3
CEE Conceptual Model

The developed CEE, as a specialized CPSE, allows users to collaboratively solve their problems through the use of predefined scientific workflows or assembling new ones. Each workflow comprises a sequence of simulations, in the form of workflow tasks, which usually ends with a collaborative visualization task. This task creates a collaborative session supported by the VR Visualization component.

To achieve its goals CEE needs to be extensible, flexible and platform-independent, allowing a transparent flow of information among different teams, systems and their models. The challenges in building an effective CEE could be scrutinized in three domains:

- ***Collaborative Visualization Environment*** – this domain encompasses very different challenges from the areas of CSCW and Virtual Reality.
    - ***Collaborative Work*** - in this domain there is the necessity of providing effective human-to-human interaction and communication for solving conflicts and enhancing group productivity. Also there is the need of some support for coordinating the execution of tasks.
    - ***Virtual Reality Visualization*** – high performance and scalability are important aspects of virtual environment architectures intended to support execution of large shared virtual worlds over long periods of time.
- ***Scientific Workflow Environment*** – this domain includes challenges related to the control of the execution of engineering simulations
    - ***Interoperability and Distributed Execution*** - in this domain there is a myriad of software that specialists, potentially geographically distributed and using distributed resources, are forced to use in order to accomplish their tasks in a reasonable time. This requires the solution to

have the ability to be easily and seamlessly distributed and demands a high level interoperability among its components.

- ***Data provenance -*** Data provenance is the capacity of maintaining information of how a given data product was generated [SPG05] and has many uses, from purely informational to enabling the representation of the data product. It is a very important feature for any CPSE once scientists and engineers often create several variations of a workflow in a trial-and-error process when solving a particular problem.

➢ ***Project Management Environment -*** this domain points to the necessity of keeping track of all the documents and artifacts generated during project's life-cycle. Multiple and different visions of the on-going project must be provided while users have different background (e.g. managers, engineers) and need different types of information to accomplish their duties.

The conceptual model of CEE (Figure 3.1) handles some of the challenges, creating specific services for them. In the conceptual model we depict the services related to each CEE specific environment.

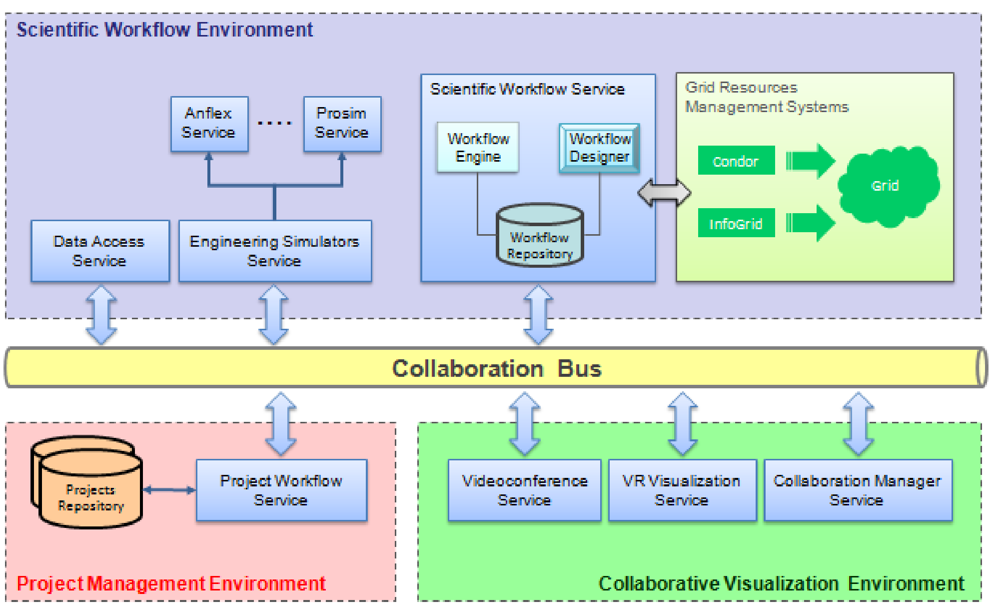

Figure 3.1 : CEE Conceptual Model.

For the ***Collaborative Visualization Environment***, we created the *Collaboration Manager Service* who is responsible for managing the user interaction with the CEE. The *Videoconference Service* and the *VR Visualization Service* work closely coupled with the *Collaboration Manager Service* to enable the creation of collaborative visualization sessions inside the CEE.

For the ***Scientific Workflow Environment****,* we created the *Scientific Workflow Service* to help the users build engineering workflows and seamlessly execute them in a Grid Computing Infrastructure (GCI). More generally for *Distributed Execution,* we use the interoperability characteristics of the ScWfMS and the distributed execution support provided both by the GCI of the CEE and by the SOA backbone infrastructure furnished by the Enterprise Service Bus (ESB). For *Interoperability* among applications it was developed a common format for data exchange among engineering applications in the Offshore Engineering field (see Section 3.2.2).

The *Engineering Simulations Service* provides a Webservices interface [LMN+04] for remotely execute an engineering simulation program. In the Offshore Engineering, some of those simulators are, among others, Anflex [MGJ95] a Finite Element riser analysis software, and Prosim [JE94] a coupled analysis software for the design of floating production systems.

For the ***Project Management Environment***, the introduction of a *Project Management System* is a valuable resource. Although very important for a real CEE implementation, the use of a Project Management System is out of the scope of this thesis.

Based on a thoroughly analysis of the domain of OE projects used as our target scenario, we present more detailed information about the adopted visualization and collaborative features to cope with the difficulties described above. In what follows it is presented the major CEE functionalities towards this direction.

3.1. Collaborative Visualization Environment

Collaborative systems should not only allow multiple users to interact with shared objects but also to communicate and to coordinate their actions. Collaboration may be seen as the combination of communication, coordination and cooperation [FRG+05]. Communication is related to the exchange of messages and information among people. Coordination is related to the management of people, their activities interdependencies and the used resources. Cooperation is the production of common artifacts taking place on a shared space through the operations available to the group. This model, called 3C model, was originally proposed by Ellis et al. [EGR91] and identifies the three essential high-level components of conceptual collaboration models.

In CEE, those three aspects of the conceptual collaboration model are enacted by the use of a Scientific Workflow Management System (ScWfMS), Videoconference System (VCS) and a Collaboration-Bus, a collaborative infrastructure support for integrating the execution of engineering applications with our VRV component allowing the users to collaboratively visualize their results and optionally create virtual Annotations, to share knowledge about the engineering artifacts being visualized.

The ability to collaboratively create persistent annotation on the model improves its usefulness. An Annotation, in our context, is any textual information that users want to add to their projects to enrich the content or just for documentation purposes. It can have a private or public (shared) scope. Annotations can be associated to any engineering artifact manipulated during a collaborative visualization session. An Annotation could, for example, represent a kind of instructional information denoting a sequence of operations that should be undertaken during an equipment maintenance intervention in a production unit. It can also be any textual information used to highlight interesting or anomalous events observed on the simulation results. Examples of such events could be unexpected values for an engineering quantity, violations of integrity, etc. Annotations can also have a more dynamic behavior, while they can represent distance measures between distinct objects that should be monitored during a simulation, e.g. the distance between two different elements in two different ascending risers to a floating production system. Some of the discussed examples can be seen in Chapter 5.

Another important aspect in the collaborative visualization session is the possibility of having Virtual Guided tours, where the coordinator of a session can create virtual paths through critical results in the simulations in order to demonstrate or discuss possible anomalies in the results of the simulation with other users. When following these paths the camera movements of the coordinator are retransmitted to other participants in the session allowing them to share the same view. This is also a very valuable tool for improving the knowledge of the simulation.

The collaboration features of CEE can be summarized according to each aspect of the 3C Model [FRG+05] as follows:

- ***Communication support* –** is a fundamental feature in our scenario. The VCS offers different communication support to CEE, synchronous or asynchronous, enabled in various media types (audio, video and text based communication). It is seamlessly integrated into CEE so that users can start a videoconference communication at anytime, while modeling their workflows or during visualization of results. They also should be able to plan a certain time lag for a specific communication interaction, especially when long-lived processes are enacted in the execution of the workflow. The communication support should be integrated to the other tools in the CEE and provide means of recording conversation and retrieving old ones. This feature helps the user to solve their project's problems in critical situations, with fast interaction and negotiation, and it allows the recovery of useful pieces of communication used to solve similar problems in the past.
- ***Cooperation and flexibility support*** – there should exist flexible process modeling support, like dynamic change of process instances during run-time to support dynamically evolving processes, possibility of executing rollback of processes (reset, redo, undo, recover, ignore, etc), reuse of process fragments and component libraries. The cooperation support must provide different levels of data access: local and distributed, shared, public and private access, versioning control of engineering models and related data, concurrency control and synchronization. It is also necessary to provide support for different types of data interchange, concurrent work on shared copies, change propagation, and physically shared data access. Different types of model visualization should also be available at the CEE, as well as some data management infrastructure related to these models, like real-time simulation and visualization of 3D models, possibilities of walkthroughs in the models, object interaction and manipulation, edition and planning and also access to organizational work history.

Cooperation also occurs during the assembling of useful engineering workflows that will be used to orchestrate the execution of engineering applications, and also during visualization of results when the users can collaborate to better understand the model. Users can also share persistent annotations about interesting facts, as previously discussed.

- ***Coordination and Awareness –*** there are different types of awareness support provided in CEE. In our scenario, the most important ones are:
  - ***event monitoring –*** observes what is going on in the VRV, in all separate parts and provide active notification to the right person, at the right time and the right sub-system;
  - ***workspace awareness in the virtual environment*** – provides control of collaborative interaction and changing of the user location;
  - ***mutual awareness*** – allows users see each other's identity and observe each other's actions;
  - ***group awareness*** – facilitates the perception of groups of interest connecting people who need to collaborate more intensely. Group awareness enables the user to build his own work context and to coordinate his activities with those of others'. Informal communication enhances team awareness, even with no support to cooperation and with restricted coordination functionalities for controlling the simultaneous use of communication channels [Mack99]. User awareness is a very important subject for CEE once it is a desirable feature to provide mutual awareness during the collaborative visualization session allowing users see each other's identity and observe each other's actions specially when creating Annotations in the model.

3.1.1. Video Conferencing

Audio and video communications are fundamental components of collaborative systems [IT94]. Audio is an essential channel for supporting synchronous work, and video is important to provide a sense of co-presence facilitating the negotiation of tasks.

Multimedia Collaborative Systems such as VCS, contain no knowledge of the work processes, and therefore are not "organizationally aware". These systems are best suited for unstructured group activities once that audiovisual connectivity and shared documents enable flexible group processes. The drawback is that all coordination tasks are left to the conference participants [RSV+94].

The development of a custom videoconferencing system, CSVTool [PRS+03, LKR+07], allowed us to automatically establish videoconferencing channels among the participants of a conference which greatly simplify and improve the communication. We can also tightly control the multiple audio and video streams among participants implementing different scenarios of usage, described in section 3.1.3.

Besides the transmission of audio and video to multi-participants, with different operating systems platform, CSVTool provides extra interesting features for CEE:

- the video stream sent by each participant can be switched from the image captured by the camera to the captured screen, to allow the use of video for remote display of the interface operation or for the presentation of other contents on the screen and for consistency checks;
- a textual chat tool, which is providential in some situations (for instance, when somebody is having problems with capture devices);
- snapshots, useful for documenting the work session.

In CEE, a videoconference session is started by the creator of the workflow when he wants to share the construction of the workflow or collaboratively analyze the selected simulation results. Each conference is attached to a CEE Collaborative Session that is registered in the CEE Server.

3.1.2.
VR Visualization

Modern floating production units' construction projects are carried out with the creation of a so-called Virtual Prototype. The aim of virtual prototyping is to build a full virtual model in such a way that design and manufacturing problems are anticipated and discussed within a cooperative and distributed work environment [BFD+03].

The applications available for CSCW can be classified depending on how the support for collaboration is related to the application implementation. They can be seen as collaboration-aware or collaboration-unaware applications

[RSV+94, PMH+98]. Collaboration-unaware applications are originally developed to be single user applications, but may be used collaboratively by means of an external support system. This external support system may be an application-sharing system or a GUI event multiplexing system. In both cases the applications do not explicitly support collaboration; they are implemented as single user applications [Tietze01]. This is important since, in our case, the applications developed for OE projects at Petrobras fits in this type.

Collaboration-aware applications, on the other hand, are specially developed or adapted to support collaboration. They typically constitute distributed systems, with centralized or replicated data sharing, where each user has access to a locally executed application instance. All running applications are connected to a server process, in a client/server architecture, or interconnected, peer-server or peer-peer, and exchange information over designated communication channels. All the peers are aware of the communication channels shared with its peer applications; which information is exchanged among them; the number of connected peers and their role in the collaboration; and the coordination policies adopted by the group.

Environ (ENvironment for VIRtual Objects Navigation) [RCW+06, RSS+09] is a tool designed to allow visualization of massive CAD models and engineering simulations in immersive environments (VR and Desktop). It is a system composed of a 3D environment for real-time visualization and plug-ins to import models from other applications, allowing users to view and interact with different types of 3D data, such as refineries, oil platforms, risers, pipelines and terrain data.

In order to serve as the CEE’s VRV, Environ was adapted to be transformed into a collaboration-aware application with the support provided by the CEE collaborative infrastructure.

3.1.3. Collaboration Manager and Collaboration Bus

The Collaboration Manager is responsible for managing the users’ participation in a collaborative session and also integrates the resources of VRV and VCS. There are three kinds of sessions available:

- Informal – where each participant uses its individual telepointers all the time. There is no mediation of camera movements and the users are free to move around the scene propagating the camera movements to others. In this model, once a collaborative session is created, audio and video can be used at any time by all users. The only mediation mechanism supported is furnished by the social protocol available whenever a videoconference is started.

- Classroom – where one specific participant, the instructor, acts as a coordinator of the session which means that all camera movements he performs are followed by other users, while the other participants have their telepointers disabled. The instructor also controls the audio and video channels of the participants, and he is also allowed to pass control of collaboration resources (telepointers, camera control, etc.) among participants, taking it back at any time.

Users can request the coordination role to the current coordinator who can accept or reject the request, generating a visual feedback to the requestor. Upon the occurrence of a *"change coordinator"* event in a CEE collaborative session, all users are notified by the CEE Awareness mechanism.

- Lecture – where one specific participant, the speaker, acts as a coordinator of the session, with the same characteristics as in the Classroom session. In this type of session there is no exchange control between the coordinator and participants and the participants can only receive audio and video stream from the coordinator. This model of session is used for example when the speaker wants to create a virtual guided tour showing important details of the results of a simulation to other participants.

At any time the user can disconnect from the session, for doing some private work, and reconnect to session in later time, when its state is synchronized with the sate of the session, that is controlled by the *Collaboration Manager Service*.

The *Collaboration Bus (CBUS)* is a key component of the overall architecture and provides synchronous and asynchronous communication for the CEE components. The CBUS is an infrastructure for communication based on the JMS Service Provider, the Message Oriented Middleware (MOM) used for giving the public/subscribe and point-to-point paradigms, and the Enterprise Service Bus (ESB). The CEE *Awareness Service* is an awareness service providing appropriate actuators for events received from the CBUS. It is responsible for signaling distributed events to the users participating in a collaborative session. In one side all components trigger events to this distributed bus, and in the other side awareness components listen to the bus for information about what is happening in the system. For example, when users leave a collaborative session or when there is a change in its state from offline to online and vice-versa, *"update user"* events are triggered to the CBUS and the CEE Awareness mechanism send messages to *VRV Visualization Service* and *VC Service* notifying the event. By their turn, those services signal those events in their user interfaces making the user conscious of what have happened. Examples of such kind o signaling could be: using different icons in the GUI for showing the state of the users; windows messages warning the entrance of a new user in the session or the leaving of the user from the session, etc.

The integration of the VRV and the VCS with the other components is done in a seamless way through the Collaboration Bus, in a way that the user always interacts with the same interface independent of the application he/she is currently using. This is a very important aspect of the solution to keep the user conscious of what he/she is doing and what should be the next steps of the current task being executed.

3.2. Scientific Workflow Environment

A Workflow, actually, in this context, a Scientific Workflow, is composed by coupling service interfaces in the desired order. These workflows specifications are created through a graphical or textual front end and the actual service calls are generated automatically and have their execution controlled by the workflow engine

All the consistency, adequacy and compatibility of the shared data among its users should be done by the kernel of the CEE, in order to avoid, or at least to diminish, non useful iterations during the project's life cycle. The ability of reusing partial workflows, which were previously stored in the system with some guidelines, provides an optimized usage of the available computational resources and also a better control of the costs and time scheduling.

Similarly to the VRV and VCS, the integration of the ScWfMS with the other components is also done through the Collaboration Bus.

3.2.1. Scientific Workflow Service

According to Ellis [Ellis99] Workflow Management Systems emphasize coordinated communication allowing groups of people execute, monitor, and coordinate the flow of “work cases”, in our context engineering simulations, within a distributed environment.

Although the above definitions make reference to “Business Process”, WfMS is not only employed by business applications. In recent years, several industries have improved their operations through WfMS, improvement of data management and better coordination of activities through specific Business and Scientific and Engineering Process. However, there are remarkable differences between Business (BWfMS) and Scientific Workflows (ScWfMS). In [MVW95] the authors identified that in a scientific environment scientists will typically specify their workflows themselves, while in a business environment, a system administrator is commonly responsible for this task. Another characteristic of ScWfMS mentioned in their work is the need to trace workflow executions. An engineer may need to reuse a workflow in order to reproduce results. The operations a user performs on a given data must be recorded in order to provide engineers with the benefits of successful and unsuccessful workflows.

Scientific Workflows (ScWfMS) describe series of structured activities and computations that arise in scientific problem-solving. In many science and engineering areas, the use of computation is not only heavily demanding, but also complex and structured with intricate dependencies. Graph-based notations, e.g., Generalized Activity Networks (GAN), are a natural way of representing numerical and human processing. These structured activities are often termed studies or experiments. However, they bear the following similarities to what the databases research community calls workflows:

- Scientific problem-solving usually involves the invocation of a number and variety of analysis tools. However, these are typically invoked in a routine manner. For example, the computations involve much detail (e.g., sequences of format translations that ensure that the tools can process each other's outputs), and often routine verification and validation of the data and the outputs. As data sets are consumed and generated by the pre and post processors and simulation programs, the intermediate results are checked for consistency and validated to ensure that the computation as a whole remains on track.

- Semantic mismatches among the databases and the analysis tools must be handled. Some of the tools are designed for performing simulations under different circumstances or assumptions, which must be accommodated to prevent spurious results. Heterogeneous databases are extensively accessed; they also provide repositories for intermediate results. When the computation runs into trouble, semantic roll forward must be attempted; just as for business workflows, rollback is often not an option.
- Many large-scale scientific computations of interest are long-term, easily lasting weeks if not months. They can also involve much human intervention. This is especially so during the early stages of process (workflow) design. However, as they are debugged, the exceptions that arise are handled automatically. Thus, in the end, the production runs frequently require no more than semiskilled human support. The roles of the participating humans involved must be explicitly represented to enable effective intervention by the right person.
- The computing environments are heterogeneous. They include supercomputers as well as networks of workstations (clusters). This puts additional stress on the run-time support and management. Also, users typically want some kind of a predictability of the time it would take for a given computation to complete. Making estimates of this kind is extremely complex and requires performance modeling of both computational units and interconnecting networks.

Consequently, it is appropriate to view these coarse-granularity, long-lived, complexes, heterogeneous, scientific computations as workflows. By describing these activities as workflows, we bring to bear on them the advanced techniques that have been developed in workflows research. These include sophisticated notions of workflow specification and toolkits besides environments for describing and managing workflows.

Scientific workflows often begin as research workflows and end up as production workflows. Early in the lifecycle, they require considerable human intervention and collaboration; later they begin to be executed increasingly automatically. Thus in the production mode, there is typically less room for collaboration at the scientific level and the computations are more long-lived. During the research phase, scientific workflows need to be enacted and animated (fake enactment) far more intensively than business workflows. In this phase, which is more extensive than the corresponding phase for business workflows, the emphasis is on execution with a view to design, and thus naturally includes iterative execution. The corresponding activity can be viewed as a “Business Process Engineering” (BPE). For this reason, the approaches for constructing, managing, and coordinating process models are useful also in scientific settings. In this way, Scientific Workflows are to Problem Solving Environments what Business Workflows are to Enterprise Integration (EI).

ScWfMS are more data-flow oriented while BWfMS are more control-flow oriented. BWfMS require the coordination of a number of small messages and document exchanges. In ScWfMS usually no documents undergo modifications. Instead, often a dataset is obtained via analysis and transformation of another dataset. BWfMS need complex control flow, but they are not data-intensive pipelines. On the other hand, ScWfMS must deal with the heterogeneity, complexity, volume, and physical distribution of scientific data. In addition to these data problems, ScWfMS often deal with legacy or third-party programs, which can also be heterogeneous, and possibly with no source code available.

Business Process Execution Language (BPEL) was chosen for the ScWfMS in the CEE implementation. BPEL is further explained in the Appendix A.

3.2.2. Data Access and Engineering Simulations Execution Interoperability

Engineering simulations are computer and data intensive. In a typical scenario, data is usually passed from one program to another in order to complete several steps of the simulation. In the CEE, the sequence of operations to perform an engineering simulation are modeled as scientific workflows [DGS+09]. This creates an interoperability problem, since in most of the cases, data conversion steps are needed every time a different program needs to be run over the data. To solve the data interoperability problem, allowing applications to share engineering data in the context of such scientific workflows, a unified data format have been defined and developed. This format is called GXML, Galileo

XML [SBM+09]. As the name says, it is based on XML, which can be easily handled by applications using standard XML APIs.

For scalability purposes GXML classifies data as light and heavy, according to the amount of information it represents. In this sense, light data is allowed to be stored in the GXML file's body, while heavy data is stored in HDF5 (Hierarchical Data Format) [HDF] in an internally compressed format and described in the GXML file. HDF5 provides efficient ways for reading and writing huge volume of data which is very important for engineering and scientific data.

3.2.3. Grid Computing Infrastructure (GCI)

Compared to other models of computing, systems designed and implemented in the grid style deliver a higher quality of service, at a lower cost, with greater flexibility. Higher quality of service results from having no single point of failure, a powerful security infrastructure, and centralized, policy-driven management. Lower costs derive from increasing the utilization of resources and dramatically reducing management and maintenance costs [GridOracle05].

SOA has emerged as a superior model for building applications, and SOA concepts align exactly with the core tenets of grid computing.

3.3. CEE SOA Architecture

A Service Oriented Architecture (SOA) is a very attractive architecture for allowing independence between service providers and consumers. ESB represents the next generation of integration middleware, which establishes an enterprise-class messaging bus that combines a messaging infrastructure with message transformation and content-based routing in a layer of integration between service consumers and providers. The use of an ESB in the CEE architecture allows a seamlessly integration of distributed applications modeled as SOA services. For each external engineering application that might be invoked by the Scientific Workflow during the execution of a user job, we built a service interface (*Engineering Simulation Service*) that allows the application to be called from inside the workflow or from any other application connected to the ESB.

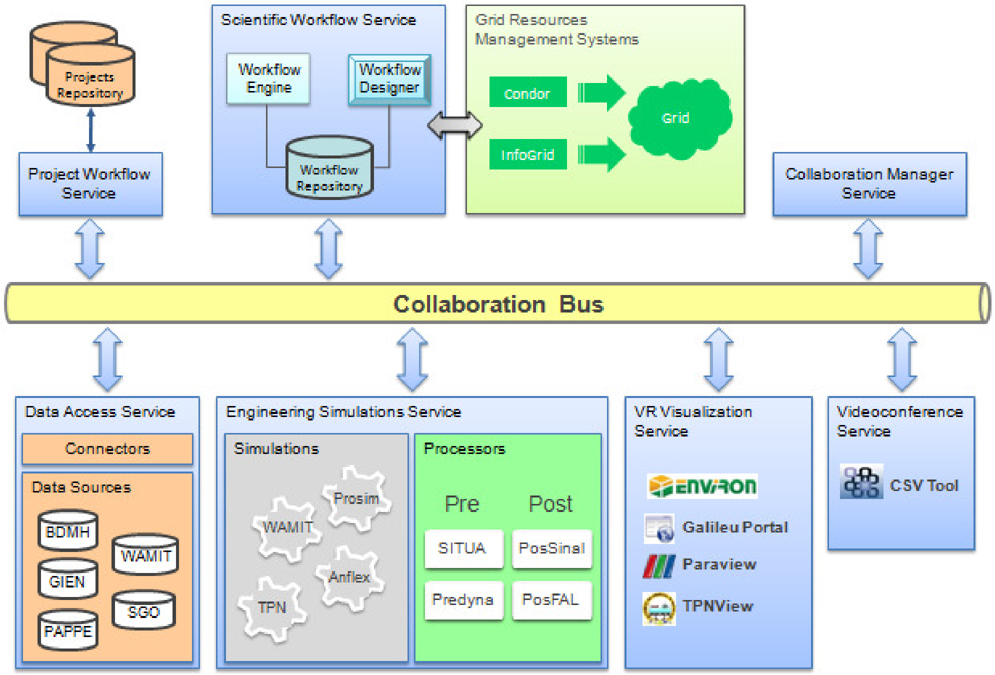

Figure 3.2 : Basic Service of the CEE SOA Architecture.

The proposed CEE has component-based architecture in order to facilitate the reuse of elements. The architecture of the CEE uses a BPEL ScWfMS as its kernel while the CSVTool (VCS), Environ (VR Visualization tool) and the other components are seamlessly accessed through the ESB according to the collaborative necessities of the teamworkers.

When the service-oriented approach is adopted for designing the CEE, every component, regardless of its functionality, resource requirements, language of implementation, etc., provides a well-defined service interface that can be used by any other component in the environment. The service abstraction provides a uniform way to mask a variety of underlying data sources (real-time production data, historical data, model parameters, reports, etc.) and functionalities (simulators, optimizers, sensors, actuators, etc.).

Figure 3.2 illustrates the CEE SOA architecture, which is an instantiation of the CEE conceptual model for the OE field. In this figure, engineering simulators, data sources, VRV tools and VCS are specialized for the target scenario chosen for this thesis.

3.4.
CEE Usage Scenario Overview

This section describes how the user interacts with the system. The user accesses the system through the CEE Portal and is able to create engineering workflows, execute them and visualize the results in a visualization session.

The diagram presented in Figure 3.3 shows the macro-processes, managed by CEE, that are interconnected with the Enterprise Service Bus in which messages are transmitted using GXML [SBM+09].

The first step in the simulator is the creation of the *Project Workflow,* whose main activities will be imported from a projects database, such as SAP [SAP]. As shown in detail, certain steps in the Project Workflow will consist of the execution of Scientific Workflows available in CEE for viewing an engineering simulation / analysis, such as the design of a mooring system or a fatigue analysis of a set of risers in a production unit. These Scientific Workflows are modeled as Abstract Workflows, previously created by teams of analysts. The Abstract Workflows will be converted into Concrete Workflows, and later executed in a Scientific Workflow Management System, in our case a BPEL Workflow engine.

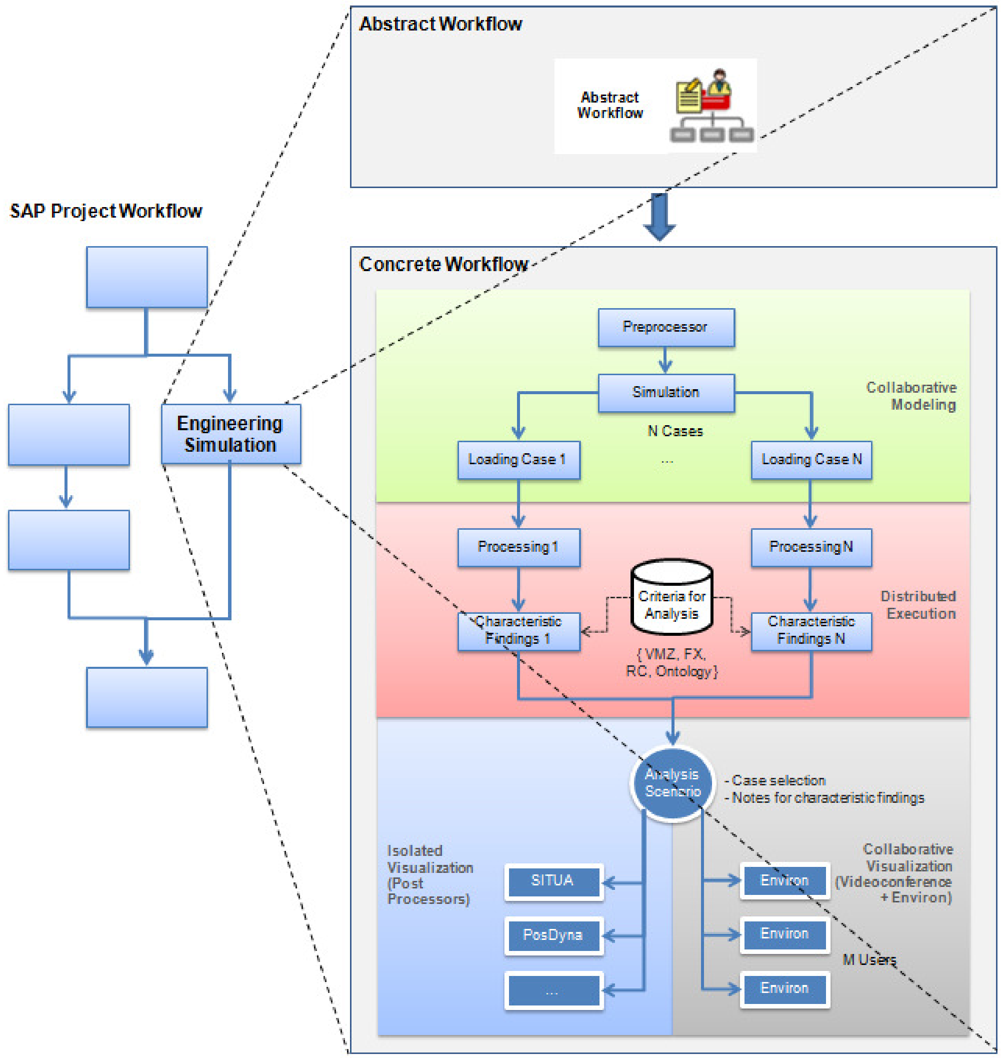

Figure 3.3: CEE Project Workflow.

In the concrete workflow, the user has to model the simulation input data through the corresponding Pre Processors (AnflexGUI for Anflex, SITUA for Prosim, etc.). Videoconference support allows the collaborative modeling of the engineering workflow, before its execution on the Resource Management System attached to CEE. After the execution, users can analyze the results separately in their Post Processors (AnflexGUI, SITUA, etc.), or in a Collaborative Visualization Session supported by Environ and the CEE infrastructure.

Figure 3.4 shows the main components of the CEE interaction. Initially after the user is logged in the system, the CEE *User Service* on the client machine registers the user in the *Collaboration Manager Service* on the CEE server, all services that the user's machine is able to support (*Environ Service, CSVTool Service,* etc) is also registered on the CEE server *Service Registry*.

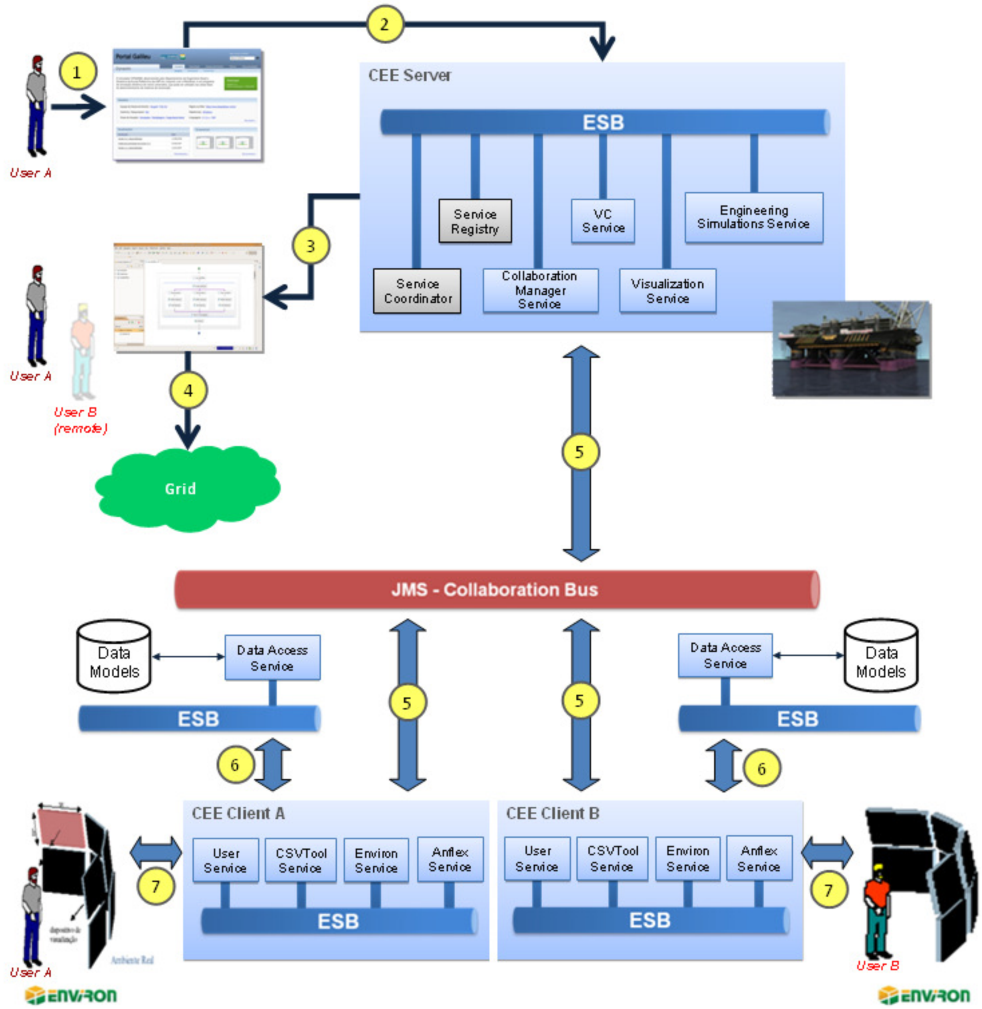

Figure 3.4 : Overview of the user interaction with CEE.

After registration of its services on the server, **User A** accesses the **CEE Portal** (**1**) through a web browser to request the execution services on the CEE server on his behalf (**2**). As an example, **User A** can model collaboratively with **User B** a *Concrete Scientific Workflow* (**3**). When the model is assembled and all input parameters of the concrete workflow is informed, **User A** can submit the workflow as a simulation on *a Grid* integrated into the CEE infrastructure (**4**). Upon finishing its execution, the results of the concrete workflow may be visualized in a *Collaborative Visualization Session* with **User B** (**5**).

During the collaborative visualization session, the users can require the execution of alternative simulations and have its results exhibited automatically (**6 and 7**).

In the following we present an overall solution for developing a complete workflow, including a sequence of screenshots describing the creation of a collaborative visualization session between two users on the CEE through the portal. Chapter 5 will give more scenarios tested with the CEE.

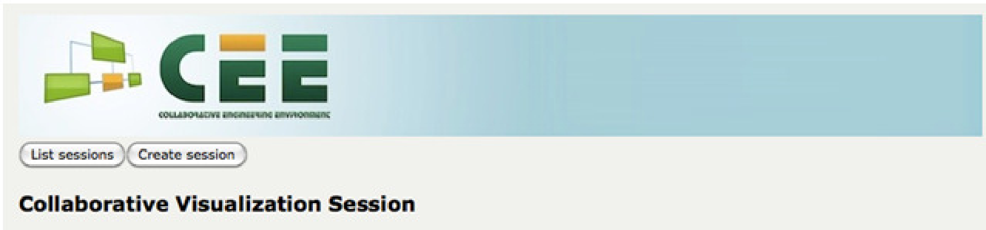

Figure 3.5 : Creating the collaborative visualization session

First the user inside a web browser accesses the CEE-Portal and then selects the option to create a new visualization session (Figure 3.5). The user has to select which users, already registered in the CEE server, will participate in order to create a session. The session name, its type (Informal, Classroom or Lecture) and the role of each participant (Coordinator or Participant) should be also selected (Figure 3.6).

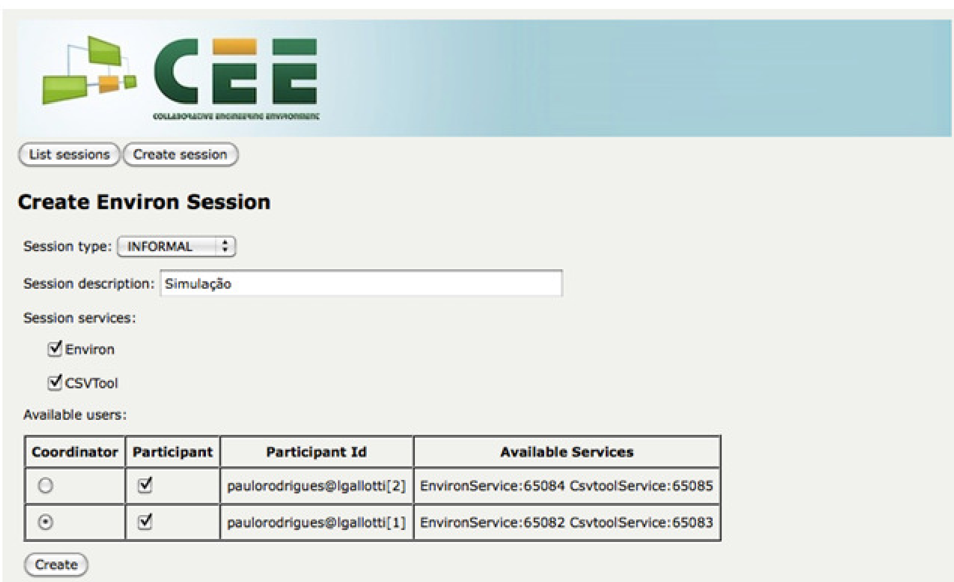

Figure 3.6 : Selecting the coordinator, the kind of session and the users that will participate.

Once the session is created the user can send commands (Figure 3.7 : Sending commands to load a simulation to visualize in the session to all or individual participants. One such command could be to load the simulation that could be analyzed in conjunction with another specialist (Figure 3.8).

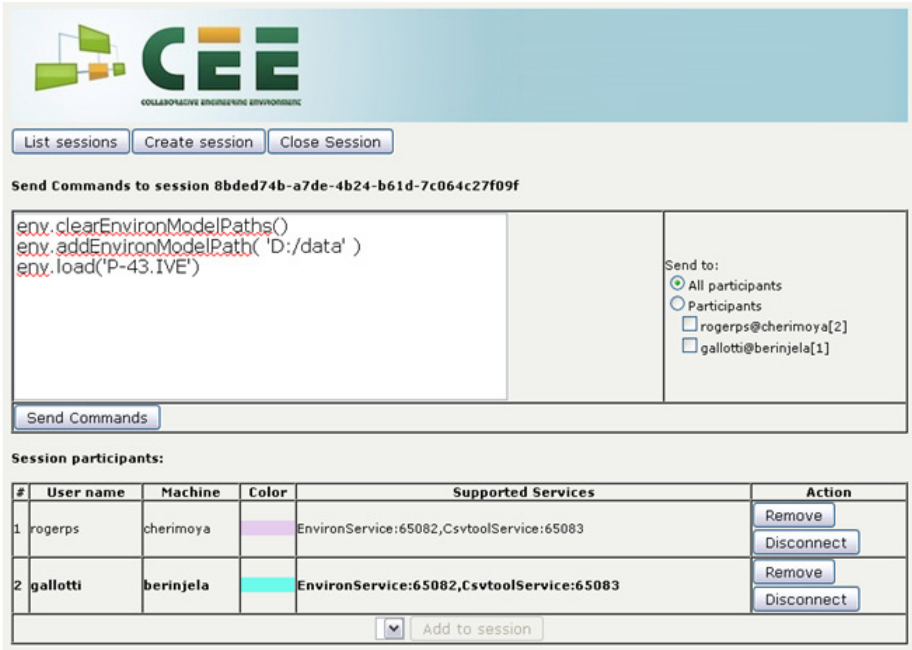

Figure 3.7 : Sending commands to load a simulation to visualize in the session

An example of command that might be used can be load a simulation to be analyzed in conjunction with another specialist.

Notice that the awareness mechanism indicates the status of each user (on-line or offline, i.e. momentarily disconnected from session), its role (coordinator or participant) and the user system ID.

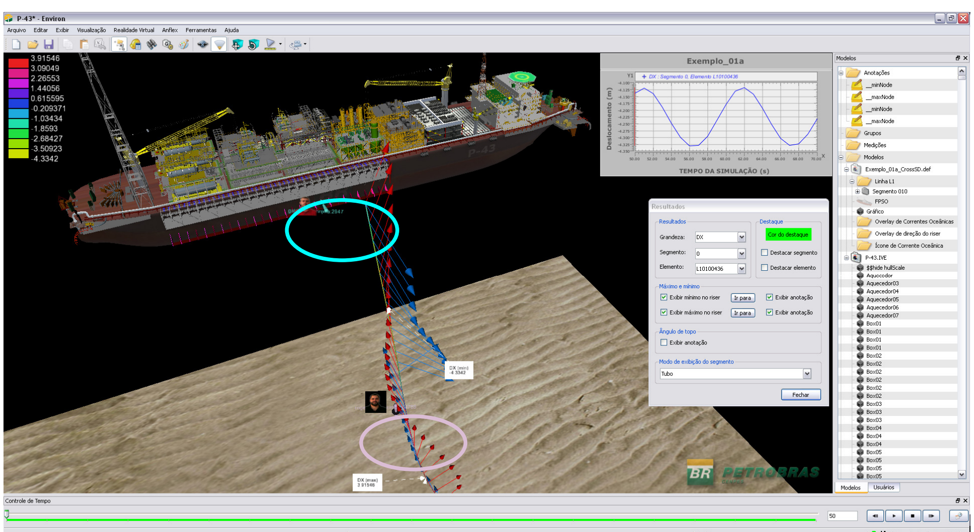

Figure 3.8: Riser simulation visualized in collaborative session.