BREIN
Business objective driven REliable and Intelligent grids for real busiNess

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TABLE OF CONTENT

1. Introduction 6
1.1 BREIN Objectives 6
1.2 BREIN & Cloud Relationship 7
2. BREIN Results 11
2.1 BREIN Exploitation Items Packages 12
2.2 BREIN Exploitable Knowledge 12
2.3 Realised Application Scenarios 19
3. BREIN Impact 24
3.1 BREIN Achievements 24
3.2 Dissemination, Collaboration and Standardization Impact 26
4. Conclusions 29

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LIST OF FIGURES

Figure 1 - BREIN can enhance Cloud features 8
Figure 2 - BREIN provides Cloud services 10
Figure 3 - Overall picture of software exploitation items in BREIN 11
Figure 4 - ANSYS Wind Power Application Results after using BREIN 19
Figure 5 - Time frame of the demonstration. 21
Figure 6 - Represented organisations in the demonstrator. 22
Figure 7 - Demonstrator complexity. 22

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LIST OF TABLES

Table 1 – Software EIs Exploitation Strategy 13
Table 2 – Methodological EIs Exploitation Strategy.....16

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1. Introduction

The research Project BREIN, which was partially funded by the EC under the FP6, had as main objective the creation of an infrastructure that supports collaboration among companies in a dynamic and changing environment. The project had a strong focus on business requirements established amongst others by the definition of two distinct scenarios (Virtual Engineering and Airport Resource Management) driven by two main end-user stakeholders in the project: ANSYS Europe Ltd and Stuttgart Airport.

Thereby BREIN developed a framework that extends the possibilities of applying the Grid to new target areas than the traditional academic ones – namely thefrom the business domain. Thus, BREIN wass dealing to provide all necessary functionality for a business Grid to enable enterprises to simplify their relationships complexity by using intelligently their infrastructure. To this end, BREIN gives the best support possible to enhance business and to optimize business execution whilst minimising interaction and knowledge about the underlying technical nature of the system from the individual participants.

1.1 BREIN Objectives

BREIN had a set of objectives, which were identified to be of utmost importance to be addressed for fostering the uptake of Grid in business.

Summarizing, the four main objectives for BREIN were to enable/enhance:

(1) Autonomy and Automation to allow for automated business enactment by aligning and negotiating individual goals to fulfil the overall business task(s).

(2) Self-Optimization to optimise the configuration of Grid services (deployment, workflow enactment etc.) in a way that meets the individual business goals of the respective service provider best under the restrictions of the global Virtual Organization.

(3) Context-Aware Security to allow the security system to identify the relevant security means on basis of the given conditions.

(4) Reduced Complexity of Use by following a “plug’n’play” approach according to the strong definition of SOA and by enhancing the declaration of individual business goals and policies is with Semantic Web Technologies (to allow abstract definitions).

This all was targeted by integrating two so far in parallel developed technology domains into the Grid – Multiagents and Semantics.

1.1.1. Key technologies in BREIN development

To build this framework, BREIN combines concepts provided by different research areas and apply them to a Grid situation. These areas include: semantic web, multi-agent and workflow technologies in order to enable interoperability, flexibility and adaptability.

Concretely, semantic Web concepts provides to Grid business i) simplicity to users since they can describe services, SLA terms… in the language and domain they know, ii) allows for interoperability among providers (semantic descriptions

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of resources, services, SLA terms, security) and iii) increases the automation of human tasks decreasing time and effort in the creation and maintenance of services.

On the other hand, multiagent technology allows for i) dynamic adaptation, so that, recognising and reacting to potential problems increasing reliability: ii) adaptative negotiation for defining enterprises collaboration contracts driven by enterprises objectives, iii) decision taken without human intervention.

1.1.2. Key concepts in BREIN development

A key concept in the BREIN approach is that of the "**bipartite** (that is two-party) agreement", which is the contract established between two parties, deriving from a negotiation and describing the service, its quality and the terms under which it is delivered. This model closely follows real B2B practice and does not impose any restriction on the aspect of the value chain or the pricing model of each participant. It does not require the previous establishment of a virtual organization beforehand and defining the participants in the process. Therefore, there is no central component that manages the Virtual Organization lifecycle, and each participant establishes bipartite relationships with other participants, to govern their business interactions and the services traded between them.

Another fundamental concept in Grid is **virtualization**. This provides companies with means of provisioning for a service in any way they see fit, as long as it is compliant with the terms of the agreements they have with their customers. A provider could change their internal infrastructure and their clients do not perceive any change. This provides the freedom of managing the internal resources without any restriction and facilitates the adaptation to changing business circumstances.

Finally, **orchestration** achieves the realization of customer workflow towards business requirements, in terms of the integration of different provider's services and collaboration with different enterprises.

1.2 BREIN & Cloud Relationship

Although BREIN started as a Grid Computing project, BREIN has faced and provided some technologies and results related to the Cloud Computing one. Clouds refer to the **IT infrastructures** enabling **Utility-like** features in "**X as a Service**" models, where customers can pay in a pay-per-use model with a on demand usage. This is a business concept which can be provided by BREIN technology. In addition, it is possible to say that BREIN can enhance some Cloud Features:

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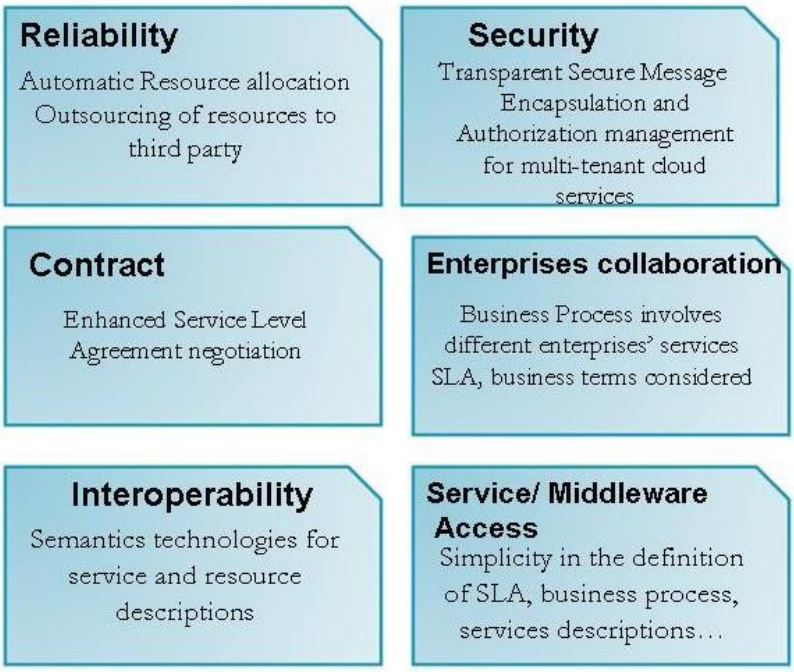

Figure 1 - BREIN can enhance Cloud features

- Reliability: BREIN increases the reliability for resources and services since it is able to detect failures and adapt the system in response to it. This can occur on both the customer and provider sides of a business relationship. If a failure is detected on the provider (for example a resource failure or inadequate resources to meet the customer's demands), BREIN automatically allocates additional resources to address the failure or lack of resource. This happens invisibly to the customer, who, as long as their SLA with the provider is satisfied, is not concerned how the provider resources their service. If the customer-side workflow enactor detects a failure in a service, it can also take automatic action by selecting a new provider or service or in the provider side by looking for new resources in the same provider or outsourcing to a third party, like Amazon.
- Security: BREIN provides a transparent and secure message encapsulation framework, which ensures transparent protection of cross-organizational message exchanges, as well as authorization enforcement. The authorization management for multi-tenant cloud services allows customers to centrally enforce authorization policy on resources hosted in external multi-tenant services, such as resource services in the cloud.
- Contract: BREIN allows the different enterprises involved in the business to sign a contract establishing a set of terms to guarantee a service level agreement. Thereby it provides a dedicated SLA Management Framework which goes beyond the limitations of existing solutions. With its extensions, this framework is able to intelligently process Service Level Agreements by taking into account the business entities capabilities, policies and goals. The embedded use of semantic and multiagent concepts makes it more flexible in terms of discovery of

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problems and reaction on them and provides by that the needed reliable solution for eBusiness.

- **Enterprise collaboration:** BREIN provides a framework which addresses complex collaboration patterns and value chains. Each participant's business objectives are taken into account – this is important as a participant's objectives form the reason for them to take part in the value chains. This is achieved by allowing each partner is able to specify their business goals in the form of SLA requirements for interactions with other partners, whether they are the supplier or customer in any pairwise relationship. BREIN has lowered the entry barriers to complex collaborations because of the high level of automation it provides, with a consequent reduction in cost. The lowering of entry barriers and costs means that many more participants are enabled to join complex collaborations than before the project started. An example of this is the reduction of transaction costs: the human involvement in enterprise collaborations is decreased since many tasks are automated (for example the selection of the providers and negotiation of SLAs with them).
- **Interoperability:** Enterprises have different systems, infrastructures, data (format) and domain conceptualization, dealing with this diversity implies a heterogeneity problem. The reason is that respective specification standards are either 1) not being adopted by a critical number of enterprises to allow realizing network externalities or 2) are only concerning low-level technical and syntactical issues, but without semantics, especially for application domain specification. Thus, in order to solve this, BREIN is using semantic technologies providing interoperability in the specification of services and workflow, resources and SLA descriptions.
- **Service/Middleware access:** One of the main objectives of BREIN is to provide an infrastructure that is easy to manage and operate. BREIN has achieved this by reducing the complexity of resource management and configuration. It is also important to simplify the framework and the user interface for the development, deployment and maintenance of Grid applications in order to reduce the complexity, that way making it also easier to find staff with the needed knowledge.

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Figure 2 - BREIN provides Cloud services

Moreover, BREIN can provide some Cloud services:

- Software as a service (SaaS): Provision of a) desktop software programs or b) business management applications as a Service. In this way, the ANSYS application used in the demonstration is provided in a pay-per-use model so that as SaaS.
- Platform as a service (PaaS): Enable to rent a) "containers" where you can run your application or b) "programming libraries" (e.g., Hash Table). It is possible to say that all the BREIN components, deployed as services, are PaaS, so that, they can be used by developers
- Infrastructure as a service (IaaS): Enable to rent a) virtual machine instances to run your application or b) storage space. All the data centers, BSC, PSNC, HLRS expose their machines as services providing computing and storage capabilities so that IaaS.

The focus of BREIN is clearly at the PaaS layer; the emphasis on the higher-level aspects of service delivery (e.g., reliability, negotiation, automated monitoring and management) is a clear differentiator from the lower-level IaaS models. Moreover, this clearly enables third parties to build their own SaaS provisions on top, so serving particular pieces of software up in relevant ways to specialist industries. Yet we can also see that in the longer term there will be a clear benefit overall, both to industry and academia, from working towards standardizing the PaaS level that BREIN has mapped out so that there can be many providers of such higher-level execution and data-management services. The space of potential differentiator attributes of the services (e.g., physical location, pricing model, speed) will mean that this is not an area where a single player can easily dominate to the exclusion of all others, and hence future standardization will be valuable to both customers and service providers.

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2. BREIN Results

BREIN has adopted an exploitation items identification strategy to define BRIEN results. It involves gathering these items from the partners interests, mainly, those results they expect to exploit (both commercially and in an academic way) in the future.

As definition, exploitation items are BREIN results which can be directly exploited by partners inside or outside the project. Thus, some of these exploitation items are developed and provided as software packages or items (mainly software components), while others are related to methodology or know-how. In this matter, we have identified two kinds of exploitation items groups: software exploitation items and Methodological and know-how items, which are BREIN results but not related to software but knowledge.

The software EI are software results which have the ability of being directly exploitable by the consortium partners and even external organizations and are scenario-independent. Depending on the package complexity as, they can be classified as:

BREIN Toolkits: These toolkits are formed by groups of components that enable an innovative functionality in BREIN. Examples: service broker, resource broker, gateway, SERA…

BREIN Frameworks: These packages are formed by groups of BREIN toolkits and possibly some additional components that enable also an innovative functionality in BREIN.

Figure 3 represents the overall picture of the BREIN software EIs, which is the result of partners' exploitation interests.

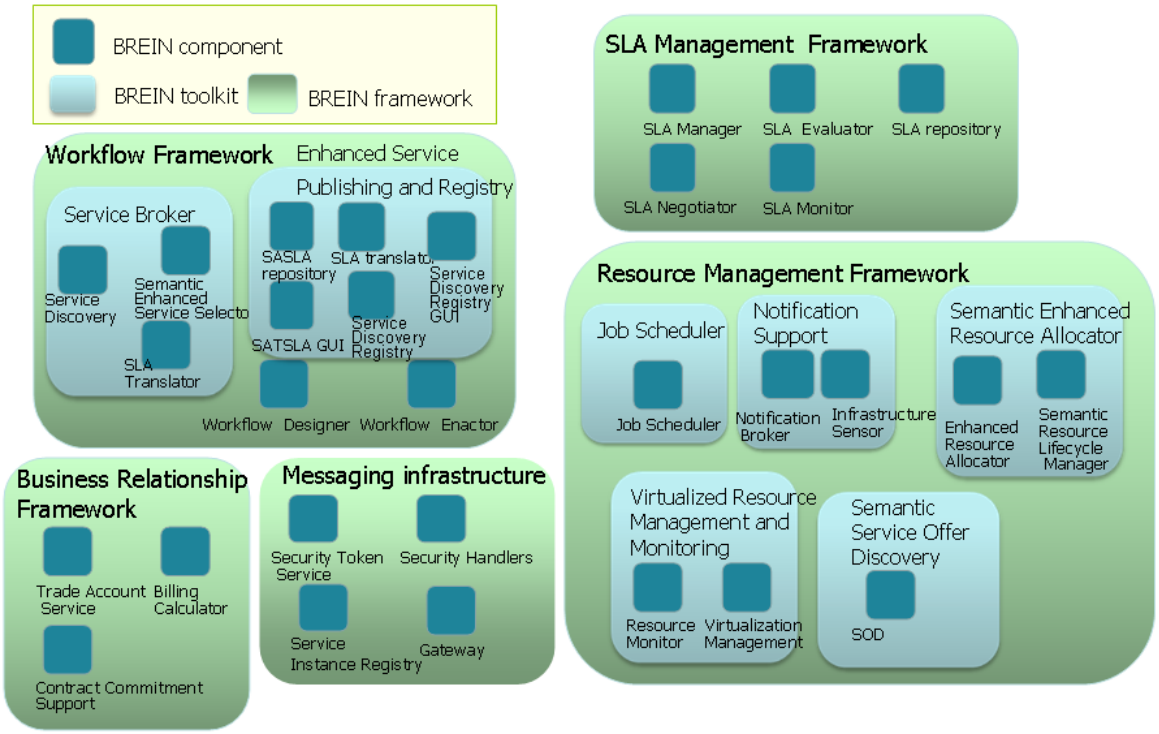

Figure 3 - Overall picture of software exploitation items in BREIN

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Basically, BREIN provides some frameworks related to main BREIN functionalities, like Workflow, SLA management, Business relationships, security and Resource management framework. Moreover, it has a set of toolkits to provide concrete functionality.

2.1 BREIN Exploitation Items Packages

The BREIN software exploitation items, identified as exploitable or innovative, has to be disseminated as an essential part of the project, There are many channels to accomplish dissemination, but the main one has been through packaging the components involved in these EIs and creating installers. Thus, BREIN has packaged these EIs in a simple and easy manner, with documentation and even the source code as well as providing installers for an easy installation and configuration by end-users. The output has been used in the project as input for both scenario demonstrators and is also publically available at BREIN's Website[1] .

2.2 BREIN Exploitable Knowledge

As the identification of these BREIN EI has been performed based on exploitation interests by partners, partners have faced exploitation opportunities and have identified some exploitation strategy to exploit them. All this information is collected in the Chapters 4 and 5 in this deliverable, where BREIN partners comments about the exploitation opportunities and strategy of the BREIN EIs formalized as exploitation plans. Table 1 and Table 2 summary the strategy by BREIN partners to exploit the exploitation items to transfer them into other research activities or to be incorporate into new products or services.

Table 1 incorporates the list of software EI commented previously, as well as the innovations they have which make them to be beyond the market. These innovations have been explained in D6.1.1 Exploitation plan as part of the BREIN exploitation methodology, so that; they are not going to be commented in this document.

Moreover, these software EIs are protected under a license, which has been decided by BREIN partners (the component owner), being all of them open software license like Apache 2, LGPL, GPL. Some partners have decided to use a GPL license to work on a dual licensing.

Finally, the table shows the different exploitation strategies adopted by BREIN partners both software owners and interested partners. In fact, they can be different exploitation strategies. Mainly, academic partners are interested in a results transference into others research projects and industrial partners in the transference of this results (both software and know-how into new products or services).

On the other hand, Methodological and know-how items are not really software results but they are related to BREIN methodologies or methods as well as knowledge learnt.

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[1] http://www.eu-brein.com/index.php?option=com_content&task=view&id=137&Itemid=134

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Table 1 – Software EIs Exploitation Strategy

Exploitable Items	Innovations	Patents or other IPR protection	Exploitation strategy	Sector(s) of application	Partners
Service Broker	Automatic service selection in terms of SLA templates and customer requests	LGPL	Know-how: influence in architecture in the TID cloud platform	Enterprises, SMEs	TID,
			Know how: distributed architectures for semantic service discovery Software: research projects Semantic discovery of service	academic	CRMPA
Job Scheduler	It provides standard-based interfaces to manage resources and jobs submitted in a cluster. It also allows the advance reservation of its resources.	Apache License v2.0	Result transference into other research projects Is a part of an internal SMOA project (as a SMOA Computing component)	academic	PSNC
Semantically Enhanced Resource Allocator	Automatic Resource Reallocation Resource Virtualization Scalability on demand	LGPL	To be integrated in the GRID superscalar		BSC
Virtualized Resource Management and Monitoring	Resource Virtualization	LGPL	To be part of the BSC Emotive Cloud		BSC
Semantic Service	Outsourcing in runtime	BSD license	Provision of new services to Northwest	Grid	UMAN

Offer Discovery			Grid infrastructure by the usage of SOD.	infrastructure	
Notification support	Notification Support for Web Services, agents, and users	Apache License v2.0	Result transference into other research projects. Is a part of an internal SMOA project (as a SMOA Notification component)	academic	PSNC
Semantically Enhanced Service Publishing	Simplicity in the definition of SLA templates and services	Some components license as LGPL. Others as GPLv3	Result transference into other research projects		ATOS
Workflow Framework	Simplicity in the Workflow Design Grid service grounding Adaptive business process and workflow management Dynamics and interoperability in BP Workflow driven by goals and SLA	LGPL	To integrate a Dynamic Workflow Management tool in business applications requiring a fast adaptation of the workflow to the changing business processes, minimizing the effort of the domain operator.	Finmeccanica group, business	ED
				science, engineering and environment	IT Innovation
Workflow Framework	Simplicity in the Workflow Design Grid service grounding Adaptive business process and workflow management Dynamics and	LGPL	To improve scalability in knowledge management Software (GescoRed) due to high numbers of users. Use semantic web and grid results to apply them to an interoperability and cooperation knowledge management inside GESCORED.	SME R+D Centers Public Administration	ADEI

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	interoperability in BP Workflow driven by goals and SLA		Cooperation Network for the promotion and transfer of technology and applied knowledge in the health sciences and technologies sector) Exploit distributed computing tools for the biotechnological research. Multi-tenancy as an enabler to sharing resources among users and applications: business and research centres in a multi-community scenario. To share resources among millions of users (e.g. keeping various users´ data in the same table and secured).		
SLA Management Framework	Simplicity in the SLA management Interoperability between different SLA terminologies Automated and coordinated SLA negotiation SLA driven Resource management	GPLv3	To be deployed in cluster operated by HLRS	academic users	HLRS, ATOS
Resource Management	Automatic Resource Reallocation	LGPL	To integrate components in the BSC Emotive Cloud		BSC

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Framework	Resource Virtualization Scalability on demand Outsourcing in runtime		Know-how: influence in architecture in the TID cloud platform		TID
Business Relationships framework	Provider Opinion of Customer Customer Opinion of Provider	LGPL	Trade Account Service, which records the opinion of a service provider regarding their different customers. To provide different capabilities		IT Innovation
Messaging Infrastructure Toolkit	Virtualisation, Encapsulation & Messaging Extra-organization resource security management Claims based security support for 'legacy' protocols	Apache/BSD	Knowledge and technology transfers and collaboration in future projects.	Microsoft	EMIC
			The gateway to be deployed in cluster operated by HLRS		HLRS

Table 2 – Methodological EIs Exploitation Strategy

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Exploitation Strategy	Sector(s) of application	Owner & Other Partner(s) involved
Advanced knowledge of the field of Agents-		To be integrated in IT-Tude	Business	ATOS

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Semantics-Grid combinations Understanding of issues, possibilities, hurdles and opportunities in the combination of these technologies				
BREIN Airport Ontology: A conceptualization in the airport domain	Airport ontology	Integration with other logistics ontologies	Airport, Logistics	UHOH
BREIN results in term of semantic support: It involves several aspects related to: ontologies, semantic matching, mapping data, reasoning, defining and use rules	Ontologies, methods for mapping, reasoning…	Knowledge to be transferred into new research projects	Research/academic	CRMPA/ UMAN
Application integration via Roadmaps (Roadmap to BREIN Convergence): The Roadmap provides a graphical representation of key elements of BREIN to organize and simplify the content.	Reference models	The Roadmap to BREIN Convergence is a use case of service oriented knowledge management. Here the reference models which are the basis of the roadmap will be exploited.	Business	BOC, SZTAKI
BREIN Modelling Framework: Modelling methods and their integration (supply chains, business processes, goal modelling, knowledge management, technical languages like UML, etc.)	Methods and their integration	Integration of methods inside the Next Generation Modelling Tools of BOC built upon a web-based modelling environment.	Business	BOC
Modelling Services: Web based modelling services (Semantic modelling services, Web modelling service and Web Process Stepper)	Services and architecture for next generation modelling	Integration of individual web modelling services into products, e.g. PROMOTE®	Business	BOC
BREIN Modelling framework: Methods for project related modelling (supply chains, business processes, goal modelling, knowledge management via roadmaps, etc.)	Integration of managements methods inside SME and Public Administrations	Perform market assessments, including feasibility studies to transfer the developed technology to the industry Allow Companies establish collaboration environment in a less	Business/Public Administration	ADEI

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		complex way, more quickly and reducing costs by offering resources and services between them.		
BREIN Application Integration know-how: How to integrate different types of services and applications with BREIN		Offering application integration know-how to our partner ASPs.	Business/academic	SZTAKI
The BREIN architecture		Application of BREIN architecture to new services/new research projects	Business/academic	TID, CRMPA
BREIN Resource Management: Use of virtualization, integration with agents, and experiences with running real world CFD ANSYS applications	Resource management components	Scientific papers, and application in computing infrastructures and subsequent research projects	Business/academic	BSC, PSNC

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2.3 Realised Application Scenarios

The BREIN project includes a formal Demonstration Activity aimed at convincing potential users of the BREIN technology of the maturity and effectiveness of the results, by illustrating them in a realistic context close to that of real production use and bridging the gap between research and real application.

The Demonstrators are based around real life cases supplied by the two end users, ANSYS UK, the Virtual Engineering Demonstrators, and Stuttgart Airport (FSG), the Airport Demonstrators. These are used to validate the results of the BREIN project.

2.3.1. Virtual Engineering Scenario

Engineering analysis software for Computational Fluid Dynamics (CFD) and Finite Element Stress Analysis (FEA) has traditionally been associated with large scale computing. The vision underpinning the Virtual Engineering Demonstrator cases is to generate significant new business opportunities in software and services by exploiting the capability of Cloud computing to analyse large numbers of independent simulations quickly, cheaply and in a secure fashion, to be able to study the sensitivity of the solution to the input parameters, for example through a formal Design Of Experiments process, and to generate response surfaces showing how the solution responds to changes in parameters, and to optimise the solution.

Main achievements

In the project we have illustrated the benefits of the approach for industrial users through three case studies:

- Wind power modelling in hilly regions, taking into account the sensitivity of the solution to the underlying terrain and wind variations. The figure below shows a 3D representation of the flow speed around hills to the North of Barcelona, superimposed on the terrain in Google Earth. These detailed results enable wind farm developers to plan their wind farms with greater certainty, complementing the traditional simpler methods they previously adopted.

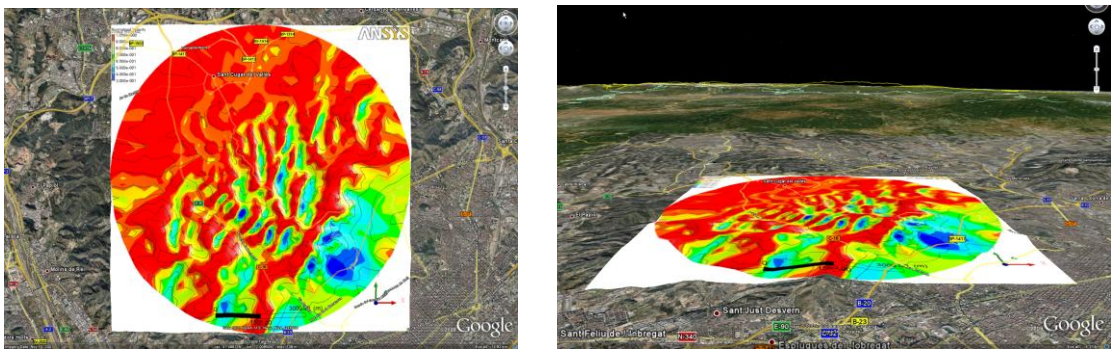

Figure 4 - ANSYS Wind Power Application Results after using BREIN

- The demonstrations showed how a simple web based front end could be used to easily set up the problem, and then submit cases with many flow directions to the BREIN Cloud infrastructure, with the runs being carried out on the cheapest computing services that were available, and overflowing onto other services, including the Amazon EC2 cloud computing service, in

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additional resources are needed, or if one of the systems fail, for example by running out of licences.

- A second case study was based on Data Centre cooling, using the MareNostrum system at the Barcelona Supercomputing Center. This examined the temperatures within the data centre, and showed how they controlled, for example by varying flow rates.
- The third case study used the ANSYS Workbench software, to set up a formal Design Of Experiments for a parametric simulation, and from an end user's desktop, using cloud computing to carry out the desired number of solutions concurrently.

These case studies have been used to illustrate the benefits of the results of the BREIN project, with features such as ontology based service discovery, secure data transfer, intelligent job scheduling, and resource management through Service Level Agreements. The results have also enabled quantitative assessments to be made of the approach, and have demonstrated significant cost reductions by reducing the total cost of ownership through Cloud Computing.

2.3.2. Airport Scenario

The Visionary Airport Management Scenario is based around the aim of Stuttgart Airport to create a new market as a hub for airlines that operate on a point-to-point basis. The new business opportunity is that if its ground handling operations can be further automated across organizational boundaries in a reliable and securely way, there is the potential for Stuttgart Airport to act as a hub for different carriers, and for it to be more competitive on a European scale. It will also have provide new opportunities for the carriers, to enable them to plug into intra -airline networks, but still retaining all the attendant benefits of operating in a point-to-point manner. Again, as the market currently does not exist, all the players in the hub environment will benefit from the increased throughput in Stuttgart Airport. At the same time, incremental improvements in the existing ground handling operations will still give big benefits to FSGStuttgart Airport, enabling it to reduce costs and increase the reliability of its logistic operations.

The general underlying idea of the visionary scenario is to create/obtain a new generation of aviation airport management software. It is not the business itself being to 100% new, but critical advancements of the underlying IT solutions that the IT method that need to be made to enabling the business idea. These advancements must allow for supporting the business. Properties like

- Faster and fully automated plan adaptation in case of events,
- Lower costs for technically integrating all relevant value chain participants,
- More efficient use of resources, and
- Potential for handling more tasks/flight movements with the same amount of resources.

2.3.2.1. Scenario demo

Demonstration in the airport management scenario was guided by two main objectives: (1) Showing how BREIN innovations can help improving ground handling processes respectively its short-time coordination, and (2) showing how the BREIN

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framework and its components can actually be used in a challenging, non-standard, large-scale application scenario beyond conventional Grid computing.

The BREIN Airport Scenario Demonstrator has to show a real world scenario from Stuttgart Airport. This airport has about 400 flight movements per day. Most of the flights arrive and depart in two peak time periods: in the early morning and late afternoon. These are the most interesting time slots, thus the airport demonstrator simulates one of this peak time periods, i.e., approximately 80 to 100 flight movements.

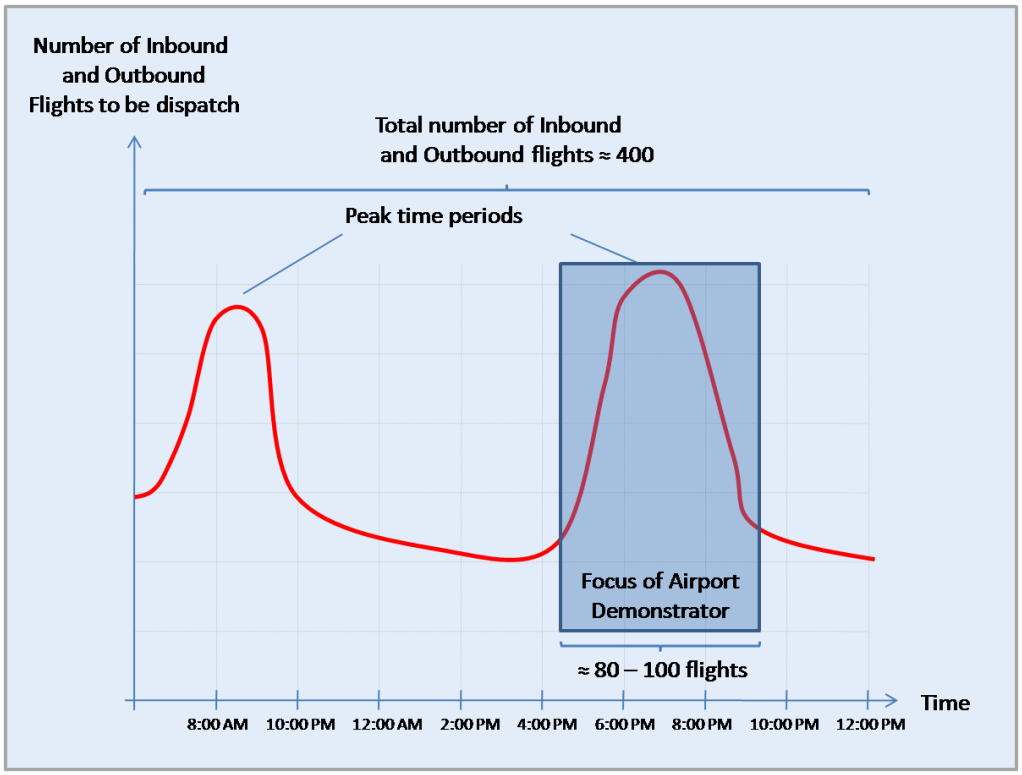

Figure 5 - Time frame of the demonstration.

For the purpose of demonstration the real-world data of one day has to be adapted in order to cover all requirements of the three demonstrators that have been defined as Normal Airport Operation, Process Adaptation, Process Re-Planning. The organizational setup is consisting of three independent ground handling companies and the airport authority, acting as a neutral provider of flight data

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Figure 6 - Represented organisations in the demonstrator.

The complexity of the demonstrator has been chosen in a way that real word conditions were matched.

Parameter	Final Demonstrator
Number of ground handling companies	3
Number of resource types	3 (bus, luggage, un/loading crew)
Number of resources	58
Number of service types (offered by resources)	5 (PassengerTransportation, Deliver2Flight, DeliverBaggage2ClaimArea, Loading, Unloading)
Service description complexity	Additional parameters
Planning horizon	full day
Number of airlines	15
Number of aircraft types	18
Number of flights	82
Number of SLAs	676 SA-SLAs
Intra-process dependencies	Yes, as described in D3.3.5
Inter-process dependencies	Yes, as described in D3.3.5
Time frame	06/03/09, 16:30-20:30
Time unit	1 second internally 1 minute in simulation

Figure 7 - Demonstrator complexity.

2.3.2.2. Conclusions

The overall experience with the airport management scenario and its demonstrators was very positive. It got obvious that the innovations resulting from adopting Grid

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computing to the logistics domain and introducing decentralised coordination mechanisms can help solving critical problems in short-term resource allocation during peak times.

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3. BREIN Impact

3.1 BREIN Achievements

BREIN had a set of objectives, which were identified to be of utmost importance to be addressed for fostering the uptake of Grid in business.

Summarizing, the four main objectives for BREIN were to enable/enhance (1) Autonomy and Automation, (2) Self-Optimization, (3) Context-Aware Security and (4) Reduced Complexity of Use. This all was targeted by integrating two so far in parallel developed technology domains into the Grid – Multiagents and Semantics.

During the projects lifetime a set of achievements has been reached, which will be detailed in this section, referring also to the above mentioned four main objectives.

Autonomy and Automation

With respect to this objective, BREIN has achieved several enhancements of the State of the Art. With the integration of Multiagent concepts, an Agentification of Grid Resources is now possible, meaning that BREIN represents each grid resource and service provider by means of goal-driven software agents based on the Semantic BDI architecture paradigm. Thereby decentralized coordination mechanisms were embedded into the BREIN Framework which allow now for use of reverse and combinatorial auctions for resource allocation (such as the Combinatorial Contract Net Interaction Protocol, CCNP). In terms of Resource Reallocation based on SLAs, the BREIN Semantically Enhanced Resource Allocator toolkit enhances the resource allocation mechanism in SP by using semantics and virtualization technologies allowing this task to be automatic. BREIN foresees that all SLAs offered are in-accordance with the management policies of the service provider. These policies can be priority-driven (based on the overall business goals/objectives of the service provider) and with that, they will influence the decisions taken in the system. The Resources themselves can behave in a self-adaptive manner, to ensure fulfilment of SLAs. In case of unexpected events, the BREIN resource management framework adapts the resources automatically and by that enhances the reliability level for the User.

Self-Optimization

BREIN provides enhanced Discovery and Service Selection functionalities, by supporting semantic annotations of service properties. The same annotation mechanism also enables the automation of negotiation of Service Level Agreements which at the same time take into account the business policies and goals of the respective participants. Whilst the overall BREIN framework targets the fulfilment of SLAs, the concept of preventive SLAs (adaptation of the SLA document with thresholds to enable early detection of upcoming violations) tries to avoid violations where possible. This implies also Risk Management technologies on side of the Service Provider as well as for the Customer. As BREIN bases on the concept of Goal-Orientation, BREIN adopts and extends the BDI paradigm which requires representing goals of each software agent and thus actor in the Grid formally and explicitly based on a common conceptualization of the domain (BREIN Scenario Ontologies). With that it enables Agent-based SLA Negotiation, Adaptive Workflow Execution and Agent-based Resource Allocation.

- Context-Aware Security

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- The BREIN security functionality addresses the challenge of bridging between the high-level security requirements that stem from businesses' objectives on one hand and the concrete security configuration at the deployment level on the other hand. In particular, BREIN addresses the dynamic nature of virtual organizations, e.g. the fact that employees of new customers dynamically need to be provisioned with access to a provider's services. Previous systems often ignored the fact that subtle changes in a user's 'context' must result in different authorizations. In addition, BREIN addresses the necessity to put security controls on resources which are outside of the own organizational boundary.

    - Reduced Complexity of Usage

- Of utmost importance for BREIN being a success was the balance between of complexity of provided solutions and the easy access towards using them. BREIN hides the complexity of the framework by extensive automation, e.g. allowing for automatic creation of virtual machines on-demand, encapsulation of the resource infrastructure (Infrastructure as a service, being transparent to the Service Provider). The semantic annotation of Resource, Workflow, Service (and by that SLA) descriptions enables enhanced capabilities of specification of terms and their mapping within the system. Most prominent is the Semantic Annotated SLA specification which was developed during the projects runtime.

3.1.1. Future Work

The list of achievements is long, however, not all results of BREIN can be considered to be in a product, commercial-like state yet, which means that further work is necessary to conclude the according developments. Given the status, we can identify three main areas of remaining gaps to improve commercial interest in the results:

3.1.1.1. Missing Features

Some of the components and exploitation items still lack some features and capabilities that would make their usage (more) appropriate for commercial usage. This was all detailed in D5.6.2 – Evaluation Report, which is available as a public document on the website. In most cases, the according features are comparatively simple to realise, yet were not so far in the primary interest of the project - this involves in many cases graphical user interfaces for controlling behaviour or executing configuration.

3.1.1.2. Integration

BREIN's primary concern rested on innovation, rather than on full-fledged integration of the system to a standalone BREIN framework. It is the principle of all Service Oriented Architecture that through the modularity of the components, higher capabilities can be achieved than through large-scope processes. In particular in the course of BREIN, additional features were identified that are only available through integration of capabilities originally not planned to work together. For example, it has been noted that the Messaging Infrastructure could provide additional capabilities by integrating service discovery into its policy handlers.

3.1.1.3. Stability & Usage Scope

Finally, another gap relates to the stability and range of applicability of the respective items. Agent systems are typically specialised for a specific usage scope

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and additional adaptation work is needed for applying reasoners to new domains. As can be seen by the individual test-bed scenarios, the overall concept of BREIN applies equally well to different scenarios, if some time is vested on adapting the configuration etc. The BREIN framework is not completely independent of the actual usage scope it is applied to, even though it shows wider applicability than comparable frameworks incorporating both general and specialised capabilities.

To further the scope of usage, additional information sources, such as a policy handler repository for the messaging infrastructure or more general mechanisms for SLA negotiation (in terms of higher automation degree and flexibility with respect to the protocols) is needed.

3.2 Dissemination, Collaboration and Standardization Impact

3.2.1. Dissemination Impact

- In total, there have been 47 conference papers, with a number of them on high quality (A-rated) conferences: e-Science, AAMAS, ESWC, NCA, GRID, and ECIS. Two of the BREIN conference papers were also awarded with the Best Paper Award. There have been almost 100 presentations of BREIN to both industrial and academic events and a number of successfully workshops have been organized, with an international public and various presentations of BREIN. During the last phase, there have been also increased demonstration activities where BREIN results have been exposed in a number of exhibitions.
- After the first slow start phase of the project website, the page views and visits on the BREIN portal have been constantly increasing, reaching a number of around 20.000 page views and more than 1.500 unique visits by the end of the project. From monitoring our visitors profiles we can summarize that the most visited sections of the website has been the Downloads and the Publications sections, where most of the BREIN public material can be found (Publications, Presentations, Demo videos, the BREIN CD, public deliverables, Training material etc). In specific, there have been around 13.000 downloads of the public deliverables, with the most downloaded being the State of the Art, the Modelling Framework and the Glossary deliverable. The Business Whitepaper was also one of the most downloaded of the other items with 500 downloads.
- There were around 300 websites referring to BREIN website through a direct link and most of the visitors' traffic (>60%) has been originated by Google search engine.
- **Plans for continuation after the project end**
- In order to ensure the continued access to the software and the know-how obtained from the BREIN project, the consortium has started a close collaboration with IT-Tude (www.it-tude.com) so as to progressively move the most important content to this portal. IT-Tude is a cloud computing and grid related meeting point between research and business, and is expected to follow the success of Gridipedia in this area, with an increased number of visitors. To start with this collaboration, a dedicated BREIN project website has been created (www.it-tude.com/brein.html) where general information on the BREIN project can be found: a description of what is BREIN, the main objectives of the project, its architecture and a description of the basic software components of it, the Exploitable Items. Currently the Ontologies and Glossary wiki are also being transferred there and as a next step, the portal will also

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serve as a repository, where all the software components (EIs) now available at the BREIN website will be also available and obtain higher visibility and promotion.

3.2.2. Collaboration Impact

BREIN has collaborated with 47 other European projects over the lifetime of the project, as well as numerous national projects. BREIN has also supported the formal concertation process, chairing a majority of the technical working groups and co-organizing one of the yearly major concertation events.

Some of the key collaborations have been with:

- Akogrimo, which has supplied prototypes of many of the services that BREIN built up into our architectural fabric.
- BEinGRID, where we have been sharing approaches to SLA negotiation and have contributed content to the IT-Tude site.
- CoSpaces, which has adopted the BREIN messaging framework as one of their fundamental components.
- NESSI, where we have been contributing our architectural approaches, particularly in the areas of agreement formation and workflow management.
- PlugIT, which is adopting both our knowhow and components for modelling of services in a business context.
- Stasis, with whom we have organized a major workshop on semantic systems and technology.
- TrustCom, which has been a major contributor of technology for describing service level agreements.

3.2.3. Standardization Impact

BREIN participated in a number of standardization groups. Project partners were members of 11 standardization groups holding 4 official positions (such as chairs, secretaries, etc.). BREIN contributed to 6 specifications and provided 12 another contributions. The most important are the following:

- OGF Grid Resource Allocation Agreement Protocol Working Group (GRAAP), WS-Agreement and WS-Agreement Negotiation specifications. Presentation of the WS-Agreement/WSLA merge approach. Discussion about the necessity of defining a new language. Review and comments on the WS-Agreement Negotiation approach. Presentation of the negotiation protocol.
- OGF Grid Resource Allocation Agreement Protocol Working Group (GRAAP). The SA-SLA presentation to the GRAAP WP group during OGF25 in Catania.
- OGF JSDL-WG, JSDL v1.0.1 specification, Parameter Sweep extension, Activity Instance Document Schema. Specification co-authoring (authoring of sections). Providing input on the parameter sweep extension design (based on experiences gathered with implementation of simple own extension for parameter sweep jobs).
- OGF DRMAA-WG / DRMAA 2.0. The advance reservation interface is API in a look and feel of the DRMAA specification – the ARES API presented at the meeting with DRMAA group representatives. BREIN components that use

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ARES also presented during OGF25. A specification of ARES was proposed to the group will be discussed at OGF28.

- OGF OGSA Basic Execution Service (OGSA-BES), OGF OGSA HPC Profile (OGSA-HPCP). Components that use HPC-Profile and the advance reservation extension presented during OGF25. The experience report on use of OGSA-BES and OGSA HPC Profile prepared for OGF28.
- OGF OGSA Information Modelling Guidelines. Reviewing & feedback, example design.
- OGF OGSA-RSS-WG Resource Selection Service (specification authoring). This suite of specifications captures many of the BREIN experiences with advanced service discovery.
- OGF Usage Record Production Profile (OGF OGSA-UR WG). Specification authoring, taking into account the experiences acquired during BREIN.
- OGF Grid Scheduling Architecture Research Group (GSA-RG). Participation in a definition of scheduling scenarios and requirements as well as interoperation tests.
- eCl@ss – International Standard for the Classification and Description of Products and Services. Co-editing of new segment 43 entitled "Logistics Services", providing basic concept, contributions to all sections of the specification.

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4. Conclusions

BREIN has successfully validated the “Brain meets brawn” concept. The Framework was designed and partially implemented and validation took place according to two distinct scenarios (“Virtual Engineering” by ANSYS and “Logistics at the Airport” by the Stuttgart Airport).

The project achieved to evolve diverging research in business grid into a coherent architecture/concept and ended at a state allowing alignment and validation of the framework with the new upcoming Cloud (Infrastructure) Technologies, such as Amazon EC2.

With the successful integration of Semantics and Multiagent concepts into the Grid, a more powerful and flexible solution has been provided, which is closer to Clouds as they are targeted as of today, then to the classical Grid concepts.

An important lesson that was learned within the duration of this project was that embedding “foreign” concepts and technologies can help to overcome the restrictions of the current State of the Art. Even though, this multi-domain integration requires high efforts to align the different viewpoints from the domain experts and to bring them on a common knowledge and language level. This should be taken into account when planning further activities like this.

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