (PM2)	RTDs provided a new Grid architectural solution able to support Windows and a new set of CODES requirement were consolidated into a new release of the user requirement document (D1.1) and software taxonomy report (D1.2). SMEs agreed during Progress Meeting 2.

2.1.3 Deviations

The most important deviation was caused by the lack of Windows support.

A delay of 4 months appeared at the end of the first years.

2.1.4 Deliverables

Del. no.	Deliverable name	Delivery date
D1.1	Software Requirements Report	Rev 1.0 available from M08 Rev 1.1 available from M12.
D1.2	Software taxonomy Report	Rev 1.0 available from M08 Rev 1.1 available from M12.
D1.3	CODES Design environnent Requirements	As Annex of D1.1

2.2 WP2 - HPC Technology Assessment

2.2.1 Objectives

- Examine the existing Grid technology in order to assess the available state-of-the-art middleware and to ensure that the most suitable technology were used within the project.
- Find a solution to entirely support the Windows OS,
- Identify a CGF software decomposition in agreement with CGF architecture.

These activities have been performed together with the User Requirement analysis.

2.2.2 Progress towards objectives

- GRIDSYS provided a comparative analysis about InnerGrid and GT4;
- ISTI provided a comparative analysis about WSRF.NET and GT4.

At the end of this evaluation, GT4 was adopted as the CODES Grid the middleware: it is OpenSource, reliable and standard, as required from the SMEs.

Windows OS support

However GT4 did not provide full support for the Windows platform: GRAM and GridFTP were (and are) not available on Windows.

IDS cooperated with ISTI-CNR, UNILE and IT-Link in order to find alternative solution to cover to Windows platform requirements.

The following alternatives were evaluated:

- To develop ad-hoc, partial replacements for GridFTP and GRAM services on Windows, either with a custom interface or, alternatively, with a subset of the interface exported the original services.

- Directly build Web Services on top of E.M. programs execution, bypassing the need for GRAM or an equivalent service.
- Use the CoG Toolkit, which contains also Windows versions of the Personal GASS Server and Personal Gatekeeper, two services that can be used as somewhat limited replacements of, respectively, GridFTP and GRAM.

At the end of these feasibility analysis RTDs and all the SMEs agree to use the CoG kit to replace the services not provided by GT4.

2.2.3 Deviations

The most important deviation was related to the missing GT4 services for Windows OS.

This lack caused additional work and led to the adoption of further Grid software modules (Java CoG Kit), not planned in the beginning of the project.

2.2.4 Deliverables

D2.1 Application functional requirements report

D2.2 CODES Grid Environment software requirements

D2.3 CODES Grid Framework software requirements

2.3 WP3 - Deployment of internal CODES computational Grid

2.3.1 Objectives

The implementation of a working computational Grid (the CODES Compute Grid), to be used as the using environment bed for subsequent test activities of the parallelized codes or for concurrent execution of distributed codes.

2.3.2 Progress towards objectives

During the first year of activity, in the frame of WP3, the CODES partners implemented several local Grids instead of a big and shared Grid among all them. Several factors led to that decision:

1) SMEs are leaders into the market of software for electromagnetic simulation but they had little competence in the world of "Grids". The best way to take confidence with the Grid-technology was to allow all the partners to build and try to work with an internal Grid;

2) SMEs had different needs within the scope of the CODES project, the availability of an internal Grid that could be easily accessed helped them to best find the strategy to follow;

3) typical customers are needs that electromagnetic simulation to be performed under dedicated security policies..

However, all the internal Grids were built following the same principles: they shared the same architecture and middleware.

During the second phase of activity, all the CODES partners worked together to merge their own local Grid into a geographical one that has been used for code testing during the WP5, and for dissemination purposes.

The following figures show the local that SMEs and RTDs have set-up in the frame of WP3 activity.

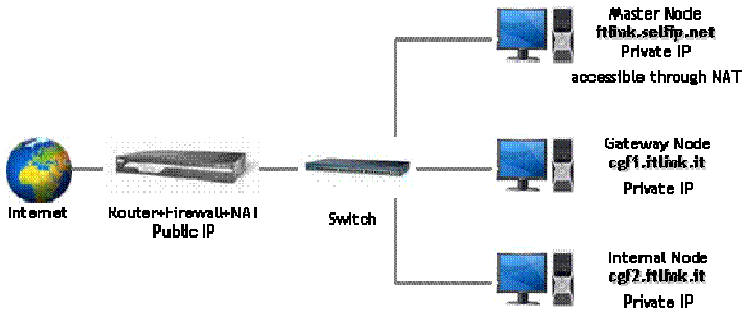

Fig. 2-1 IT-Link Grid

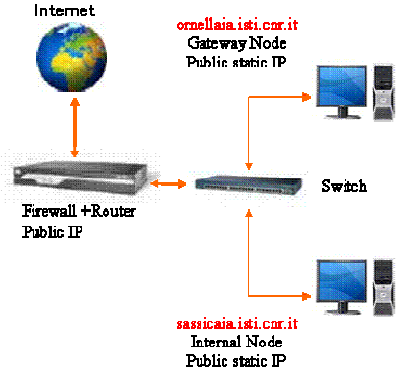

Fig. 2-2 ISTI-CNR Grid

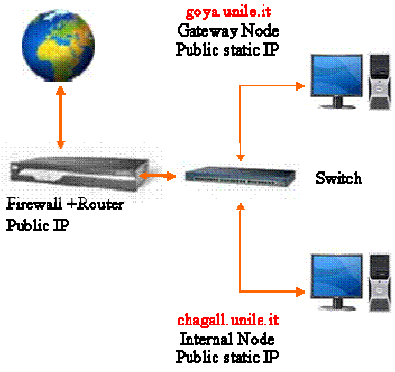

Fig. 2-3 UNILE Grid

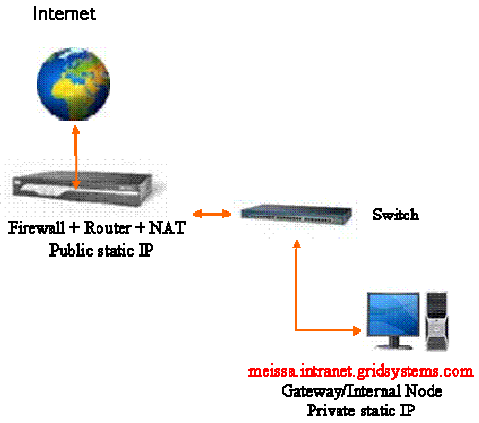

Fig. 2-4 GridSys Grid

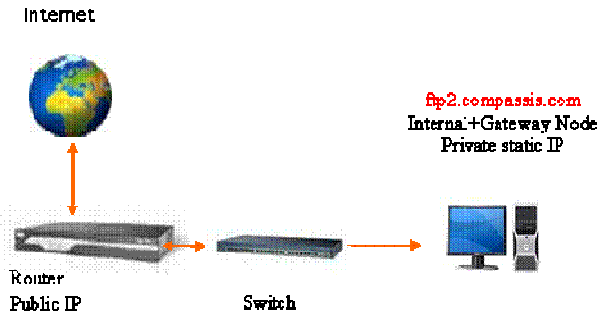

Fig. 2-5 Compass Grid

2.3.3 Deviation

Apart from the decision to postpone to WP6 the implementation of the CODES geographical Grid, no substantial deviation occurred.

2.3.4 Deliverables

D3.1 CODES GRID Architectural Design Document

D3.2 CODES GRID

2.4 WP4 - EM codes parallelisation using Grid computing

2.4.1 Objectives

The main objective is to Enhance the EM software performance by the parallelisation using GRID technology.

2.4.2 Progress towards objectives

The only SMEs involved into this workpackage was TICRA. All the other SMEs choose task-dispatching approach. TICRA's activities in this work package involved TICRA, UNILE and ITLink.

TICRA completed a comprehensive redesign of it main software code GRASP9 thus obtaining a version where parallelization is utilized whenever possible in the most calculation intensive analysis features such as field calculation using Multi Reflector GTD. As a result of these activities, a new and load-balanced parallel version of GRASP9 has been obtained and the measured parallel efficiency has been improved by up to a factor of five on heterogeneous computer clusters connected by a LAN.

The question was now if this enhanced version of GRASP9 could be Grid enabled thus performing the calculations on a Grid rather than on a LAN.Due to the current missing support of MPICH-G2 for the Windows platform, it was decided that the further activities should be targeted towards a Grid running on the Linux platform only. However, since the implementation is platform-independent, the resulting Grid-enabled GRASP9 will work on Windows when the prerequisites become available.

UNILE trained TICRA in using the Grid technology and TICRA obtained the proficiency and skills for porting GRASP9 towards a Grid and for future Grid developments. The selected middleware was installed on a number of computers at TICRA and the Grid-enabling of GRASP9 was performed by TICRA under UNILE supervision. This activity involved adaptation of the MPI implementation in GRASP9 towards the Grid-enabled MPI library MPICH-G2. This activity resulted in a Grid-enabled version of GRASP9 that was tested on a LAN-based Grid at TICRA

Finally, the Grid-enabled GRASP9 was tested on the Linux subset of the CODES geographical Grid and the measured performance was very encouraging. The Grid-enabled GRASP9 is an excellent starting point for further exploitation of Grid-technology by TICRA.

2.4.3 Deviations

No deviation occurred.

2.4.4 Deliverables

A demonstration of the Grid-enabled GRASP9 was made at the final presentation. The software was running on a geographical Grid consisting of 3 Linux platforms – one in Pisa (Italy), one in Lecce (Italy) and one in Copenhagen (Denmark).

2.5 WP5 – EM computation distribution using Grid computing

2.5.1 Objectives

The objective of this WP5 was the implementation of the CODES Grid Framework.

2.5.2 Progress towards objectives

In the frame of this WP, RTDs worked together to satisfy the requirements stated in WP1 with the Grid technologies identified in WP2.

IT-Link had the role of coordinator of the work of the other RTDs. It also was responsible for the set-up of a local Grid used for debugging purposes and for the software integration.

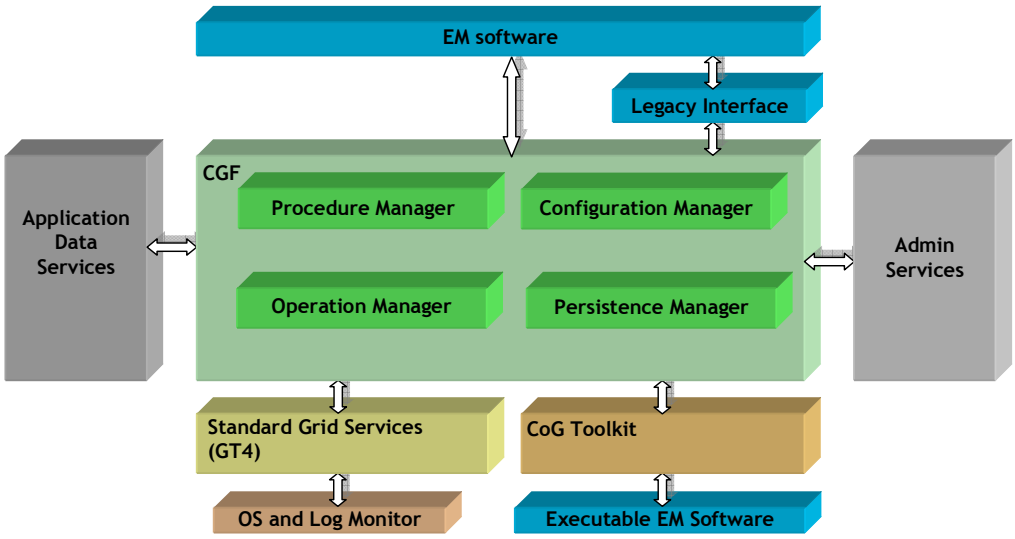

Fig. 2-6 CGF logical decomposition

The system can be logically subdivided into 4 main components:

- User Application components (blue blocks);
- CGF Middleware components (green blocks);
- Standard Grid Services components (yellow/orange blocks);
- Utilities components (grey blocks);

where the GT4 components are used:

- for authentication services;
- to hierarchically propagate information with MDS;
- as a common interface for Grid Services (container);

and the Cog Kit is used:

- for command and control (job execution management);
- for data management (files transfer).

The CGF set-up and configuration is supported by the Administration GUI, that allows the "system user" to define the topology of the Grid nodes and the parameters of the EM programs to be executed, as shown in the following figure.

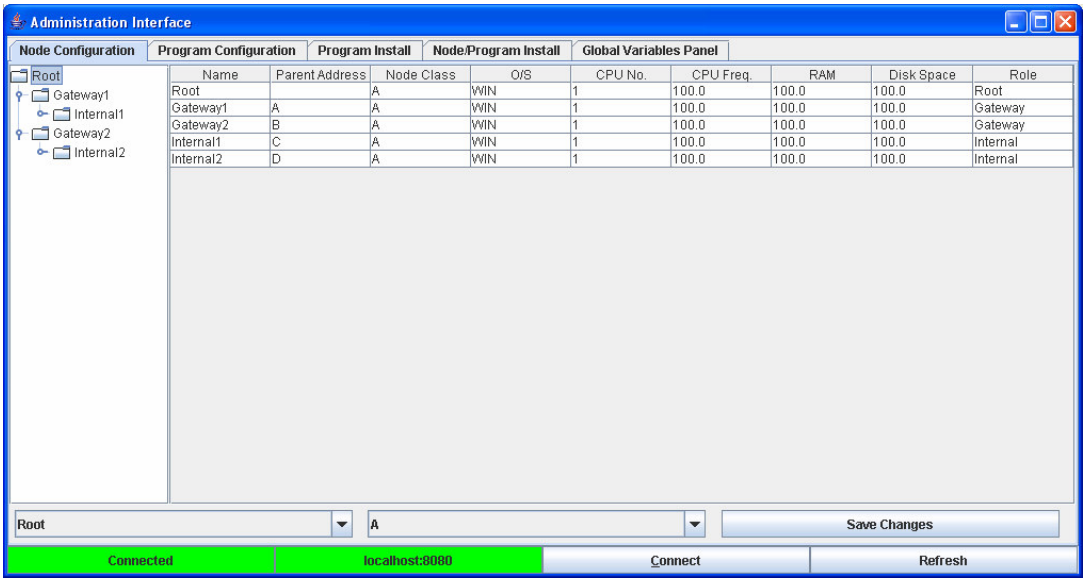

Fig. 2.7 - The CGF Administration Graphical User Interface, displaying all the Grid nodes.

At run-time, the Monitoring GUI shows the list of the EM computational procedures and operations running together with the nodes where they are executed, as shown in the following figure.

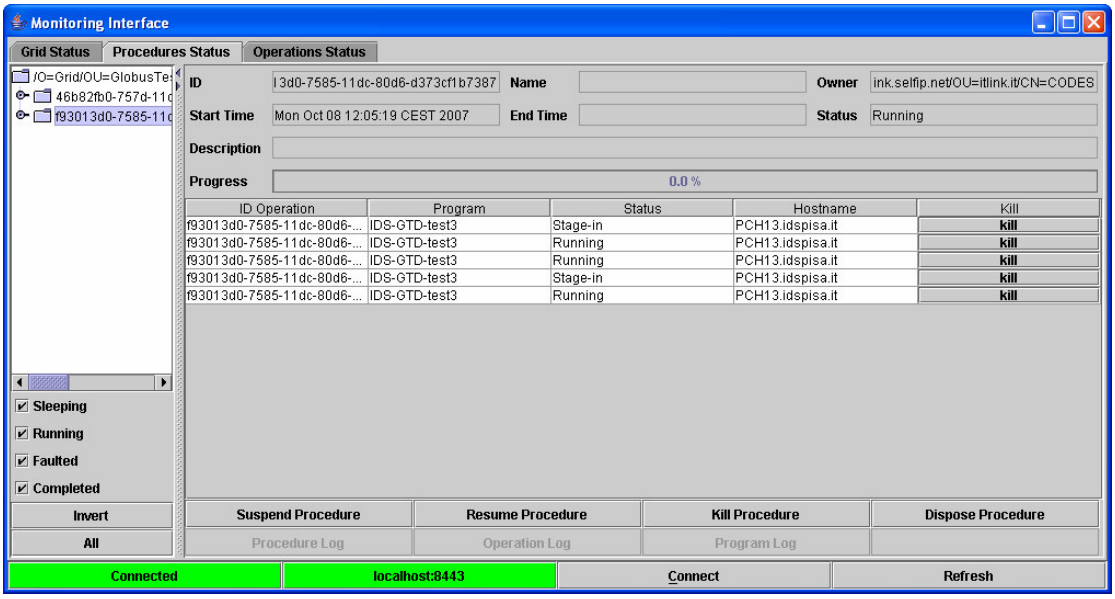

Fig. 2.8 - CGF Monitoring Graphical User Interface

Legacy Interface

The need of a "legacy interface" was related to the fact that during the user requirements phase (WP1), IDS required to keep unchanged the existing IDS software used to run E.M. computation.

During the architectural design phase, IDS defined the features of a "Legacy interface" component.

This component has not been implemented during the software developing phase, however this implementation has been taken into consideration by IDS in the plan for the exploitation of CODES results.

2.5.3 Deviations

Some issues in selected GT4 middleware caused additional effort for solutions and workarounds:

- very limited GT4 support for Windows: missing WS-GRAM and GridFTP – they are essential services for CGF;
- partial replacement for missing services: CoG GASS Server and Gatekeeper. They have strong functionality limitations (example: cannot retrieve E.M. programs exit value) forcing CGF to implement workarounds;
- the large number of functionalities required by the SMEs and some difficulties arising in the integration of the CGF caused additional effort provided by the RTDs, however the deadline on CGF at M24 was respected.

2.5.4 Deliverables

Deliverable	**IDS Activity**
D5.1 EM computation Distribution Activity Planning	This document describes the activities to customise the CGF middleware for the E.M. computation distribution.
D5.2 CODES Grid Framework	This is the CGF software code.
D5.3 New versions of EM software codes adapted to work in conjunction with CGF	It includes all the DataService developed by the SMEs to encapsulate its E.M. software code in order to run in conjunction with CGF. The result of this activity is described into the deliverable **D5.3n**.

2.6 WP6 – Dissemination and Exploitation

2.6.1 Objectives

The WP6 objectives are summarised in the following:

- disseminate the results;
- the implementation of the CODES geographical Grid to connect all the CODES participants;
- explore a new business model for EM simulation and design services based onto the on-demand approach;
- Internal and external exploitation of the achieved results.

2.6.2 Progress towards objectives

2.6.2.1 Dissemination of the results

The dissemination of the CODES results has been delegated to UNILE.

As reported in deliverable D6.1, UNILE defined a dissemination plan according to which CODES results and knowledge can be disseminated among IT and EM scientific and industrial environments. Such a plan includes:

(1) publishing scientific and business publications;

(2) organizing trainings events, workshops and participating in awareness events organized by other entities;

(3) becoming involved in collaborative efforts with entities and organizations within EU and worldwide,

(4) publishing and collecting documents, as well as open source applications and components in an open access repository,

(5) collecting and structuring knowledge from past and currently running EU-funded and other projects,

(6) setting-up further partnerships,

(7) reaching awareness among business and governmental institutions.

Differently from the research target groups that can be reached by means of journals and conferences in the appropriate subject areas, the dissemination towards the business and governmental institutions needs different approaches. Therefore, *flyers and introductive materials* were included in the dissemination.

The Consortium communications also benefited from the *project website* which presented the project objectives, results, status, consortium publications and useful links to the topics related to the project and from the services offered by the *CODES Virtual Centre*, where a distributed infrastructure allows an easy flow of knowledge and results across the project team members: file sharing, meeting results distribution, researchers information available on line, etc.

The CVC plays a key role in our planning for using and dissemination the knowledge since it acts as the hub to allow the distribution of the knowledge produced and for the full use of the results produced by the project by the CODES Participants

A key point for both the dissemination plan and the exploitation plan was the implementation of a Grid acting as a demonstrator of Grid computing applied to electromagnetic computation and design. By integrating the *CODES Grid* with the *CODES Virtual Centre*, a *CODES Dissemination Grid (CDG)* is built. The CDG provides a virtual centre where it is possible to access the results of the project as well as use a pilot design environment based on CODES pan-european compute Grid.

2.6.2.2 CODES Geographical Grid

In the frame of this WP, the local Grid that were set-up in the frame of WP3, have been merged together and SMEs and RTDs have been connected into a geographical Grid that has been used to test the functionalities of CGF software.

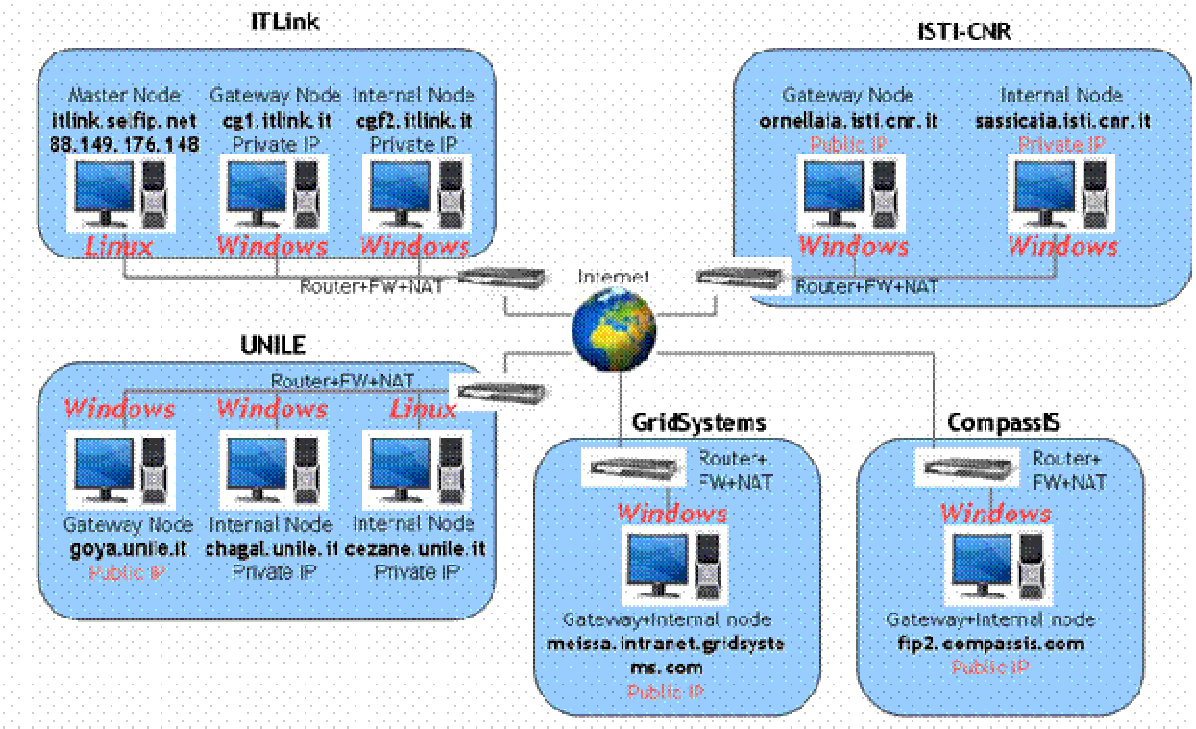

Fig. 2-6 CODES Geographical Grid

2.6.2.3 Computing On demand

In the frame of this activity, a computing on demand model has been successfully implemented by TICRA.

TICRA decided to implement an interface that is tightly integrated into our existing customer support site, thereby opening up the computing on demand facilities as a natural part of the customer relationship with TICRA.

The technical goal of this activity was a software system where the user prepares the analysis and sets up all required input files locally. The system should then enable the user to perform an analysis remotely while taking advantage of the computational resources in the CODES geographical Grid or other Grid resources. The steps required by the user include uploading the related input files, receiving various status emails from the system, and finally downloading the

results of the calculation. The GRASP9 software package is very suited for this approach because the antenna system can be designed and formulated with a preprocessor without access to the underlying analysis engine.

The computing on demand solution developed by TICRA was written in Python in order to facilitate an easy integration with the existing TICRA support site based on Python/Apache. The system uses the secure http-protocol that ensures that all data sent across the Internet is encrypted. In addition, the automatically generated emails contain no passwords and no actual data to avoid sending sensitive data on an un-encrypted channel. The results of the analysis are available to the user as a password-protected file that can be downloaded from the TICRA support site.

The computing on demand solution was successfully developed, tested and demonstrated to the CODES partners.

2.6.2.4 Internal and external exploitation

For the internal and external exploitation, IDS with ITL performed the following activities:

- The set-up of the geographical Grid to put to connect all the RTDs and also some SMEs for testing and dissemination purposed.
- The developing of a "Data Service" for the IDS-GTD code. The GTD Data Service is a software adapter needed to run the GTD code in conjunction with the CODES Grid Framework
- The definition of a real GTD procedure based on the task-dispatching approach. The GTD procedure used for the testing activity is very simple: it is formed by several operations without any dependency, in this case the initial input data set stated for the GTD procedure is split in several sub-input data set each one needed to evaluate only one frequency of the initial input data set.
- The developing of a software demonstrator used to run the GTD procedure. This demonstrator is a Java-program used to simulate a real use-case for a GTD execution.
- The set-up of a local Grid based on GT4 (Globus Toolkit 4.0) to run the IDS-GTD demonstrator.

2.6.2.5 CODES Test Grid

The following figure shows the CODES test Grid that has been set-up in IDS for the final meeting demonstration:

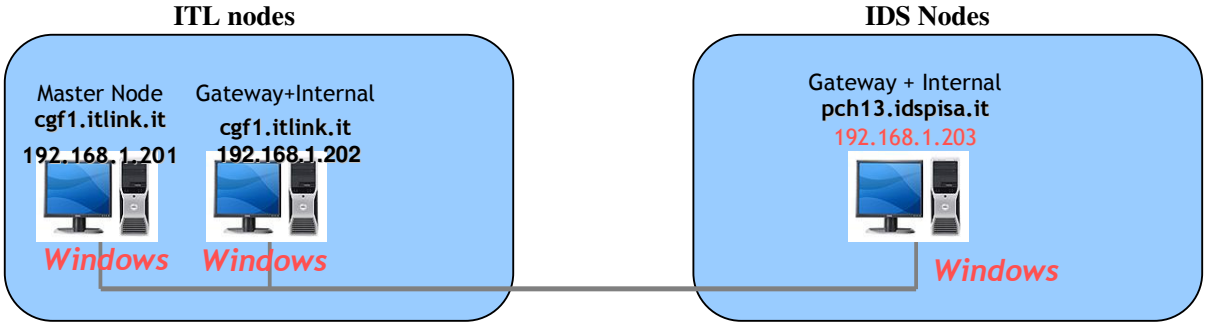

Fig. 2-7 CODES Test Grid

CODES results have been demonstrated over a local network for the following reasons:

- Security: The need to run EM examples on a protected network (Security credential cannot be applied to the geo-Grid)
- Efficency: To have an example that can be easly demostrated during the meeting
- Strategy: Thinking to a geographically distributed Grid shared among different organizations could be out of market at the present time. In the typical case, for IDS, the final deployment of the CGF will be always limited to an internal network.

2.6.2.6 IDS-GTD Procedure launcher

The IDS GTD procedure launcher is shown in the following figure:

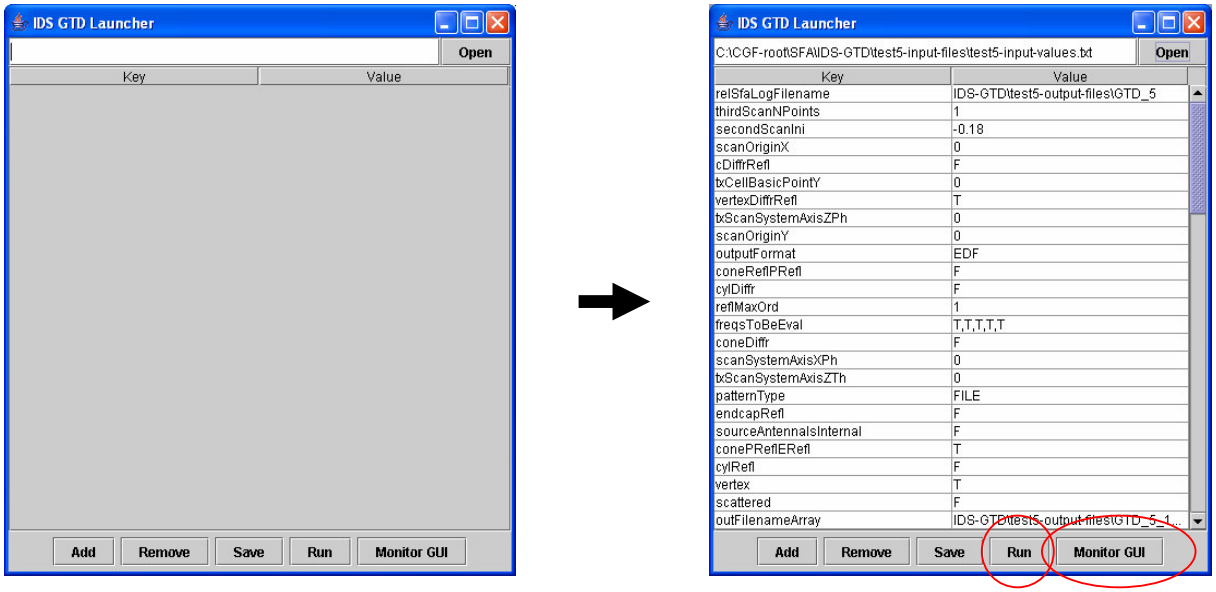

Fig. 2-8 IDS-GTD Procedure Launcher

- Load the input data for the IDS-GTD code;
- Prepares an “empty” procedure which contains only the input environment and set the “procedure pre-processor” to “IDS-GTD”
- Submits the Procedure to the CGF Procedure Manager
- Opens the Monitoring GUI to monitor the status of execution on the procedure.

2.6.2.7 IDS-GTD Procedure

The parallelization is based on frequencies sweep splitting:

- The IDS-GTD procedure requires the near field computation for 5 frequencies
- The IDS-GTD DataService prepares 5 operations, one for each frequency

The running procedure has been monitored using the CGF Monitoring GUI as shown in the following figure (

Fig. 2.):

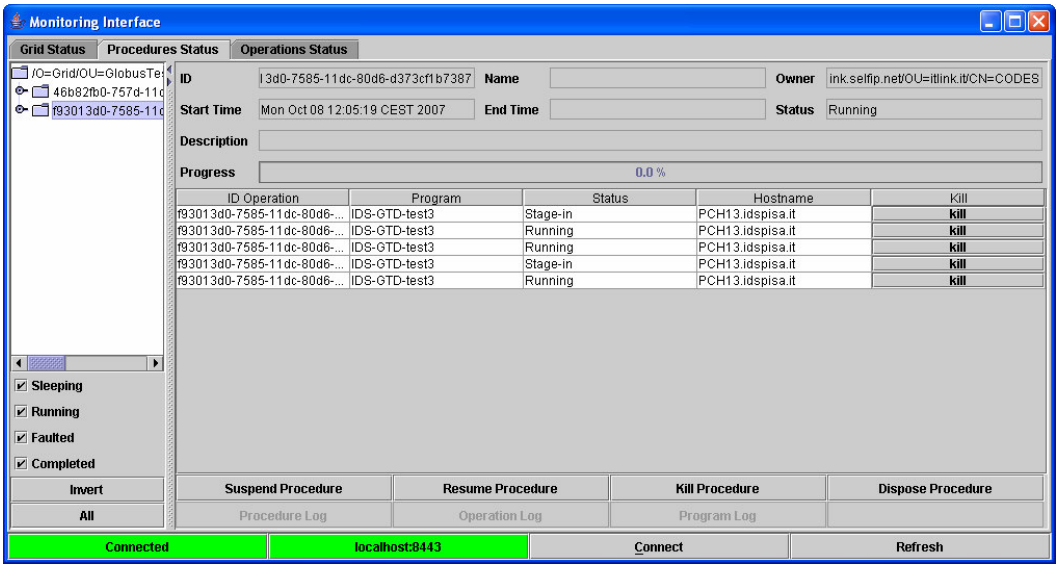

Fig. 2-9 CGF Monitoring GUI

2.6.3 Deviations

No deviation occurred.

2.6.4 Deliverables

D6.1 CODES Plan for using and disseminating knowledge
D6.2 CODES Dissemination grid specification
D6.3 CODES Dissemination Grid (CDG)
D6.4 CODES Business Analysis Report
D6.5 CODES Virtual Centre (Public Web Site)

2.7 WP7 – Project management

2.7.1 Objectives

The broad aim of this work-package is to assure the success of the project through managing and co-ordinating the activities, while maintaining an efficient relation with the Partners and the EC. In particular this work-package intends to achieve the highest standards of quality of deliverables, and to do so on time, and within budget.

2.7.2 Progress towards objectives

Some difficulties occurred during the first year of the CODES project.

In the beginning, the CODES Project was planned in a timeframe of 24 months, but during the first year the following aspects emerged:

1. the status of the selected standard middleware (GT4); it was clear that GT4 was missing the Window OS support, thus leading to a critical situation, unpredictable at the beginning of the project, where alternative solutions needed to be studied;
2. the needs of SMEs about Grid Computing in Electromagnetic Software required a longer time to be analysed both from the technical and commercial point of view; the SMEs constraints were faced by the solutions provided by RTDs and an extensive study of the benefits/effort ratio was performed and agreed between the RTDs and the SMEs.

In this frame, an extra work became necessary, thus causing a **4 months delay**, as reported in the CODES Periodic Activity Report (Year 1), paragraph 1.2. The 4-months delay mainly derived from the extension of the WP1 (Requirements Analysis) and WP2 (HPC technology assessment) that were closed at month 12.

After the first year of activity the CODES participants re-planned the CODES activities to recover the initial delay and, at the same time, asked the commission for an extension of the contract (6 months). The extension was mainly dedicated to the exploitation of the CODES software by a longer time available in WP6 (Exploitation and Dissemination) in order to better demonstrate the benefits coming from the distribution of large computations over a Grid of computers.

Moreover, in these 6 months of extension, the deployment of the CODES software over a geographical Grid has been implemented, thus complying with the suggestions coming from the Commission during the first year review.

The technical objectives in the new timeframe remained the same of the previous one, where the CODES project has to develop a new software platform that allow to realize Computer Aided Design tools dedicated to electromagnetic engineering with better performances and lower costs.

3. Conclusions

A lot of knowledge in the frame of Grid technology has been acquired by all the CODES participants:

- several Grid middleware have been evaluated in studied in order to find the most suitable to cover with the SMEs requirement;
- Globus Toolkit and the additional components for the Windows OS support were selected as the best available, as OpenSource and reliable, as SMEs required;
- SMEs were trained on Grid technology to acquire the necessary skill to set-up a Grid based on GT4 service.

The enhancement of the EM software performances have been obtained in two different ways:

- running parallel threads of executions on distributed platforms (***parallelization***)
- distributing autonomous tasks (***distribution***)

The main CODES outcome can be summarized in the following points :

- detailed analysis of HPC computing requirements for SMEs involved in complex design and engineering activities;
- a framework to Grid-enable legacy software tools used in the world of engineering and design based on multiple heterogeneous software tools, the **CODES Grid Framework** (**CGF**);
- a demonstrator of Grid design environment working on a geographical Grid involving all the project partners;
- the task dispatching approach, able to integrate existing legacy software not designed to run on a Grid *without modifying it;*
- reusable for any engineering environment based on legacy HPC-demanding software tools;
- fully use of Opensource, reliable, standard Grid middleware in the realm of different emerging Grid solutions