The Role of Workflow in Next Generation Business Oriented Grids: Two Different Approaches Leading to a Unified Vision

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Abstract

The Grid is currently living an exciting evolution step to turn from a niche technological infrastructure to a widely used Business environment. To this aim, Workflows are playing an important role acting as the link towards the well-established Business Process Management environment. A number of Grid projects worldwide are trying to implement this link and create the Business Grid but no definitive proposal has been provided yet.

In this paper, we analyse two European Grid projects, Akogrimo and NextGRID, both investigating the Business usage of Grid from architectural perspectives but each one adopting a different approach in proposing solutions. The comparative analysis we report provides interesting elements to define a unified vision of the Next Generation Grids where Workflow Models, Languages, and Engines constitute a fundamental building block. Understanding and sharing this vision can be the first step to get to an effective architectural design for Business Grids.

1. Introduction

Grid is eventually coming next to a new exciting phase when it will be decided if it will emerge as a worldwide technology innovator, like the Web or the mobile phones, or if it will remain an attractive evolution of traditional distributed computing. The Grid vision has already started to materialise into concrete technologies and products, enabling new and more demanding applications and services that go beyond the borders of research labs. Moreover, the convergence between Grids and Web Services, Grids and Semantic technologies, and emerging Service Oriented Architectures promises enabling the provision of computing, data, information and knowledge capabilities as utility-like services in the future, including services which intersect with the physical world through a wide range of computing devices [1].

However, even more than technology advances, a key point to allow Grid playing a fundamental role in the next future scenarios is surely understanding how it can be turned from a scientific infrastructure to a Business Oriented environment enabling different kind of users with different objectives to get advantages from the Grid itself. Workflows are playing an important role in this process mainly because they constitute a link from the technology based infrastructure that is now the Grid to the Business Process Management environment with its well-established principles that rule and model the Business world. Workflow Management Coalition is providing evidence of effective usage of Workflows in many different contexts from Web Services architectures to massively parallel implementation [2]. Still, workflow has not reached a common definition and role within the Grid context, even if a number of Grid projects worldwide are addressing workflow management [3] as the proposal solution to fill the usage gap and create the Business Grid.

In this paper, we analyse two European Grid projects, Akogrimo and NextGRID, both addressing the Business Grid from the architectural point of view. Their common objective is defining a Next Generation Grid (NGG) architecture even if the first one is focused on implementing a kind of operational prototype to demonstrate architecture needs, while the second one is aimed at providing an architecture blueprint supported and validated by specific components demonstrators. Despite the different approaches, the comparative analysis we report provides evidence of the key role that workflows can play in providing Business oriented flavour to the NGGs. Interesting elements emerge from this analysis, suggesting a unified vision of Next Generation Grids where Workflow Engines, Languages, and Models are a fundamental building

block. Understanding and sharing this vision can be the first step to get to an effective architectural design for Business Grids.

2. Workflows in the Akogrimo Grid Mobile Environment

The Akogrimo architecture is intended to support business process designs that both enable and take advantage of dynamic, mobile services and users [4]. The Akogrimo project is driven by the basic idea that Next Generation Grids should be built on Next Generation Networks. This means that an Akogrimo NGG must be able to address the needs of an environment where users experience potentially fast changing context (Bandwidth, Device capabilities, Location, etc.), different network access providers and local services while aiming to participate in complex collaborations using resources provided by service providers from different organizations.

Akogrimo intends to cater for the mobility of participants (both users/clients and services) in a business process. One consequence of this is that the business processing components must "track" users and services as they change location while retaining their identity, but must also support the ability of the process to adapt to changes in context of such mobile agents, for examples, changes in their capabilities, discovery of alternative services, and to respond to situations where an agent becomes disconnected.

In order to fulfil the goals of a business process, the services on offer must be combined and controlled through the use of structured workflows. The Akogrimo architecture includes support for such service orchestration, provided by the Business Process enactor module. As a consequence of the previously described dynamicity of the Akogrimo environment, the business process enactment sub-system needs to have access to the context information associated with all its users/clients and services. Mobile clients and (particularly) mobile services may have changing requirements and capabilities, which must be taken into account in workflow management.

In Akogrimo, large-scale business processes are "decomposed" into multiple smaller workflow templates, so reducing the problem in two ways. Firstly, both the choice of template to use, and the instantiation of the template with "concrete" service instances, are based upon the current dynamic context (as well as negotiation and policy management). Secondly, context-dependent choices of action will be supported within the workflows themselves, though the intention is that each workflow instance should be of sufficiently short duration that context change is less of an issue.

The enactment of a Business Process that corresponds to an application can be divided in the following steps:

- triggering of a workflow by some (possibly external) event: by a user request for a service, or by an action from another workflow;
- choosing a workflow template: based on both static and dynamic (e.g. contextual) requirements;
- resolving a workflow template's abstract services into concrete services: using service discovery and negotiation;
- enactment and monitoring of the activities within a workflow;
- detecting and reacting to exceptions: SLA violations, failures to uphold policy;
- completing a workflow.

The following use case, represented in Figure 1, could help the reader to understand a possible Business Process handled by Akogrimo: "Management of a Virtual Emergency Environment" [5].

A patient whose ECG (electrocardiogram) is being constantly monitored carries a mobile ECG measuring device with him that is connected to a PDA. The PDA hosts the ECG Data Source Service that can send the ECG data via WLAN to a data sink, in our case the Medical Data Logger service. At the network layer IPv6 and MIPv6 are used. The PDA is also capable of providing geographical location information.

In the case of an anomaly detected in the ECG data of the patient, an emergency call (from a patient or directly from his heart monitor) is handled by an Emergency Centre Operator, who gathers further information, selects appropriate medical staff, and initiates the emergency workflows.

The orchestration module requests the operator to contact the patient in order to get additional information about the symptoms. After the operator has signalled his availability, the orchestration module connects the VEE operator and the patient by phone.

The operator asks the patient for his symptoms. In this procedure the operator is guided by a Diagnosis Support service and can view the ECG data of the patient.

The operator may request a cardiologist to evaluate the anomaly of the ECG data. An initial diagnosis of the heart problem is prepared and stored in the Electronic Health Record of the patient. On the recommendation of the cardiologist, the operator decides whether the patient should be brought to a hospital or not.

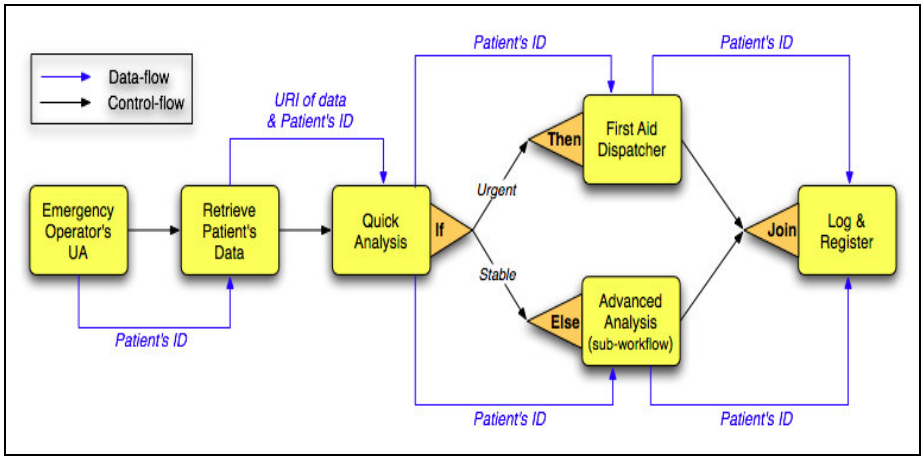

Figure 1: "Manage Virtual Emergency Environment" use case

The orchestration module has been divided in four sub-components each one responsible for a part of the workflow instantiation and execution. The logic behind this choice is to isolate a piece of 'intelligent' in each sub-component adding reliability and flexibility to the entire module. One single component could be modified without affecting the other ones and each one is responsible for the interaction with other Akogrimo modules [6].

The Workflow Manager: it is the actual central unit for processing and is the decision-making component of orchestration module.

The Enactment Engine: it is directly responsible of the service method invocation, of managing the I/O data, and of submitting all the necessary requests (through classical communication protocols HTTP and SOAP).

The Workflow Registry: it is just a repository of the description, or implementation, files of the workflows published in the Akogrimo environment. Some sort of database manager will serve such registry.

The Monitoring Daemon: it is in charge of subscribing and receiving events of entities involved in the workflow enactment.

A particular relevance has the interaction with the *Mobile Grid* layer that is the immediate lower layer. The *Mobile Grid* is a full inheritor of the Grid with the additional feature of supporting mobile users and resources in a *seamless, transparent, secure and efficient way*. It has the ability to deploy underlying ad-hoc networks and provide a self-configuring Grid system of mobile resources (hosts and users) that are connected by wireless links forming arbitrary and unpredictable topologies.

One of the consequences of Akogrimo's mobile and dynamic nature is the need to build on-the-fly secure Virtual Organizations (VOs), where the data can be shared among the dynamically changing members but prevented from falling into the hands of outsiders. Two kinds of VOs are considered with similar functionalities, but applied in different context: Base VO (BVO) and Operative VO (OpVO). The BVO is a static VO that lives until at least one Service Provider belong to it and manages all action performed in a VO. The OpVO is more dynamic adding to management action of the BVO all operation necessary to drive the execution of a business process. The OpVO has the same lifetime of the business process: it is the transient environment corresponding to instanced services and users brought together for business purposes.

At lower level, the orchestration module relates indirectly with the Grid layer via the Execution Management System (EMS) that is in charge of instantiating and executing services. The interaction between the Enactment Engine and the EMS is transparent to the user because the Enactment Engine always invokes Service Agent (that act on behalf of the service carrying information about identity). The SA will directly call the service or it will call instead the EMS. Therefore, the decoupling of the Orchestration module and the Grid component has a big advantage. It permits the administration of the services instantiation and execution at two layers.

From the Business Process perspective, the services are executed and managed by the orchestration module. The Business Process designer does not have to know anything about Grid, it will just see all the services offered as simple web services. In the other end, the orchestration module does not have to care about problems at low level that can occur during the service execution. The EMS will do the monitoring and metering of the services execution.

3. Workflow Programming Models in NextGRID

The goal and primary output of NextGRID project is to define architectural components that will lead to the emergence of the Next Generation Grid. The NextGRID vision is of future grids, which are economically viable; in which new and existing business models are possible; in which development, deployment and maintenance are easy; and in which the provisions for security and privacy give confidence to businesses, consumers and the public [7].

Understanding the architectural components required and how existing Grid technologies need to be modified and extended can be reached analysing characteristics of current and future Grid business models. A global Grid marketplace where computing resources, information and services can be bought and sold has been envisaged for several years now. The ability to select and use service components from a variety of independent sources and to integrate them into an application that delivers the functionality and performance desired is central to the vision of NGGs.

Business relationships are generally codified in contracts making all relevant details explicit: defining what is to be provided, relevant business practices and standards to be used, as well as pricing and penalties for breach. In a service provision relationship, part of the contract is frequently expressed in a service level agreement (SLA). NextGRID is using the idea of a SLA to provide an explicit context for relationships between Grid entities, be they resources, individuals, or organisations. This context will determine many of the technical policies to be applied within the relationship.

Representation of the interactions between software components and people in a business process is best done in terms of workflows and therefore workflows play a critical role in the agile, dynamic federation of Grid services. Workflow techniques can be used to express the composition of service components and can support process flexibility by soft-coding application behaviour. There is little work so far addressing higher-level issues such as co-location, workflow comparison and composition, adaptive behaviour or cross-organisational issues. Non-functional aspects of distributed workflow (performance, privacy, security, availability etc.) are particularly important. These dimensions need to be predictable and reliable if the approach is to be useful in business critical applications. Modelling of system performance where components are independently developed and provided is of particular concern.

In NextGRID, the workflow components, the services and their environment compose an infrastructure that is described as the concept of Grid Virtual Infrastructure Model or Grid VIM [8]. This infrastructure is designed to allow Grid applications and Grid business models and processes to be combined at run-time providing adaptability to distributed Grid environments. This is an essential architectural feature without which it would be impossible to design applications independently of the business models for provision and procurement of services from which they are composed.

Workflow activity in NextGRID has been therefore focused on the following aspects:

- Analysing and understanding Workflows Role and Lifecycle in Business Oriented Grid.
- Implementing a Virtual Infrastructure Model to enable representation and enactment of different types of workflows, according to the reference scenario derived from previous analysis.
- Defining Workflow Programming Models based on workflow representation and implementing a tool for supporting model definition (Semantic Workflow Programming Tool).

Following the Workflow Lifecycle and analysis, it has become clear that NextGRID has to support multiple business roles which all should contribute to the way an application behaves when it is executed on the Grid (see Figure 2), such as:

- the application developer who needs innovative tools and interfaces for programming the Grid taking advantage of the knowledge of their specific application domain,
- the application end user who needs a “conventional” user interface to control submission of the application and its subsequent execution;
- the end users’ procurement manager, who should decide what process the end user must adopt when the application has to use commercial Grid services that must be paid for by the end user’s organisation;
- the service provider who needs to manage SLAs with the users of his services; these will define terms and conditions including the performance that can be expected and also constraints on the application's behaviour. The service provider will also define SLA negotiation processes, including establishing creditworthiness of the end user.

Each of these actors performs their role Authoring different kind of workflows that will be executed when the end users will trigger application execution.

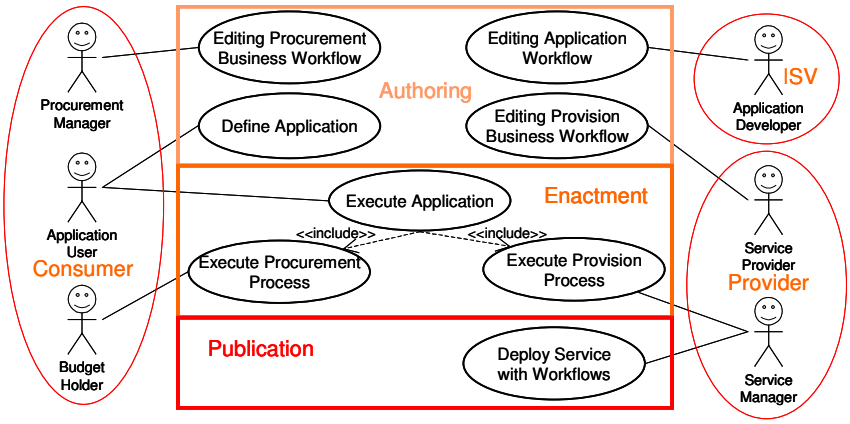

Figure 2: NextGRID Workflow Lifecycle

Further actors, likely software components will take part in the Enactment phase when both the procurement and the provision process will be executed in the context of application run.

It is worth noticing that each of these roles could be played by the same entity at different times. A service provider can act as an intermediate, developing a complex application that in turn uses services available from other providers. This means that each role can use other roles to accomplish its task. In addition, roles sharing the same objectives and/or environment can be grouped and create VOs.

The emerging NextGRID architecture will allow each of these actors to define aspects of the behaviour of an application, in the form of a workflow or a policy that constrains the execution of a workflow. Each actor should be able to do this independently, so that the application developer does not need to know what procurement process his users will follow or what the service provider's SLA terms or negotiation process will be. Without this independence, it is very difficult for the Grid to be used as a platform for commercial software. However, when an end-user wants to run a Grid application, the contributions from all relevant actors must be brought together at run time, so that the application runs in a way that is consistent with the business needs of them all.

A reference scenario was derived from this analysis to understand workflow roles and usage pattern within NextGRID dynamics, comprising Application, Business Process and Service Provisioning level. Workflows at the different architectural levels have been identified and their characteristics have been defined:

- *Application Workflows*, mainly Abstract Workflows representing functionalities according to some domain knowledge
- *Procurement Workflows*, mainly Concrete Workflows representing different Business Policies using organisational services like approved supplier registry, broker, etc.; Abstract Workflows can also be used to implement Policy portability on different infrastructure.
- *Service Provision Workflows*, mainly Concrete Workflows representing implementation of application and policy components. These workflows define rules for using the service normally as a workflow over operations of the service (or related services).

As it is evident Workflows are used as the key to express not only end-user needs in form of Application that has to be executed but also to specify Business Models and Policy that are part of the Grid itself.

4. Unifying the Vision: Lesson Learnt and New Challenges

Considering scenarios presented in the previous sections, the Next Generation Grid can be certainly viewed as a collaborative environment where diverse actors, business models, services should be managed in a coordinated fashion. Some key concepts inevitably emerge and require a common approach that should possibly produce standards. In particular, the analysis of Akogrimo and NextGRID projects in the view of a unified vision leads us to the following statements:

- Business Models and Workflow Management are key enabler of the Next Generation Grid.
- Business Models are the link between the Grid world and the Business community that intends to exploit it.
- Business Models can vary from simple applications to complex combination of nested

models that reflect the complexity of systems organisations, etc. and they can be effectively represented as (nested) workflows.

The aims of workflows in the NGG are to interpreter the Business Models and transpose them in " a pattern of business process interaction, not necessarily corresponding to a fixed set of business processes. All such interactions may be between services residing within a single data centre or across a range of different platforms and implementations anywhere."

This definition comes within the OGSA specification [9] and according to our experience it needs to be better refined. We are not proposing a different definition but adding essential elements based on the common effort of the project analysed that could, in next future, lead to a more detailed definition.

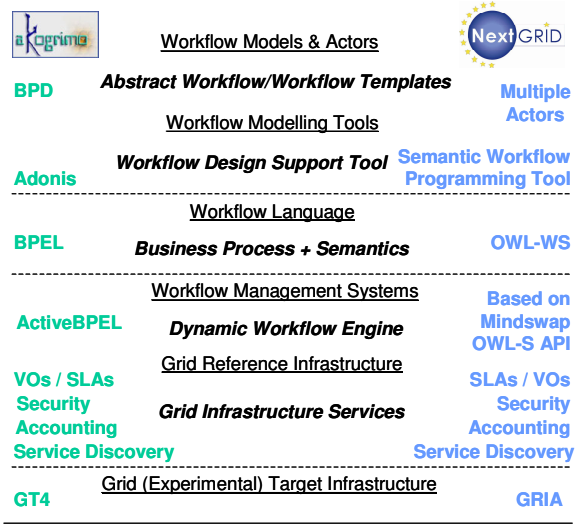

Figure 3: Workflow Based Comparative Analysis

In Figure 3 we summarize some key elements of the Comparative Analysis of the workflow based solutions proposed in the two projects.

It is worth noticing that these solutions are validated by working prototype that are being implemented on target infrastructure, respectively GT4 in Akogrimo, and GRIA in NextGRID. The description of components implementation is out of the scope of this paper but results of the demonstration are an important part of the analysis provided in the projects.

For the sake of simplicity, we have structured the analysis in three main categories: Grid Workflow Management Systems, Grid Workflow Languages, Grid Workflow Models (and Supporting Tools).

4.1. Grid Workflow Models

The first step in this comparative analysis concerns the role and importance of Grid Workflow modelling. By Grid workflow model we mean a collection of references that could be used during the modelling of a Business Process.

Both projects strongly rely on the concept of abstract services that should be somehow translated in concrete services. Abstract services, and related abstract workflows deriving from composing them, are the key concept for modelling application and business knowledge. Concrete workflows, composed by concrete services, permit to enact and somehow execute the abstract workflows. How the incarnation of the abstract into concrete workflows is performed is the core process of the Grid Workflow Management Systems (see section 4.3).

From the modelling perspective, in Akogrimo, abstract workflows correspond to workflow templates that are stored in the Workflow Repository. The Workflow templates are, in this case, the transposition of the Business Process or of a part of it; they are strongly related to the application domain. In NextGRID, the abstract workflows can be identified with both the Application Workflow, modelling knowledge in the Application Domain, and Procurement Business Workflows, modelling Procurement Process from the consumer perspective. In this case, too, the abstract workflows represent functionalities according to their meaning and non-functional constraints (e.g. QoS) while concrete services that could provide required functionality execution, are yet to be found.

The Akogrimo study has identified a fundamental actor to manage the modelling phase: the Business Process Designer (BPD), which is in charge of modelling the application. He/she should have knowledge about the basic infrastructure as well as the application specific domain. How the Business Process Designer (BPD) could write the workflow template? At the current stage, the BPD is free to write the template as he/she prefer. This could be seen as an advantage but also as a disadvantage. The advantage is to be in the position to write a workflow template without boundaries and constraints. To the opposite side, this freedom could cause the writing of a workflow not optimised, that does not exploits all the features available. In addition, it could be that the BPD has to have a deep knowledge of the middleware and thus he/she is too much bound to the project itself.

From a different point of view, NextGRID identified a multiple actor scenario where each role is enabled to use its own knowledge to represent Application and Business Processes. Ability to describe abstract workflows allows decoupling knowledge needed in the different Authoring, Enactment and Provisioning

phases. Independent on the target domain, Application or Business Process, actors must be supported in using their knowledge by means of:

- Abstract Workflows repositories, providing recurring workflow templates and insurance of related service availability.
- Domain knowledge management, likely based on references to shared ontology allowing defining and using meaningful service and workflow parameter description.

It can be easily derived that effective workflow modelling must be supported by both:

- Service Models, representing high level service according to widely understood and shared parameters
- Workflow Templates, modelling well-established workflow structures therefore suggesting the most effective usage without limiting workflow flexibility.

Finally, it must be noticed that this level of complexity should be supported by user-friendly tools adding to the traditional workflow representation utility innovative features like semantic and knowledge management.

4.2. Grid Workflow Languages

Another important aspect of workflows that must be taken into account concerns workflow languages available nowadays: do they satisfy the Next Generation Business Oriented Grid?

As already stated, the two projects presented in this paper have already arrived to the phase in which a first implementation of their proposed architecture has been done but also in this case a different solution has been provided.

Akogrimo has chosen BPEL has reference language while NextGRID has defined and adopted an extension of OWL-S. The difference between the two proposed languages does not only come from the different targets and objectives of the two projects but also from the fact that a comprehensive standard language is not yet available. Obviously, detailed research and comparison on available languages was performed before taking the final decision [8].

The nature of Akogrimo which is mainly focused on Mobile Grid and Next Generation Network leads to the choice of a language that was already available, much diffuse, to be in the position to be supported and sufficiently stable. BPEL permits to specify roles (that could be mapped with OpVO role), to design in an easy way Business Application and to handle web services. From the other hand, BPEL suffers the following limitation from a NGG perspective. It does not take into account semantic at all; Grid services are not supported (WS-Addressing is in an experimental phase). The notion of Grid is totally absent.

NextGRID project followed a different approach focusing on the most innovative aspect of workflow management and therefore stressing the need to represent semantic information. Adding semantics to BPEL was one of the first options that was evaluated but it was eventually decided to address just the basic workflow aspects, that are simple control and data flow, and investigate the complexity that semantics add to the workflow representation and management. OWL-S, that is W3C member submission, was a good candidate providing both ontology specification of services and control/data flow representation. Extensions were needed to increase the ability to represent much complex information on workflows and to cope with ontology-related shortcomings. Therefore, language requirements were formalized and the OWL-WS extension was defined to fulfil these needs.

The conclusion that comes from the language usage in both projects is that a good language for NGG should be able to:

- Represent abstract and concrete workflows that allows representation of different degree of abstraction
- Provide means to express non functional requirements likely adding semantics to both service description and workflow structure
- Allow handling dynamics and flexibility likely representing and enabling workflow substitution
- Define different kind of parameters to describe both Business and Grid oriented services and workflows without any dependency on specific models and infrastructure.

4.3 Grid Workflow Management Systems

The final step of our analysis concerns the Workflow Management System. It has been modelled in different ways in Akogrimo and NextGRID but in spite of that it is possible to distinguish some common aspects. In Akogrimo, the Orchestration Module is structured in different components each one presenting a piece of intelligence and therefore responsible for a part of the workflow instantiation and execution. In NextGRID, the Workflow Engine is the core of the Workflow Management system and great part of the business logic is coded in the workflows themselves.

In the case of Akogrimo the crossing from the abstract to concrete happens through the use of Service Discovery, SLA negotiation, dynamically VO creation.

The workflow template is filled with the concrete services and the resulting workflow is ready to be executed. In NextGRID, a concrete Procurement Process must be obtained from the department repository mainly depending on the capability of the Budget Holder that is currently executing abstract Application Workflows. In addition, a concrete Provision Processes fulfilling the requirements described in the Application Workflow must be obtained by means of a Service Discovery and Negotiation process. In the NextGRID vision, where workflow is a recurring key concept, nested workflows permits to pass from the abstract to the concrete level. Again, this could happen with the aid of Service Discovery, SLA negotiation and mainly trough the use of semantic models.

Therefore, it can be derived that an effective Grid Workflow Management System should be based on an innovative enactment engine that is able to:

- Handle with dynamics and adaptive workflows at different levels
- Take context into account to address non functional requirements and different business policy
- Orchestrate Grid Services independent on the specific target infrastructure

From this last perspective, both projects have also pointed out that Workflow Management need to relate with basic Grid Infrastructure Services that are mainly:

- Service Discovery
- VO management and SLA management (negotiation, agreement violation, etc)
- Accounting and Metering
- Security

5. Conclusions and Next Work

As it is demonstrated in the previous analysis, Workflows can play a key role in supporting Business Oriented Models and Services in Next Generation Grids. The main obstacle in reaching this goal is surely in the lack of standard (or the co-existence of too may of them) at all the different Grid levels, from Business Models to Management Systems. A lot of work is being done in this area and more is needed but no solution is emerging. This implies a great waste of resources, leading to many different specification and implementation and even worst, to a great variety of Grid models and support tools that generate confusion in the target user community.

Providing comparisons and convergence among the different Grid projects is certainly a valuable step towards the NGG specification. As we have demonstrated, comparisons in both requirements and solutions can produce fundamental information that need to be formalized and addressed by the overall Grid community.

Both projects will continue respective workflow activity refining current solutions and addressing new challenges. Moreover, participation to working groups related to standard bodies like OGF/GGF or W3C will be performed providing results of this analysis as contributing elements to build a really unified workflow vision.

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7. References

[1] Next Generation GRIDs Expert Group Report 3, *Future for European Grids: GRIDs and Service Oriented Knowledge Utilities,* January 2006.

[2] L. Fischer (Ed), *2006 Workflow Handbook*, Published in association with WfMC by Future Strategies Inc., FL, USA.

[3] J. Yu and R. Buyya, A Taxonomy of Workflow Management Systems for Grid Computing, Journal of Grid Computing, Vol. 3, Numbers 3-4, Pages: 171-200, Springer Science+Business Media B.V., New York, USA, Sept. 2005.

[4] J. Jaehnert et al: *Detailed Overall Architecture*. Akogrimo deliverable D3.1.2. 20.02.06. URL:http://www.akogrimo.org/download/Deliverables/ Detailed Overall Architecture

[5] S. Kirn et al: *Akogrimo Testbed Description*. 13 September 2005. Available at http://www.akogrimo.org

[6] A. Terracina et al: *Orchestration and Workflow in a mobile Grid environment*, to appear in Proceedings of the 5th International Conference on Grid and Cooperative Computing (GCC 2006). IEEE Computer Society.

[7] D. Snelling, M. Fisher, A. Basermann, *NextGRID Vision and Architecture White Paper V0.9,* December 2005. Available at http://www.nextgrid.org.

[8] S. Beco, B. Cantalupo, L. Giammarino, N. Matskanis, M. Surridge, *OWL-WS: A Workflow Ontology for Dynamic Grid Service Composition*, in Proceedings of 1st IEEE International Conference on e-Science and Grid Computing, pp. 148-155. IEEE Computer Society.

[9] Treadwell, J. (ed.) Open Grid Services Architecture Glossary of Terms. Global Grid Forum OGSA-WG. GFD-I.044, Jan 2005. http://www.ggf.org/documents/GFD.44.pdf