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| 1.2     | May 2007       | Intermediate version for the Community for the SOI-NWG workshop   |
| 1.5     | July 2007      | Draft for second official SRA version <ul style="list-style-type: none"> <li>• revised introduction (sharpened context; added stakeholder description)</li> <li>• extended/revised scenario (added mid- to long-term scenarios; refined derivation from vision; refined impact description)</li> <li>• refined state-of-the art (refined structure; extended scope)</li> <li>• refined challenges (extended according to full set of scenarios; added technical drivers; added correlation with requirements)</li> <li>• added description of community involvement process</li> <li>• added business indicators section</li> </ul> |

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## Executive Summary

The Networked European Software and Services Initiative (NESSI) aims to create a strategic research agenda for European research in services and their foundations. NESSI-Grid forms part of that activity by defining a vision and strategic research agenda (SRA) for grid infrastructures used in business environments and in particular in NESSI scenarios. A first version of both, vision and SRA, focussing on more short-term challenges is presented in this document. It addresses all stakeholders in this field, in particular researchers, industry and policy makers, to get a precise understanding about envisioned scenarios, state-of-the-art, challenges, business impact and actual roadmaps and recommendations for realizing the vision.

### The Driver

The main driver behind this SRA is the fact that businesses in future service-oriented economies need to act in a more agile fashion than ever before. This will be possible only if high-level business requirements can be translated into lower level ICT requirements with a high level of automation, so that ultimately the ICT environment adapts automatically to changing business needs.

### The Vision

We envision *Business Grids as the adaptive service-oriented utility infrastructure for business applications*. They will become the general ICT backbone in future economies, thus achieving a profound economic impact. The adoption of Business Grids is expected to happen in 3 steps: first as the ICT backbone within enterprises, second as a basis for hosting scenarios and ultimately as the general ICT-infrastructure for service-oriented economies. In this way, Business Grids will eventually support the emergence of new types of application.

### Business Scenarios

The industry-driven approach of this SRA is evident in its identification of the most relevant core business scenarios and associated business requirements. The scenarios cover short-term perspectives (basic enterprise, hierarchical enterprise, hosting) but also mid-to long-term setups (extended enterprise, merger & acquisition, virtual organizations, dynamic outsourcing, value chains and mega services).

### Research Challenges

Research challenges for realizing the vision of Business Grids are systematically derived from the business scenarios. They result from three major sources:

- **Societal requirements:** most important here are issues on data management (both for compliance reasons but also as “brain” of an organization), accounting, SLA management and environmental sustainability.
- **Technical trends:** most important here are application development for advanced hardware environments (e.g. multicore) and better integration of network characteristics into applications and architectures.

- **Non-functional requirements:** these cover the full variety of issues, such as dependability, security, performance, interoperability, manageability, governance, and flexibility.

# 1 Introduction

The Networked European Software and Services Initiative (NESSI) aims to create a strategic research agenda for European research in services and their foundations. NESSI-Grid forms part of that activity by defining a vision and strategic research agenda (SRA) for service-oriented infrastructures used in business environments and in particular in NESSI scenarios. The anticipated service-oriented infrastructures are supposed to leverage traditional Grid infrastructures, which ultimately aim at providing resources as a utility, to general purpose applications and business scenarios. The term *Business Grids* has been adopted to describe those infrastructures.

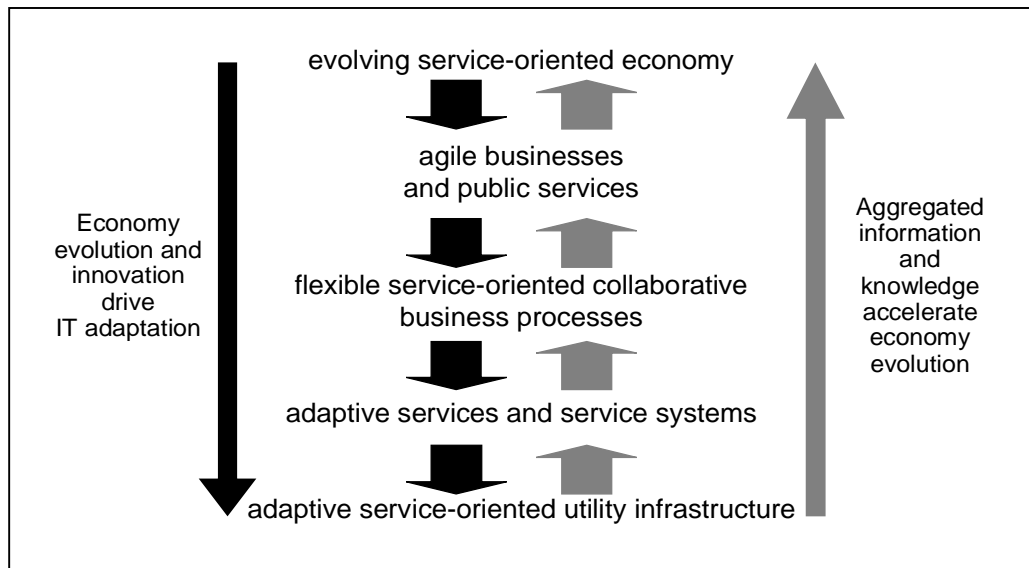
This document presents a first version of both, a business-driven vision for grid-like infrastructures as well as a first approach to a strategic research agenda and its related research challenges. Rather than describing vision and SRA in two separate documents, we decided to combine both deliverables into one document as they have a significant overlap. The vision as such is explained on a high level in the first section but also refined through various business scenarios, presented in Section 3. On the other hand, the business requirements used to characterize those scenarios in more detail as well as the order of the scenarios is already a first step towards the SRA. The SRA is then refined by concrete research challenges in Section 5. Section 6 presents the community involvement process to gather input from the wider grid community and Section 7 introduces the approach to characterize relevant business and market indicators. Section 8 provides a short conclusion.

This document is addressing all kinds of stakeholders, in particular industry, researchers and policy makers. *Industry stakeholders* will get a vision of future IT infrastructures, their related business scenarios, current technologies/challenges with respect to those scenarios as well as the specific business impact. *Researchers* get guidance for industry-relevant research topics. *Policy makers* get an understanding of possible areas of influence and anticipated market impact.

## 1.1 Vision

The main driver behind this SRA is the relationship between high-level characteristics of service-oriented economies [1] and supporting Information and Communication Technology (ICT) infrastructures. This is depicted in Figure 1.

Businesses in future service-oriented economies need to act in a more agile fashion than ever before. This will be possible only if high-level business requirements can be translated into lower level ICT requirements with a high level of automation, so that ultimately the ICT environment adapts automatically to changing business needs. Figure 1 shows the different stages of this translation process.



**Figure 1: Agile businesses drive adaptive IT**

In detail, an evolving service-oriented economy will lead to new requirements in the sense that existing businesses and services must react more quickly to changing circumstances. This means that they must adopt more flexible service-oriented business processes and be able to exploit collaborative relationships. Software technologies enabling the implementation and composition of flexible services will be important in achieving this and are now being seriously addressed by the software industry. This can be seen in the widespread trend towards service-oriented architectures and business processes built upon this architecture. At the infrastructure level, an adaptive service-oriented utility infrastructure will allow the dynamic, on-demand allocation and assembly of resources needed to support service components and assemblies. A crucial prerequisite for this layered adaptability is a proper information flow translating higher-level business goals into lower-level technical goals and aggregating lower level characteristics to higher-level capabilities.

We call this envisaged adaptive service-oriented utility infrastructure “*Business Grids*”. Business Grids will become the general ICT backbone in future economies, thus achieving a profound economic impact. In this respect they differ significantly from traditional e-Science grids. These focus on specific application areas often aiming to provide shared access to specialised high performance computing resources or datasets. Typically they deal with independently executing, stateless batch jobs which can be easily moved around a network and executed based on some given input files. In contrast to this, Business Grids are a general purpose infrastructure for arbitrary business applications, primarily aimed at providing business flexibility efficiently. Typically, business applications do not exist as independent executables but involve a complex technology stack, containing for example application servers, databases, other middleware components and other co-existing and cooperating business applications. In addition, usage patterns are often interactive or session-based. Transactions are used across all tiers to guarantee data consistency.

We anticipate that Business Grids will become the major ICT infrastructure via the following scenarios:

1. Business Grids will be the ICT backbone for enterprise solutions.
2. Business Grids will support hosting scenarios for small and medium sized enterprises.

Based on these two initial scenarios and as the interworking between administrative domains becomes commonly accepted and is supported as part of the infrastructure this will evolve to the following:

3. Business Grids will be the ICT infrastructure to support service-oriented economies and eventually support the emergence of new types of applications.

It is, of course, important to note that these developments will require changes in business culture which will undoubtedly influence the timescales for change.

## 1.2 Technical scope

Figure 2 shows the main ICT layers of existing business solutions.

|  |
|--|
| Applications (e.g. collaborative business processes) |
| Business logic (e.g. business web services)          |
| Middleware (e.g. application server)                 |
| Infrastructure (e.g. OS, hardware)                   |

**Figure 2: ICT layers of business solutions.**

Broadly speaking, the infrastructure layer is about the provisioning of any kind of hardware resources (compute power, storage, network, sensors, actuators) together with associated low-level software components (e.g. operating systems). Middleware covers generic software functionality such as application servers (e.g. J2EE), databases, messaging services, portal frameworks and also serves for hiding technical complexity (distribution, heterogeneity) from application developers. The business logic layer includes specific business functionality (e.g. processing a purchase order) while the application layer combines business logic in concrete usage scenarios (e.g. a procurement system). It is important to note that these layers do not have well-defined boundaries but are presented as an illustration of different technical areas which are relevant within business solutions.

Business Grids primarily target the infrastructure layer and partially also the middleware layer. They follow the paradigm of a Service Oriented Knowledge Utility (SOKU) [2]. The overall SOKU vision goes far beyond infrastructure problems as it “identifies a flexible, powerful and cost-efficient way of building, operating and evolving IT intensive solutions for use by businesses, science and society”. Applying the SOKU paradigm to Business Grids means that Business Grids offer infrastructure resources to higher levels according to the following main principles:

- service-oriented (i.e. dynamic allocation and assembly of resources via infrastructure services)

- knowledge-assisted (i.e. translating high-level business requirements to infrastructure requirements and infrastructure capabilities vice versa)
- utility (i.e. immediately available, dependable usage, predictable).

Business Grids need to be able to participate in the execution of the business models of the applications they support in an accountable fashion, addressing issues including auditing, billing, and linkage of resource consumption to business goals. In this context, Business Grid solutions will span several ICT layers.

### 1.3 Non-goals

Following the described scope it becomes clear that research questions related to higher layers of ICT solutions are out of scope for research in Business Grids. In particular this is the case for business models, human aspects, and business services.

- *Business Grids will not address isolated low-level grid business models.* Several trends in hardware, software, and the relative cost of IT operations conspire to make it nearly impossible to construct viable business models just around low-level grid services in isolation from the supported applications<sup>1</sup>. The added value stems from the actual services offered on top of the grid which may include provision of resources as managed services with assured performance levels.
- *Business Grids will not address human aspects* such as political, organizational or cultural issues.  
Business Grids present themselves as a utility; they are invisible to the user and even largely to the developer of applications, business logic, and middleware.
- *Business Grids will not address issues of business service engineering and service provisioning (other than provisioning of infrastructure services).* This will be addressed in other parts of the overall NESSI-SRA.
- *Business Grids will not address aspects of public networking infrastructures* which are typically provided by a network operator.  
Instead they focus on the infrastructure elements that belong to the providers of business services.

### 1.4 Methodology

Business Grids are about the provisioning of infrastructure resources to business services as infrastructure services. As resources are always bound to an *administrative domain* (there is always an entity with ultimate authority over the management of a resource), the approach of this document is based on the distinction between the following two cases: provisioning of resources within one domain and provisioning of resources shared between several domains.

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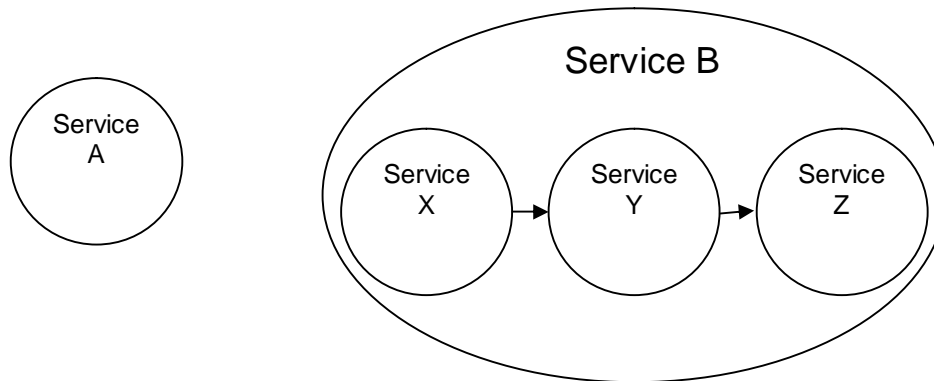
<sup>1</sup> Compute cycle, network and storage costs will continue to decrease for the next few years. Purchased network capacity, software and higher-level service costs, including infrastructure management will remain relatively unchanged. Thus the share of pure hardware costs in overall IT operation costs becomes more and more irrelevant, inhibiting companies from basing their business models on commodity resource provisioning (argumentation taken from [3]).

Consequently this document is structured as follows. Section 2 provides a basic model for describing Grid scenarios with respect to administrative domains and associates them with basic business characteristics. Section 3 details some important business scenarios that can be expressed by means of the basic model. Three of the business scenarios which are assumed to have most short-term relevance are described by fairly detailed business requirements. Section 4 reflects the state of the art, both in academia and industry. In Section 5, research issues corresponding to the short-term business scenarios are derived. Section 6 features the community involvement process followed by Section 7 which details the approach for describing relevant business and market indicators. Section 8 ends with a brief conclusion.

## 2 Basic Model

### 2.1 Services

At the core of the NESSI vision are services. Consider the diagram below:



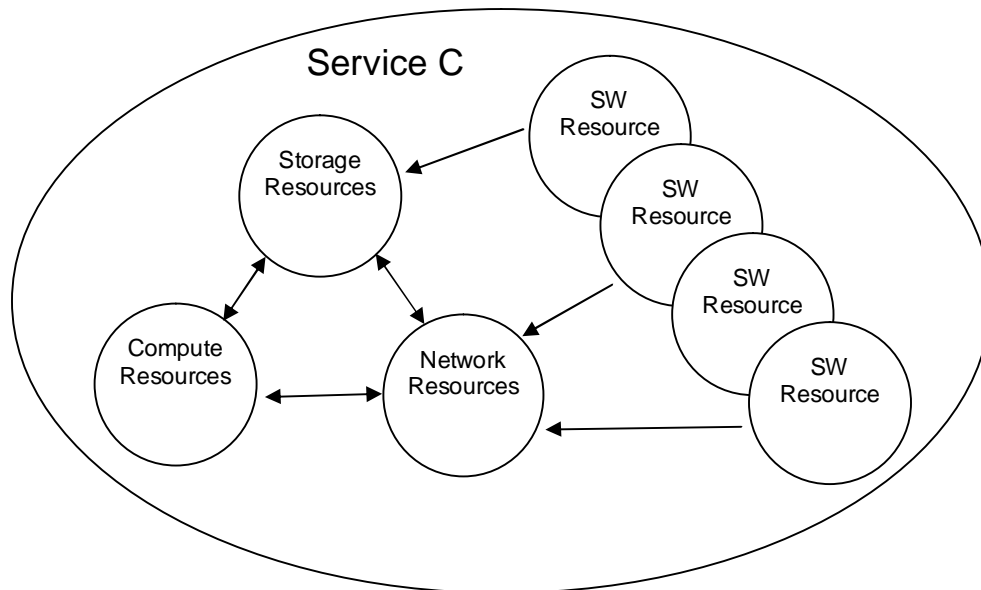
A service provides a given capability. It may be “simple”; e.g. service A, in that it provides all of the required functionality contained within itself. Alternatively, a service may be “complex”; e.g. service B, in that it may itself be made up from other services combined in some fashion. Note that the diagrams above are not intended to show the “ownership” of any given entity. It is perfectly possible that Services X, Y, Z and B are sourced from different organisations.

Services are provided and consumed. This is the case whether they are “simple” or “complex”. Relationships between organisations can be expressed in terms of this provision or consumption of services.

- A service may be provided to one organisation for its own consumption.
- A service may be provided to an organisation which consumes it to in turn provide another (complex) service.
  - Services thus provided may be provided “as-is”
  - Services thus provided may be augmented or extended in some (value-added) fashion

Services may have explicit or implicit relationships with one another. These relationships may in turn be expressed or maintained by other services (e.g. by a brokering service, a lookup service, an identification service etc.). Relationships may be static or dynamic. These service relationships allow common business models to be supported.

A service (whether simple or complex) implicitly uses resources to deliver its capability. An example of this is shown in the diagram below:



Service C uses a number of underlying hardware (e.g. compute, storage, networking, etc.) and software (e.g. operating system, applications, licences, etc.) resources. Note that there may also be other types of resources used by some services. These resources are implicitly inter-related. As in the case of the services described earlier, there is no implied “ownership” of any resource in this diagram. An organisation may use resources provided by another to deliver a service. Resources, as with services, may be provided or consumed.

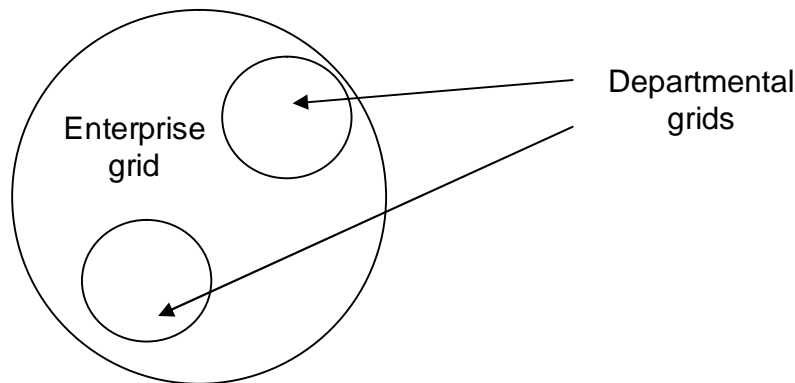
By treating these underlying resources as just another case of a service, then we can see that we can use the same models (implicit / explicit and dynamic / static relationships) to describe the relationships of both the underlying resources to one another as well as the relationships of these resources to the services they support. These relationships between services as well as those between services and their underlying resources need to be well integrated and optimised. Whilst this simple model implies that the relationships between different services and the relationships between services and resources may be expressed in a similar fashion, this does not imply that they can be implemented in a similar fashion. Currently, relationships between different services lack the efficiencies and optimisations that are found between resources and the executable software they support.

## 2.2 Enterprise grids

An “enterprise grid” is the starting point for this discussion. This is a grid within a single enterprise. The main factor identifying an enterprise grid is that it exists within a single administrative domain. An administrative domain in this context is defined by the existence of a common set of management policies. It is likely to also include a specific set of identifiers to refer to relevant entities. The enterprise grid is made up of the lowest level resources: computing, network, storage, and basic services that make these resources available for use.

### 2.3 Departmental grids

Enterprise grids naturally include those grids implemented across different departments within a wider organisation. A “departmental grid” is implicitly a subset of an enterprise grid. The diagram below shows this relationship:

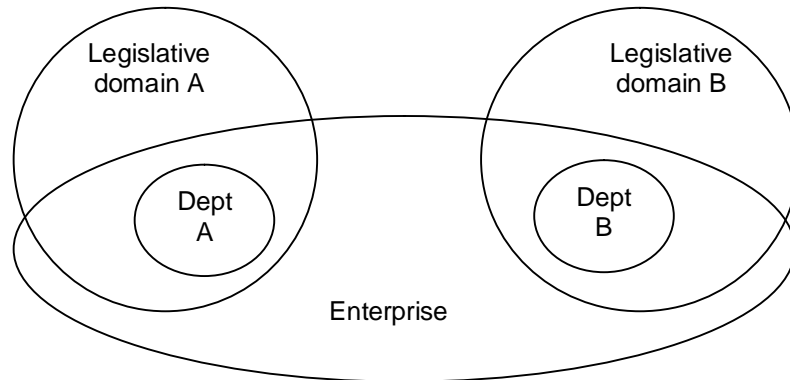


The enterprise grid can be regarded as a “grid of grids” i.e. a specific instance of a “system of systems”. It could also be regarded as demonstrating some other hierarchical relationship between the departmental grids that make it up. The depth of this relationship will define the capabilities of the enterprise grid and the attributes that it exhibits. A very basic relationship may mean that the ‘enterprise grid’ is nothing more than a loose collection of departmental grids and as such adds little value or capability. At the other end of the spectrum is a more tightly integrated vision that delivers a synergistic value to the entire enterprise through the harnessing of all resources in an enterprise. The ability of a given departmental grid to harness resources within and external to itself will vary, based upon the degree of integration. Some enterprise IT organisations are already setting up internal ‘utilities’ to provide services and resources to other parts of the enterprise. In general, these enterprises have a higher degree of sharing / utilisation than others that are less integrated.

Within an enterprise, resources or services will be owned (in the sense of ultimate authority over usage) by someone. These may be part of an identified ‘grid’ within a given department or might be owned by ‘corporate IT’ in some other fashion. In any case, they ought to be able to be utilised (subject to the appropriate permissions etc.) without necessarily formally being part of a departmental grid. Using the ‘internal utility’ analogy, a resource/service within such a utility can be used by a departmental grid without being part of it, though implicitly if the internal utility is built using grid-like primitives then there is sharing between grids demonstrated here too.

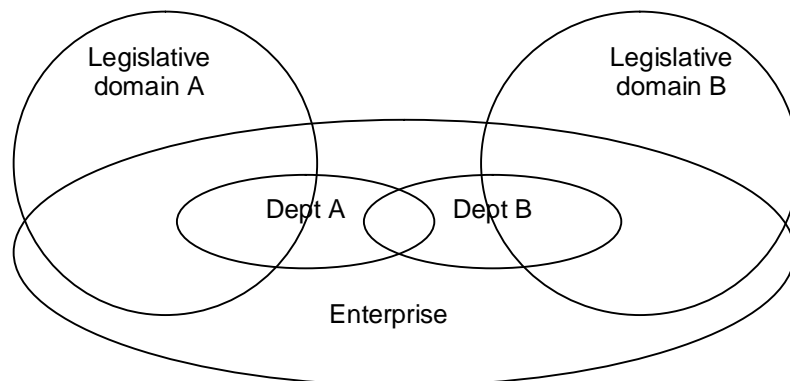
In general, any departmental grids within the same enterprise will come under the same set of enterprise administrative policy rules. For instance, they are both likely to have to conform to similar security or data protection requirements set by the enterprise as a whole. This is not always going to be the case however. Any enterprise that spans multiple countries (and hence multiple legislative domains) may have different local legal requirements (say around the protection of personal information) which need to be complied with. Similarly, some enterprises do not mandate rules to be adopted (or some

departments choose to ignore them!). In any case, there are some problems to be solved in terms of what resources can/cannot be used by whom. Consider the following diagram:



In the diagram above, we see two different departments (A and B) within a single enterprise. Each department is subject to a different legislative domain (A & B respectively). It can be seen that if there is NO overlap between the two legislative domains then there is a fundamental limit in terms of what can be shared between them. Note that this does not necessarily preclude the sharing of computational resources, but may well completely prohibit the sharing of data. This will have implications in terms of how isolation between different services and resources can be achieved (and proven to the satisfaction of the respective legislator).

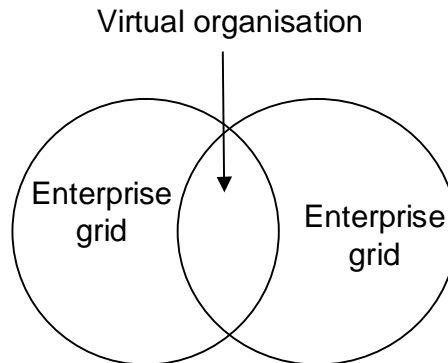
The reality of the situation is usually such that any given enterprise will have a consistent subset of administrative rules that comply with all of the legislative domains within which they operate. This will allow for the sharing of resources without major restrictions thus:



It is not the purpose of this SRA to define mechanisms to overcome shortfalls in enterprise (or departmental) administrative policy setting or in circumventing legislative restrictions. Departments that are inherently forbidden to share resources with others will be unable to do so regardless of any NESSI framework. The NESSI framework should allow such restrictions to be expressed and enforced. However, in those environments where there are consistent legal rules, then the NESSI framework should allow for the appropriate sharing of services and resources according to these rules.

## 2.4 Virtual organisations

Virtual organisations form when two or more enterprise grids intersect; more correctly when the two administrative domains (and hence their enterprise grids) overlap and share resources. The reality of a VO is that only a subset of the overall grid within an enterprise is likely to be “contributed” to this virtual organisation. The majority of the systems within a given enterprise grid are likely to remain outside the VO. The diagram below shows this VO relationship:



For the most part, contracts in the business world are between two parties. We believe that the abstractions used to describe the interaction of two administrative domains are good enough in general to be a means to describe the interaction of multiple domains (e.g. companies). Consider a tri-party agreement. This may be formed between the parties A, B & C in such a way that individual bi-party relationships describe the interactions, i.e.

- A – B
- B – C
- C – A

An alternative might be the case where the three parties form a consortium D, in which case, the relationships are between the parties and the consortium itself, i.e.

- A – D
- B – D
- C – D

Two kinds of inter-organisation relationship are typical within the business world. The first is a “master / slave” relationship. This is an asymmetric relationship where one party takes on the rules and policies laid down by the other. A typical example of this might be a sub-contractor interaction with a large manufacturer. All of the sub-contractors must meet the rules of the large manufacturer as a condition of doing business with it. One administrative domain has priority over another, such that the policies of the VO describing the relationship may be indistinguishable from the policies of the master.

The second relationship is “peer-to-peer”. This is a symmetric relationship between the two parties. Most inter-organisation relationships fall into this category. This differs from the “master / slave” relationship in that neither administrative domain has priority over the other. The policies of the VO describing the relationship are likely to be some combination of the policies of the contributing organisations.

### 3 Business Scenarios

This section describes a number of common / emerging business scenarios. The purpose of these scenarios is twofold: First, they serve for exemplifying the general Business Grid vision in a concrete context. Second, they form the basis for concrete business requirements which impose various technical requirements and challenges and ultimately lead to the overall strategic research agenda.

#### Methodology

The presentation of business scenarios is structured according the basic model introduced in Section 2. The initial enterprise scenario is used as baseline based on which all the other scenarios are described as extended (and consequently more complex) setups. Each scenario will focus on its specifics which make it different from any predecessor scenario.

Scenarios differ in when we expect them to become relevant in the context of Business Grids. The first three business scenarios (enterprise, hierarchical enterprise, hosting) are assumed to have most short-term relevance. Others (such as Value Chains) are assumed to have more long-term relevance.

The presentation of each scenario is introduced by describing the general setup, followed by the scenario-specific vision of Business Grids and its expected business impact. Then, the specific business requirements are detailed (including their relevance for the business) out of which research challenges are later derived in Section 5.

Business requirements are discussed according to the following major categories:

- *Functional & commercial issues*, i.e. issues stemming from functional requirements typical for enterprises that want to use business grids. Especially important in this area is the commercial context under which business grids are operated. This covers issues such as service level agreements, cost and revenue agreements, etc.
- *Dependability*, i.e. the trustworthiness of a computing system in terms of availability, reliability and safety. Dependability covers issues such as redundancy, autonomy, quality of service etc.
- *Security* which we list as separate issue from dependability because of its paramount importance in business interactions. Security covers issues such as confidentiality, authentication, integrity, authorization, etc.
- *Performance*, i.e. the system performs and uses resources in an efficient, predictable and accountable way.
- *Interoperability*, i.e. the inter-working with other systems including legacy systems.
- *Manageability*, i.e. the easy, transparent and low-cost management of systems in particular including their maintenance.
- *Governance*, i.e. the specification and assurance of requirements and policies at various levels.
- *Flexibility*, i.e. the capability to react on/implement changed business requirements as fast as possible. Specific issues in here are about scalability etc.

- *Sustainability*, i.e. the ability to meet environmental criteria in both purchasing and design decisions.

These categories are neither complete nor completely independent from each other. However, they serve as our major perspective under which we present the following requirements as well as the various research challenges discussed in Section 5. Except for the first one, all categories focus on non-functional requirements and as such are often hard to express, measure and quantify in current business systems.

### 3.1 Enterprise

#### Setup

Basic enterprises consist of one homogeneous administrative domain. Following Section 2, they can be supported by basic enterprise grids which should provide general-purpose infrastructure services within one domain and which should ultimately act as the ICT backbone for the complete IT infrastructure.

#### Vision & Expected Impact

The vision of Business Grids for the Enterprise follows the SOKU vision (service-oriented, knowledge-assisted, utility) as it aims for

- Providing IT resources as a service to the whole organization; this will significantly improve the flexible usage of IT resource within an organization, in particular for non-technical experts.
- Transparency on IT resources and related business figures; this will be a milestone for further industrialization and professional usage of IT within enterprises.
- IT provisioning and management as a utility; the simple and dependable usage of IT will allow for significant operational savings compared to today's systems which still require a lot of manual maintenance.

Overall, Business Grids will change the role of IT in companies from being seen as a cost driver to be an enabler for agile businesses.

#### Business requirements

The basic enterprise scenario imposes the following major business requirements.

##### Functional & Commercial

- To support the **reliable and secure management of business data**. This is vital to any business as all of its internal activities eventually materialize in changed business data.
- To allow for **operating IT infrastructures as a business**. This includes complete transparency on how system parameters or setup decisions affect the total cost of ownership.

##### Dependability

- To allow for **high availability** of (possibly virtualized) infrastructure resources in case of failures or maintenance activities. This contributes to overall high

availability of business solutions facing the situation that already short downtimes in service-economies can lead to significant loss of money or even a company's bankruptcy.

- To support the **balancing of availability levels with economic costs**. This allows enterprises to tune the actual availability to the most profitable level.
- Enterprise grids should be **autonomic** in the sense that they should be able to independently repair and recover in the event of errors, including complete failure of system components.

### Security

- To reflect **security policies on infrastructure level** thus guaranteeing integrity and confidentiality of business data at the lowest possible level.
- To support application domain specific end-to-end (infrastructure to user) security demands.

### Performance

- The non-functional behaviour and in particular the performance of applications running on an enterprise grid should be **predictable and accountable**. Thus, users can know in advance what they can get and the resources used can be accounted for properly in order to have a transparent overview of who used which resources. This is especially important in service-oriented systems where services from different providers are composed to make higher-level services.
- To support **massive enterprise job scheduling** by pre-emptive and/or planned allocation/booking of the necessary infrastructure resources.

### Interoperability

- Enterprise Grids can be implemented **transparently to arbitrary business applications**. Thus, the benefits of enterprise grids can be applied to complex existing IT stacks in place today.
- They should be **standards based and offer effective interoperability** with other standards based services within and outside the enterprise.

### Manageability

- To allow for **homogeneous, low-cost, secure, easy and transparent management** of arbitrary infrastructure resources. This leads to maximum exploitation of available infrastructure resources with the lowest possible effort.
- To remain fully-functional while undergoing **incident based or planned maintenance**.
- To enable **on-demand provisioning and termination of services**.

### Governance

- To support the **transparent translation of business requirements and policies** to infrastructure capabilities and vice versa thus supporting their reflection and enforcement at infrastructure level.
- To reflect **enterprise policies on infrastructure level** via appropriate logging, tracking and auditing of resources and services. Such infrastructure support for compliance offers most robust and reliable implementation of governance policies

even providing some resilience to badly behaving software, unforeseen security holes or erroneous sizing.

### **Flexibility**

- To support **flexible changes of business processes and applications** which impact on the underlying infrastructure, such as dynamic allocation of additional resources. This supports the overarching goal of business agility, a major prerequisite for successful interaction in rapidly changing markets.
- To **dynamically adapt to meet demand** at any point in time in its operations to support sudden ‘bursty’ or unpredictable peak workloads on demand.

### **Sustainability**

- To support **sustainable operation** of data centres with lowest possible environmental resource consumption. Apart from simple cost savings this becomes highly important for public and customer acceptance of IT solutions.

## **3.2 Hierarchical enterprise**

### **Setup**

Larger enterprises are typically organized via a hierarchy of departments, each of which following the general enterprise policies while potentially deviating from them e.g. due to different legislative constraints.

### **Vision & Expected Impact**

The vision of Business Grids for the Hierarchical Enterprise is that they allow for a harmonized enterprise-wide infrastructure that is built upon a hierarchy of departmental grids. Again, Business Grids will follow the SOKU vision as they

- Allow for sharing of IT-resources in a service-oriented way.
- Transparently reflect the organisational structure of different enterprises.
- Support automated IT provisioning and management on enterprise level (where possible) and department level (where necessary).

Overall, Business Grids will be an enabler for efficient, flexible and transparent IT operation in complex enterprise setups. In particular, they will be an enabler for realizing changes in enterprise’s organisational structure to meet internal and external demands.

### **Business requirements**

In addition to basic enterprise scenarios, hierarchical enterprises impose the following major business requirements.

### **Functional & Commercial**

- To support both **central and local service level and cost level agreements** as different departments might be operated as almost separated business entities (e.g. different cost centres).

### **Security**

- To implement both **central and local security policies at the infrastructure level** and to support them at higher service levels.

### **Manageability**

- To respect **departmental boundaries in resource management** as departments might be willing to share some resources while others are used exclusively.
- To support **a consistent approach to management from central or local resource and service delivery platforms** including autonomic conflict management and resolution.

### **Governance**

- To **reflect enterprise policy hierarchies on infrastructure level**, either following a hub-spoke model (where the degree of centralised control and policy consistency with central directives is high) or a distributed model (where the degree of centralised control and policy consistency with central directives is low because individual policy controllers retain significant freedom within a loosely defined Enterprise IT policy framework).

### **Flexibility**

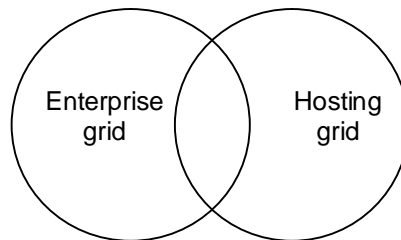
- To **propagate changes in the departmental structure** of the enterprise automatically to the IT infrastructure.

## **3.3 Hosting**

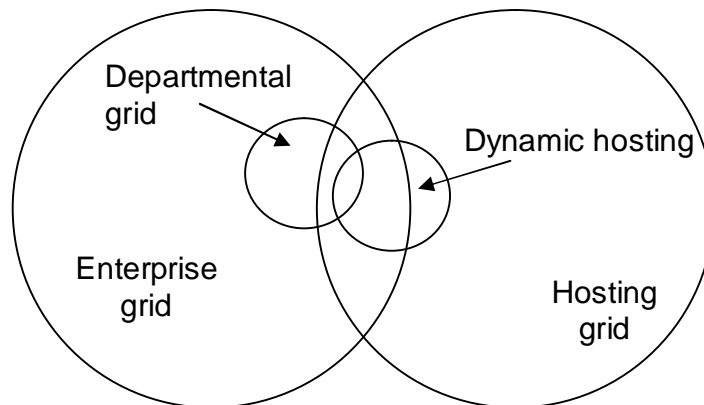
### **Setup**

An enterprise that provides hosting facilities can also be described using the terminology of an enterprise grid. Today, most hosting can be described to be 'static'; in that the resources and services are pre-allocated by the hosting company to the using company well in advance of them being used and are typically allocated for a long period of time (weeks, months, years). The relationship between the hosting and using companies is well-defined and also typically long-term. Static hosting relationships are quite predictable and hence can be billed in a well understood fashion. In the future, these static relationships will likely become more 'dynamic'. Dynamic hosting is typically much more short-term in nature. Hosting resources and services are allocated on demand and in as near to real time as possible. The length of time that a resource or service is allocated to the using company may potentially only be for a few seconds or minutes. Relationships between companies may similarly only exist for the length of time that the resources or services are being used. Dynamic hosting is much more unpredictable and is likely to require new billing and accounting mechanisms.

A hosting relationship is a variant of the Virtual Organisation, in that it is simply a special relationship between two administrative domains. Here we see a simple environment where the hosting company (represented by the enterprise on the right) provides resources to the consuming enterprise on the left.



Inter-relationships that are more complex can also exist; for example the provision of dynamic resources by a hosting company to a departmental grid within an enterprise. Such an inter-relationship can be shown thus:



Some complexity starts to arise here. There is a two-level relationship between the two enterprises. The former is the VO that is a high-level interaction between their two administrative domains (a company-to-company agreement). The relationship between the departmental grid and the dynamic hosting environment is then a special case relationship within, albeit still encompassed by the overlap of the two administrative domains. This special relationship is likely to be a subset of the VO relationship. These problems are relatively easy to solve in the case of a static hosting situation. As the hosting needs of the using company become more dynamic, the challenges of building (and maintaining) relationships, of creating the necessary security and interactive linkages and of managing the interaction between the two administrative domains become significantly harder problems to solve.

### Vision & Expected Impact

Apart from adding transparency and dependability Business Grids will support highly dynamic hosting scenarios. These are characterized by

- Automation support for negotiation and setup of hosting relationships and service level agreements.
- On demand (or at least near real-time) allocation of resources and services.
- Comprehensive management of the complete hosting lifecycle from enactment to decommissioning,

Business Grids will significantly impact hosting scenarios by supporting new hosting business models (e.g. software as a service) and by enabling short-term relationships

(down to a few seconds or minutes). Overall, they allow for much more flexible interactions between different organizations.

### Business requirements

Apart from the characteristics discussed above, basically all the requirements listed for (hierarchical) enterprise scenarios apply in hosting scenarios but to an even more rigorous extent. These and some further specific requirements are detailed below.

#### Functional and Commercial Requirements

- To support **reliable and secure accounting and billing, especially for dynamic, short-term hosting relationships**. In particular, they must support it for different business (e.g. software as a service), financial (e.g. pay as you go, monthly contract, pay in advance, pay in arrears, volume discounts) and licensing models.
- To support **SLA monitoring and penalties management** in order to deal with violated SLAs.
- To support **decisions when to break SLAs**. A provider may service different clients and it is possible that, at some times there are difficulties in complying with all SLAs. The provider may decide that it is more cost-effective to break one or more SLAs in order to be able to comply with the rest (e.g. to prioritise a large or important customer over a smaller one).

#### Dependability requirements

- To support **flexible, customer-specified dependability levels** for hosted solutions which are automatically mapped to the infrastructure setup and which can even be changed over time and per requested service. Thus, customers can choose the required availability level and balance that with the resulting costs.

#### Security requirements

- To guarantee **strongest security and isolation** of hosting resources between different customers. As hosting customers put highly sensitive data into a hosting grid they need complete confidence in their secure and isolated management.
- To provide strongest protection against external threats, e.g. from the Internet.

#### Performance requirements

- To support **highly efficient operations**, e.g. by intelligent sharing of resources among hosting customers. This is of special importance in mass hosting scenarios
- To support **prediction and enforcement of performance characteristics** (response time and resource usage) and to derive them from high-level requirements. This allows the provider to offer appropriate SLAs and plan resource deployment to deliver against them efficiently.

#### Manageability requirements

- To support **remote infrastructure management**. Though a hosting environment may belong to the administrative domain of the provider, it may be physically collocated with the client's data centre. Such setups require strong support for the remote management of the hosting environment, in particular the hosting infrastructure.

- To support **mass automation** in order to allow management effort to scale to very large numbers of hosting customers.

#### **Governance requirements**

- To support **governance and compliance for both providers and customers**.

#### **Flexibility requirements**

- To provide **hosting services in a highly dynamic and on-demand way** in order to satisfy spontaneous customer needs in extremely short time frames (seconds or minutes).

### **3.4 Extended enterprise**

#### **Setup**

Enterprises may intend to extend the scope of their IT-managed activities beyond the traditional boundaries of data centres and desktop machines. For example, pervasive scenarios aim for the integration of pervasive devices (PDAs, mobile phones, RFID systems etc.) into the ICT backbone of a company. Real-time scenarios aim for the integration of real world entities via sensors/actuators (e.g. in shop floor integration or asset tracking) thus exhibiting more real-time or event-driven characteristics.

Extended enterprises and their special-purpose devices have some characteristics which clearly separate them from traditional data centres:

- The heterogeneity of devices is much higher. In particular capabilities, interfaces and also connectivity of devices may differ significantly and sometimes have quality characteristics much lower than typical data centre resources.
- The association of devices with administrative domains may be more complex: devices may belong to the core enterprise domain, may be interlinked by concepts of a virtual organization and finally may even change their ownership (e.g. when they are sold to another party).

#### **Vision & Expected Impact**

The vision of Business Grids for the Extended Enterprise is that they allow for a harmonized enterprise-wide infrastructure that includes all types of devices. Again, Business Grids will follow the SOKU vision as they

- Allow for seamless access to a large variety of IT resources in a service-oriented way.
- Ensure transparent life cycle management that considers overlapping and changing administrative domains.
- Support automated IT provisioning and management on enterprise level (as appropriate) and device level (as appropriate).

Overall, Business Grids will be an enabler for increased real-world and real-time awareness (both globally, and locally) and will support overall enterprise flexibility by enabling local interaction which takes place close to the problem point.

## Business requirements

The extended enterprise scenario reveals the following specific business requirements.

### Dependability

- To allow for **disconnected operation** in the backend in case some special devices are not online (due to device or network failures). This is essential for assuring a company's ability to continue operation even in presence of failures (which are quite likely to happen with pervasive and real-world devices).

### Security

- To enable proper **access management** for central IT operations and local device users/owners.

### Performance

- To allow for **scalable event handling** for possibly thousands or millions of events.
- To realize an **intelligent resource management** (in particular, energy management). As resources of special-purpose devices can be quite limited it is of great importance to manage them intelligently in order to maximize the business benefit.

### Interoperability

- To establish **standard management and access interfaces** for highly heterogeneous devices.

### Manageability

- To allow for **balanced management procedures** that properly balances the needs and capabilities for local and central device management.
- To establish a **proper lifecycle management** for pervasive/real-time devices that might change ownership over time.

### Flexibility

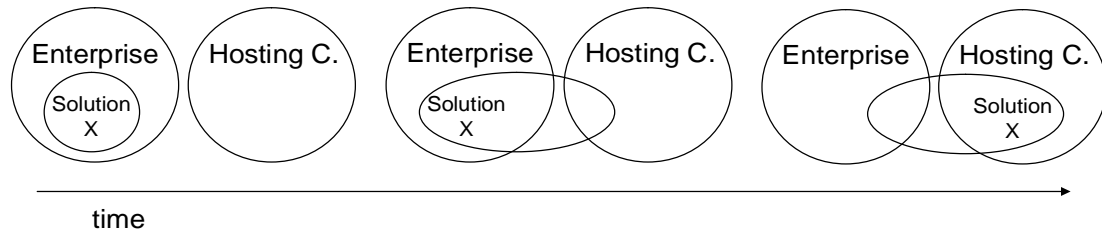
- To support **dynamic reconfiguration of devices**. This is essential for agile businesses to adapt the scenario/process under which pervasive and real-world devices are used.

## 3.5 Dynamic Outsourcing

### Setup

Decisions on whether IT systems are operated in-house or via an external hosting provider may change over time as the strategies of organizations evolve. Traditionally, outsourcing decisions do not just depend on strategic requirements but have to carefully balance these with the practical effort, overhead and side effects (e.g. interruption of business) of an outsourcing process. The following picture shows such a dynamic outsourcing process where a solution X, initially provided by an enterprise infrastructure is migrated to a hosting company. Ideally, solution X is fully operational during the whole migration process.

This could be about the dynamic relocation of IT resources while being operational.



### Vision & Expected Impact

Business Grids are envisioned to support dynamic outsourcing (and likewise insourcing) processes by realizing the SOKU vision in the following aspects:

- Automated migration of IT solutions/services between different administrative domains (service-orientation).
- Comprehensive and secure management of migration process and handover across administrative and security domains (knowledge-assisted).
- Ensuring full availability and normal operation during all phases of the migration process (utility).

Business Grids will significantly impact organization's ability to change and adapt their company strategy in terms of IT provisioning decisions. In particular, Business Grids will prevent organizations from being locked by previous decisions which over time turned out to be inappropriate.

### Business requirements

In addition to the previous and in particular the hosting scenario dynamic outsourcing reveals the following specific business requirements.

#### Functional and Commercial Requirements

- To provide **planning support** for migration processes and the impact and side-effects of outsourcing decisions.
- To support **migration** of running IT solutions/services between administrative domains and possibly across wide-area networks.

#### Dependability & performance requirements

- To support **flexible, customer-specified dependability/performance levels** for all phases of a migration process. Similar to the hosting scenarios, customers shall be able to choose the required dependability/performance level and balance that with the resulting costs.

#### Security requirements

- To guarantee **strongest security and isolation** of all services and resources which are involved in a migration process.

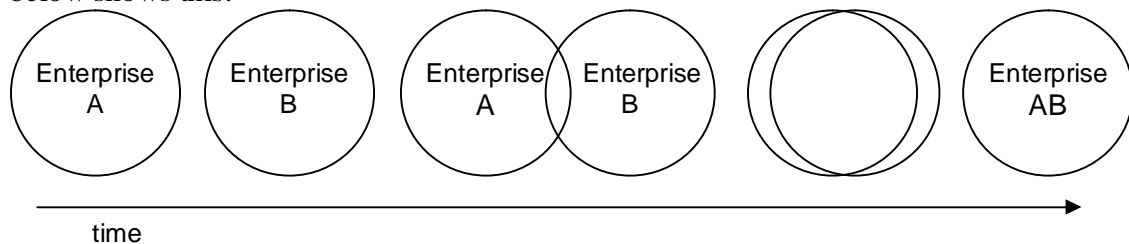
#### Manageability requirements

- To support a **transparent migration process** including a proper handover across administrative and security domains.

### 3.6 Mergers & acquisitions

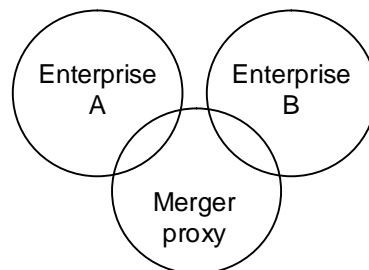
#### Setup

Merging with, or acquiring another company is an increasingly common method for companies to grow. The traditional means by which companies merge typically takes a long time to fully complete. This can be envisaged using the enterprise grid model in one of two ways. The first occurs when two enterprise grids merge over time. The diagram below shows this:



The two enterprise grids that are initially separate form a virtual organisation that links their two grids together in a limited fashion. Over time, as the grids coalesce, the virtual organisation encompasses more and more of each individual enterprise until a single merged enterprise remains. In the case of a merger, the relationship is likely to be more of a symmetric one. In the case of a takeover or acquisition, the relationship between the enterprises is more likely to be asymmetric.

One other form of merger / acquisition mechanism is also possible here. This introduces the concept of a merger proxy, as shown below:



The merger proxy is an external entity that provides a link between the two enterprises. Both enterprises form virtual organisations with this proxy and use the services of the proxy to merge logically. Such a proxy might be used to facilitate a new range of business services in this arena.

#### Vision & Expected Impact

Business Grids are envisioned to support scenarios of mergers and acquisitions by realizing the SOKU vision in the following aspects:

- Providing services supporting the actual merger/acquisition process in terms of managing the consolidation of administrative domains, infrastructure resources Automated migration of IT solutions/services between different administrative domains (service-orientation).
- Comprehensive management of merger/acquisition processes in terms of IT landscapes, components, processes and users (knowledge-assisted).

- Supporting an almost transparent shielding of the merger/acquisition process from the users of business solutions (utility).

Business Grids will significantly impact the dynamicity of economies as they lower the technical complexity for merger/acquisition processes.

### **Business requirements**

Merger and acquisition scenarios reveal the following specific business requirements.

#### **Functional and Commercial Requirements**

- To provide **planning support** for merger & acquisition processes and the impact and side-effects of them.
- To provide **support services** for conducting the actual merger/acquisition process.

#### **Performance requirements**

- To support **resource consolidation** of previously heterogeneous resources into one overall and logically homogeneous resource pool.

#### **Security requirements**

- To support **harmonization and consolidation** of security policies and associated mechanisms.

#### **Manageability requirements**

- To support a **transparent merger/acquisition process** clearly reflecting the various stages of a merger/acquisition process.

#### **Interoperability**

- To support **standards for IT infrastructures** that go beyond service-/interface-level but allow for consolidation of resources.

#### **Flexibility**

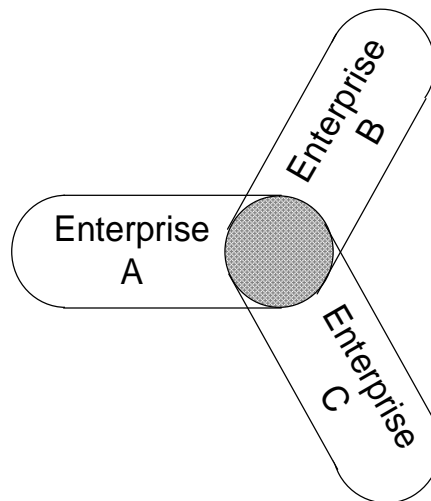
- To support different **merger/acquisition styles** including staged processes, symmetric/asymmetric processes and merger proxies.

## **3.7 Virtual organisations**

### **Setup**

As already sketched in Section 2.4 virtual organizations (VOs) are built whenever two or more administrative domains overlap and share resources. This may happen in a master-slave or peer-to-peer modus. Moreover, virtual organizations may be formed at different levels, e.g. via sharing more high-level services such as Web services or by sharing more low-level resources such as files, processing capacity etc.

Though many of the presented scenarios already revealed various VO-like characteristics we believe that the full vision of VOs has a couple of unique aspects that qualify the discussion of VOs as a separate scenario. Furthermore, specific issues gain further practical relevance as soon as at least three administrative domains overlap.



### **Vision & Expected Impact**

Business Grids are envisioned to become a trusted infrastructure for the formation and management of virtual organizations. They realize the SOKU vision in the following aspects:

- Providing support services supporting the formation and management of virtual organizations (service-orientation).
- Supporting transparent specification of VO policies which may be quite complex and fine-grained (knowledge-assisted).
- Embedding compliance with VO-aware and specific policies into the infrastructure (utility).

Business Grids will significantly impact the simplicity for initiating and maintaining dynamic virtual organizations thus contributing to the overall agility of economies.

### **Business requirements**

Virtual organizations reveal the following specific business requirements.

#### **Functional and Commercial Requirements**

- To provide logically **central support services** for the initiation, management, monitoring of virtual organizations (e.g. central registries) and the enacted, distributed business processes. Contractual details have to be specified and (preferably) automatically negotiated between the partners in a VO.

#### **Dependability & performance requirements**

- To support **accountable and isolated access** so that resources cannot be used or changed in an unintended way.
- To support **reputation awareness** of participants (i.e. their performance in terms of fulfilling promised SLAs) via appropriate recording and reuse for future reference.

### Security requirements

- To embed SLA-aware **policy enforcement** into the infrastructure (e.g. of security policies and associated mechanisms) according to the negotiated collaboration/interaction pattern.
- To allow for **secure access** to the resources of the partners, e.g. by maintaining and distributing security tokens.

### Manageability & governance requirements

- To support a **transparent specification/management** of all documents necessary for a VO, e.g. policies reflecting specific VO roles (initiator, contributor etc.), collaboration/interaction patterns, SLAs etc.

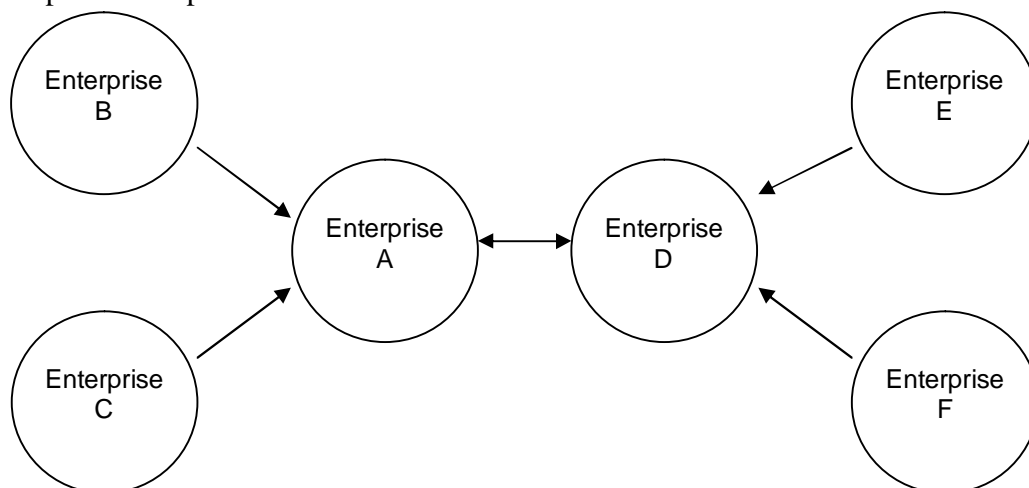
### Flexibility

- To support dynamic **changes of virtual organizations**, e.g. mechanisms which allow partners/resources to join/leave a VO or to be transparently replaced..

## 3.8 Value networks

### Setup

Value networks are ways in which organisations interact with each other to drive increased business value. There are many of these in common existence today; the supply chain being the most familiar. The application of enterprise grids to this environment will allow more exotic business value networks to be formed and dissolved as business conditions change. The following shows a business value network around the joint development of a product:



In this example, Enterprises A and D are collaborating on the development of a new product. Enterprise A has sub-contractors or partners B & C, whilst Enterprise D has similar relationships with E & F. The network (shown here with arrows) consists of a series of virtual organisation relationships in both master-slave and peer-to-peer between the respective companies. By pooling resources, information, insight & capabilities a greater business value can be achieved than by a single organisation acting alone.

Special purpose service are likely to emerge to support the formation and management of value networks such as broker services, mediator services, marketplaces, accounting, authorization or authentication services etc.

### **Vision & Expected Impact**

Business Grids are expected to become the trusted infrastructure for complex business value chains. They realize the SOKU vision in the following aspects:

- Provisioning of generic infrastructure and support services (service-orientation).
- Transparent and trusted management and accounting of resources according to value chain requirements (knowledge-assisted).
- Support for automated formation of value networks with dependable characteristics (utility).

Overall, Business Grids will ease the formation and management of complex business value chains which ultimately supports highly dynamic and innovative business interactions at the scale of complete economies.

### **Business requirements**

Value networks reveal the following specific business requirements.

#### **Functional & Commercial**

- To provide or support basic services for the formation and management of value networks, such as mediation, brokering, accounting, authentication or authorization services.

#### **Non-functional characteristics (dependability, security, performance)**

- To **reflect non-functional characteristics** (dependability, security, performance, ...) in service discovery and composition mechanisms.
- To allow for **awareness of non-functional characteristics** on the value network level, i.e. to provide prediction, monitoring and readjustment mechanisms.

#### **Security**

- To **secure accounting and management data** thus guaranteeing integrity and confidentiality of these data which partially needs to be shared between different organizations and partially needs to be kept strictly private.
- To support application domain specific end-to-end (infrastructure to user) security demands across whole value networks.

#### **Governance**

- To reflect **legal policies on value network level** via appropriate logging, tracking and auditing of resources and services.

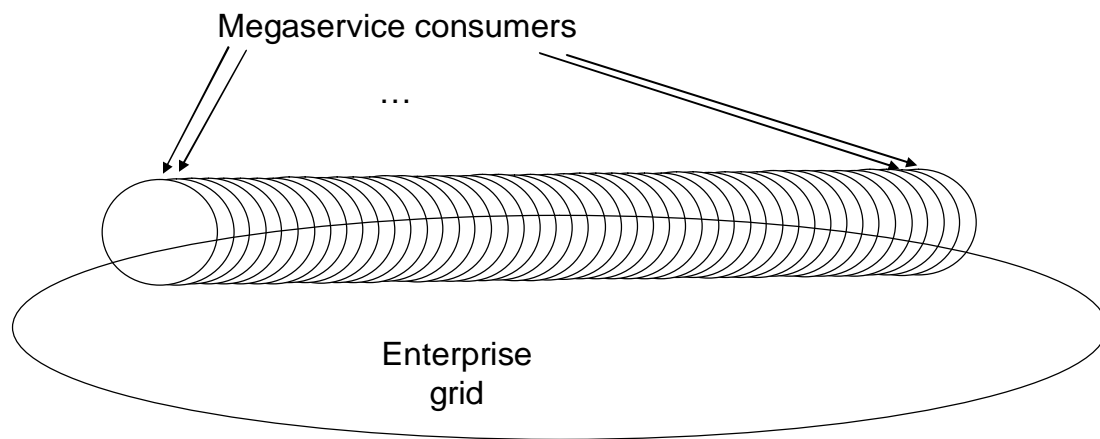
#### **Flexibility**

- To support **flexible setup and changes of value networks** which impact on the underlying infrastructure, such as dynamic allocation of additional resources or reassignment of existing resources.

### 3.9 Mega Services

#### Setup

Mega services are literally offered to millions of consumers possibly distributed over the globe. The type of services can widely vary, ranging from raw data storage / data caching, through virtual machine execution to high level software services, usually featuring personalized persistency and Web based access. The majority of the service consumers are considered to be citizens, whereas small and medium sized companies are also representing a significant customer segment.



Mega services are envisioned to be globally available, in many cases ubiquitous services, foreseen to actively shape the relationship of the population towards the information age services. Reaching extreme amount of customers mega services are expected to have significant volume, raising the most successful service providers among the largest global enterprises.

#### Vision & Expected Impact

Business Grids are expected to become a flexible and trusted infrastructure for mega services. They realize the SOKU vision in the following aspects:

- Homogeneous, dependable provisioning of globally distributed resources possibly across administrative domains (service-orientation).
- Transparent management globally distributed resources, customers and demands (knowledge-assisted).
- Support for seamless scalability of service offerings from small, localized to ubiquitous and very large scale (utility).

Overall, Business Grids will ease the provisioning of dependable mega-services in particular the dynamic provisioning of required resources. This will allow even small organizations to provide mega services in a simple and dynamic manner and also offers opportunities for intermediate resource providers to act with a global customer base.

## **Business requirements**

The requirements listed in this section are extending those marked up in the hosting scenario in Section 3.3. The differences between the two scenarios stem from the very large customers base requiring a giant service infrastructure, potentially spreading over the world.

### **Functional & Commercial**

- To support the adaptation of the business framework and the services to various country specific requirements (e.g. legislative restrictions).
- To provide a complete automation of the entire customer relationship management, service provisioning, service execution, SLA monitoring and charging. To restrict the need for human interaction to special (i.e. erroneous) conditions.

### **Dependability requirements**

- To provide highly available and reliable operation on geographically distributed service infrastructures, possibly involving several service elements operated by 3<sup>rd</sup> party partners (typically network services). Although the availability and reliability requirements are dependent on the SLAs coupled with the actual services, it is a general requirement to avoid failures affecting large customer subsets or whole geographic regions.

### **Manageability requirements**

- To support mass-scale automated remote infrastructure management. Providing services for extreme high number of customers require facilities composed by large amounts of potentially geographically distributed nodes, linked by vast networking infrastructure. This needs the utmost level of automation in the infrastructure management.

### **Flexibility requirements**

- To support extreme large geographically distributed customer bases. To support high service volume changes happening in relatively short timescale in a geographically uneven manner.

## **3.10 Additional scenarios**

Noteworthy, that the introduced scenarios can be combined in various ways in order to form more complex, compound scenarios. For example, resources from an extended enterprise might be offered via a hosting scenario. However, these compound scenarios are not described in this document as we do not assume that they create requirements in addition to the core scenarios.

A couple of additional scenarios have been suggested by the community, such as “federation of SMEs”, “resource brokering a la eBay” or “edge computing”. These scenarios will be worked out in collaboration with community stakeholders for future versions of this SRA.

## 4 State of the art

This section presents a high-level overview on the state of the art of technology relevant for the Business Grid vision. Further details on technologies with respect to the introduced business scenarios and requirements is given within Section 5. The overview here is divided into three groups: academic grid computing (both in terms of usage and research); enterprise grid computing (describing practice and commercial technology), and finally virtualization technology, both commercial and research, which provides a foundation for the strategy presented in this SRA.

### 4.1 Scientific Grids

In this section, we introduce some of the major scientific grid approaches. We will concentrate on standards, middleware, and a collection of selected research projects. In this domain, “grid computing” is an extension of scientific cluster computing, merged with concepts from large-scale distributed computing, in particular Internet-based computing paradigms, such as peer-to-peer and service oriented architectures. The primary goals are either computing research oriented, or to facilitate scientific computing, and the major themes deal with inter-organisation resource sharing, heterogeneity, scalability, decentralisation and dynamicity. While issues such as stability, security, and performance are important, these are usually deemphasised in this domain.

Originally, grid computing was an approach for using a network for dynamically sharing computers for compute-intense scientific applications [4] in situations where dedicated compute clusters were not available or provided insufficient computing power. The term Data Grid was introduced to refer to an architecture primarily focusing on the distributed management and analysis of large scientific datasets [5]. With the increased commoditization of computing hardware and pervasive business computing, the management of distributed sets of dynamic heterogeneous computing resources has emphasized the importance of grid computing techniques and research.

The existing scientific Grid Platforms present, to various extend, many features related to the NESSI-Grid requirements. This is particularly true in the areas of *Functional issues*, of *Dependability* and *Security*, and naturally of *Performance* and *Flexibility*. In many cases the ongoing research efforts, software component and platform development, and standardisation, will be an interesting basis for either inspiration or usage in enterprise grids. In the next paragraph we sketch the existing platforms within and outside Europe; then we detail the main ongoing research efforts, projects, and standards, classifying them with respect to the main issue they relate to.

The EGEE-II [12] project has inherited from EDG [36], LCG [37], and EGEE-I [12] a grid software stack consisting of a combination of Web Services, Globus middleware, Condor [38], and custom services to provide the gLite [11] software set which is used by hundreds of sites to provide the EGEE grid environment. The services of gLite are grouped in five main categories, namely access services, security services, information & monitoring services, data services, and job management services. Currently gLite (the grid software) and EGEE (the computational grid overlay network) form the world’s largest general purpose scientific grid.

Other significant academic grid environments include DEISA (Distributed European Infrastructure for Supercomputing Applications) [39], which is a collaboration of 11 European supercomputing sites to link their resources (35,000 processors, of various kinds) through common interfaces to enable joint or shared computing capability. UNICORE [17] has been adopted as a common portal to DEISA. Within France, the Grid5000 [40] research grid provides 3500 cores across 9 sites for a private grid computing network, emphasizing inter-site and parallel grid computing. The US provides both the OSG (Open Science Grid) [41] and TeraGrid [42]. OSG has a similar background to EGEE, and is based on a combination of Globus, Condor, and the VDT (Virtual Data Toolkit) software released by NMI (NSF Middleware Initiative), and links computing clusters from over 60 sites, mostly found in the US. TeraGrid links together 9 supercomputing centres across the US, with a total capacity of over 40 Tflops. Within Japan, the NAREGI [43] grid testbed utilises project-specific middleware across 11 sites providing over 3000 computing cores and over 17 Tflops. China has also started a national grid project ChinaGrid [44], initially involving 9 sites with over 4000 cores.

#### **Interoperability: standards.**

The Open Grid Forum [6] is the main standards development organization devoted to grid computing, with a focus on standardising a service oriented architecture based on OGSA (Open Grid Services Architecture) [7] [8]. This defines relevant services such as logging, reservation, and workflow, and formed the basis for the initial OGSi (Open Grid Services Infrastructure) proposal, which was an extension to WSDL and existing Web Service standards. This evolved into WSRF (Web Service Resource Framework), providing compatibility with existing Web Service standards. The open source *Globus Toolkit* [10] is a widely used middleware package used to build scientific grids. It provides mechanisms for remote process invocation (GRAM – Grid Resource Allocation and Management), data transfer (RFT – Reliable File Transfer – and GridFTP), monitoring (MDS – Monitoring and Discovery Service), and security (via X509 proxy certificates). A few Web Service standards from outside of OGSA are being explored and developed by the grid community, specifically WS-Agreement [34], which provides SLA functionality for service negotiation, and WS-Context [35] which provides a mechanism to track session state between WS invocations.

#### **Security: access control, authentication, infrastructures**

The use of X509 certificates as a common mechanism for identity management and system/service security is dominant in grid computing and largely an outcome of the Globus X509 proxy certificate concept, which has since been standardised by the IETF in RFC 3820 [45]. The complexity of generating and working with proxy certificates has been facilitated by the MyProxy [46] project which allows remote delegation and management of X509 certificates. The use of Attribute Certificates [47] is also gaining in popularity, as users find they need to distinguish between different roles and VOs within a grid domain. The VOMS [48] system from EGEE [12] and PERMIS [49] provide VO and Attribute Certificate management functionality. Many academic grid projects work within trusted domains, relying on PAM/LDAP based shared authentication between systems, or the use of DSA/RSA keys (from SSH), while other web-portal based grid environments hide the grid behind the portal and only require web username/password

for access control. Regarding security policies and access control management, these have generally been done on with per-VO task queues and manual configuration and synchronisation of which VOs are permitted within a site, and which users (via X509 DNs) are part of a particular VO. Some work has been done to control access via XACML [50], SAML [51], and GACL [52], and via the OpenPERMIS tools. XACML and SAML suffer from a complex notation and lack of tools for constructing, checking, and interfacing to security policies. GACL has been developed out of the GridSite[53] project which has also provided X509-based wiki system, HTTPS file system, and a modification of the Apache HTTPD project's suexec program named "gsexec" which provides \*NIX account switching based on X509 certificates. This combination of tools encounters increased usage within the EGEE community.

**Functional issues: data management.**

File handling and data management are key issues in academic grid computing, and were one of the original motivators for the EDG project. This work can be broadly divided into grid file systems and grid databases. The latter has been covered by OGSA-DAI [54], and is of particular interest to the health and bioinformatics domains where data is generally stored in relational databases rather than files. To date, most grid systems have implemented their own bespoke interfaces to expose database resources. Regarding grid-enabled file access, there is a much greater level of experience and convergence around the requirements. These systems require access control facilities, replication, data staging from mass storage systems (e.g. tape silos), meta-data catalogs to locate relevant files, and systems to map from logical (grid) file names to physical (on-disk) file locations. Furthermore, this system must integrate with task scheduling and task placement, and for large data sets consider pipelining task data staging (both in and out) to avoid leaving processors idle while data is moved across network links and to disk. gLite already takes data requirements into consideration during task scheduling, and systems such as Condor Stork [38] allow for explicit scheduling of data movement. SDSC has developed the widely adopted SRB [55] system which is now being redeveloped as iRODS [56]. GridFTP and RFT from Globus provide mechanisms for high-throughput reliable file transfers, including third party transfer orders. The LCG project has critical requirements related to data management, staging, replication, and provenance, therefore a number of file catalogs and meta-data catalogs have been developed. In certain grid environments advanced network file systems are used, such as GPFS [57] or AFS [58].

**Interoperability: data and application deployment, software management, task management.**

One of the key issues in grid operation is the deployment and management of software, both in terms of persistent grid middleware services, and short-term services or applications required for a particular user group (VO) or individual task. Several different standards have been proposed to deal with this. WSDM (Web Services Distributed Management) [59] from OASIS presents standard interfaces to be implemented by conformant Web Services to allow them to be controlled via a common system. The OGF standard CDDL (Configuration Description, Deployment, and Lifecycle Management) [60] provides a model for configuring Web Services, then managing their deployment and overall life cycle. This is a standard specific to Web

Services. The ETSI Technical Committee on Grid Computing (TC GRID) has started work to standardize the Grid Component Model (GCM), developed by the CoreGRID NoE project for describing grid software components. The first part of this standardization will cover interoperable deployment of grid software components or applications, via a standardized format for different computing environments: grids, clusters, peer-to-peer networks, desktop “grids”, or a local machine. Later GCM standards will cover applications, Fractal ADL (Architecture Description Language) and component management. For computational grids, the OGF standard JSDL (Job Submission Description Language) [61] is being widely adopted as a common task description language. It provides an XML syntax which identifies the key properties and requirements of a grid “task”, thus allowing it to be appropriately scheduled and then subsequently launched. Task/application execution is being standardized via the OGF BES (Basic Execution Service) [62] Standard, and the OGF SAGA (Simple API for Grid Applications) [63] standard.

**Functional issue: application development; Flexibility: reconfiguration; Dependability and Performance: self-repairing, autonomicity.**

Another key area for grid adoption is a rich set of tools, libraries, and application development environments. The Globus Toolkit **Error! Reference source not found.** has provided grid libraries for almost a decade and is now the premier provider of WSRF and “classic” grid services and libraries. OMII (Open Middleware Infrastructure Institute) [64] has acted as a clearing house for grid software, providing an environment for testing, quality control, packaging, and release of numerous grid services and libraries. The NMI VDT (Virtual Data Toolkit) [65] specifically provides “hardened” versions of Globus, Condor, and other key grid software packages and is used by OSG and EGEE. The European CoreGrid research network has worked on the GCM (Grid Component Model)[66], which extends the Fractal component model to grid computing, and provides a basis for software component composition in a grid environment. The INRIA project ProActive [67] has provided a rich Java-based grid application development environment which simplifies the development of parallel distributed applications which execute equivalently on a single system or with distributed/remote objects across a grid. The GridCOMP FP6 project takes the Grid Component Model (GCM, coming from the CoreGRID Network of Excellence) as a first specification, and use the ObjectWeb ProActive Open Source implementation as a starting point and reference implementation. ObjectWeb ProActive Grid middleware ensures interoperability with other standards: EGEE gLite, UNICORE, NorduGrid, Globus, LSF, PBS, SGE, Loadleveler, Web Services, etc.

## 4.2 Enterprise Grids

Enterprise grid deployments generally rely on the same base technologies as the academic/scientific grids mentioned above, but due to the lack of adequate security mechanisms (or at least their perceived lack or difficulty of use) are usually restricted to a single administrative domain within an enterprise. It is not uncommon to find deployments that span several administrative domains within an enterprise, i.e. between different arms of the internal IT organization (such as engineering, business and general

desktop divisions), but there is no technical support for supporting interactions between these administrative groups in the technical infrastructure deployed. Current enterprise grids rarely support transactional applications. Usually they are used for a few dedicated, compute-intensive applications such as in life-sciences, engineering simulations and financial analysis. There is a dearth of data-management solutions for grids. Managing information life-cycle and data movement is left to individual applications.

Commercially available solutions for these environments feature policy based scheduling and workload management on heterogeneous infrastructures made out of desktops, servers and clusters. These systems contain basic resource control and mechanisms for fault tolerance as well as analysis tools for performance and debugging. Due to the lack of standardization in this space these solutions typically support a variety of *de facto* standards and translate them to a solution-specific format. Finally, these solutions often contain their own billing and user management solutions, partially integrating with common security infrastructures prevalent in enterprises.

The formation of the EGA (Enterprise Grid Alliance) in April 2004 provided a forum for discussing the requirements of enterprise grid computing and interoperability between the major grid computing technology providers (for software, hardware, and services). The EGA Reference Model [68] was the main output of this group before it merged with the GGF in February 2006 to form the Open Grid Forum. The EGA Reference Model represents the common view of an enterprise computing environment and the requirements which should be addressed by a grid technology.

Recently, a standardization activity has been started under the umbrella of ETSI (European Telecommunications Standards Institute). ETSI is an independent, non-profit organization, whose mission is to produce industrial standards. In July 2006 ETSI has announced the creation of a new Technical Committee, (TC) GRID, to produce interoperability standards, contributing to the global progress of GRID. The ETSI Board approved the move. TC GRID will be responsible for ETSI's contribution to Information Technology (IT) and Telecommunications convergence standards in the GRID domain and the work will start with writing of test specifications and progress towards a broader range of GRID standards to integrate the use of telecommunications infrastructures in networked computing. In May 2007, a new Memorandum of Understanding between ETSI and the Open Grid Forum (OGF) has been signed. The two organizations are working together to ensure that their standards for GRID communications are written with common goals by their respective industrial and the research communities.

Examples of such commercially available solutions (without weighing their market share or importance) are IBM Grid Computing solutions [20], SUN's "N1 Grid Engine" [21] Platform Computings "Enterprise Grid Coordinator" [22], DataSynapse [23], Univa Globus Enterprise [24] or Cluster Resources's "Moab" suite [25].

### **4.3 Virtual machine based grids**

A variety of IT vendors, both large and small, are offering solutions that can transparently manage arbitrary collections of applications in execution containers that can be dynamically deployed onto a homogeneous pool of physical hosts. These containers then are treated like jobs in a “normal” grid but can be dynamically controlled and the resources allocated to them adjusted.

Typically these containers are implemented using virtual machine monitors, and hence contain an operating system together with the deployed application. Examples of this technology are XEN [26], VMWare [27], Virtual Iron [28], SUN’s Solaris Container [29] or the (planned for 2007) System Center Manager from Microsoft [30]. Containers can also be implemented without hypervisors inside the operating system (i.e. SWSoft’s Virtuozzo [31] or IBM’s virtualization suite [32]).

Features of these solutions are similar in capability to what enterprise grid solutions offer, but add “steady state” resource management, additional security mechanisms by encapsulating applications in the containers and by adding control of network partitions through setting up of virtual VPNs.

## 5 Research challenges

In the following we describe the main research challenges resulting from the business scenarios presented above. To this end, we follow the categories introduced in Section 3. First, some more specific research challenges within each category are identified with reference to the business scenarios. In subsequent sections the state of the art in each area is briefly described together with a discussion of the nature of, and motivation for, the requirements in each category.

### 5.1 Derivation of Research Challenges

Requirements from each of the business scenarios have been analysed and a number of common themes identified. The results of this analysis are summarised in **Error!**

**Reference source not found..** Many of the requirements arise in several business scenarios although there may be differences in the details.

| Requirement/Scenario                                   | Ent. | Hier. Ent. | Hosting | Ext. Ent. | Dyn. Out. | M & A | VO | Value N. | Mega-services |
|--|------|------------|---------|-----------|-----------|-------|----|----------|---------------|
| <b>Functional and Commercial</b>                       |      |            |         |           |           |       |    |          |               |
| data management  | X    | X          | X       |           | X         | X     | X  | X        |               |
| applications development                               | X    | X          | X       | X         | X         |       |    |          |               |
| network connectivity                                   |      | X          | X       | X         | X         | X     | X  | X        | X             |
| IT as a business                                       |      | X          | X       |           | X         | X     | X  | X        |               |
| accounting   |      |            | X       |           | X         | X     | X  | X        |               |
| SLA-based management                                   |      |            | X       |           | X         |       | X  | X        |               |
| Environmental issues                                   | X    | X          | X       | X         |           |       |    |          |               |
| Adaptation to different markets                        |      |            |         |           |           | X     | X  | X        | X             |
| <b>Dependability</b>                                   |      |            |         |           |           |       |    |          |               |
| appropriate dependability levels with customer control | X    | X          | X       | X         | X         | X     | X  | X        | X             |
| self-repairing   |      | X          | X       | X         | X         |       |    |          | X             |
| resilience to intermittent and disconnected operation  |      |            |         | X         |           |       |    |          | X             |
| predictable dependability                              | X    | X          | X       |           | X         | X     | X  | X        | X             |
| <b>Security</b>  |      |            |         |           |           |       |    |          |               |
| support for security policy enforcement                | X    | X          | X       | X         | X         | X     | X  | X        | X             |
| hierarchical security policies                         |      | X          | X       | X         |           | X     | X  | X        |               |
| guaranteed and auditable security and isolation        |      | X          | X       | X         | X         | X     | X  | X        |               |
| external threat mitigation                             |      |            | X       | X         | X         |       | X  | X        | X             |
| integrity and confidentiality of partially shared data |      |            | X       | X         | X         | X     | X  | X        |               |

Table 1: Research Challenges vs. Business Scenarios

| Requirement/Scenario                                     | Ent. | Hier. Ent. | Hosting | Ext. Ent. | Dyn. Out. | M & A | VO | Value N. | Mega-services |
|--|------|------------|---------|-----------|-----------|-------|----|----------|---------------|
| <b>Performance</b>                                       |      |            |         |           |           |       |    |          |               |
| predictability on shared infrastructure                  | X    | X          | X       | X         | X         | X     | X  | X        | X             |
| dynamic adaptation                                       |      |            | X       | X         | X         |       |    | X        | X             |
| scalable scheduling/provisioning                         |      |            | X       |           | X         |       |    |          | X             |
| <b>Interoperability</b>                                  |      |            |         |           |           |       |    |          |               |
| support for arbitrary applications                       | X    | X          | X       | X         | X         | X     | X  | X        |               |
| interfaces to infrastructure resources                   | X    | X          | X       | X         | X         | X     | X  |          |               |
| interoperability with foreign (e.g. customer systems)    |      | X          | X       |           | X         | X     | X  | X        |               |
| <b>Manageability</b>                                     |      |            |         |           |           |       |    |          |               |
| consistent across heterogeneous systems                  | X    | X          | X       | X         | X         | X     | X  | X        |               |
| low-cost (automated)                                     | X    | X          | X       | X         | X         | X     | X  | X        |               |
| scalable to very large systems with global distribution  |      |            | X       | X         | X         |       |    | X        | X             |
| lifecycle management for infrastructure devices          | X    | X          | X       | X         | X         |       |    |          |               |
| decentralised policy definition                          |      | X          | X       | X         | X         |       | X  | X        |               |
| business process support (BVN, VOs, M&A etc.)            |      |            |         |           |           | X     | X  | X        |               |
| business-infrastructure mapping of policies and events   | X    | X          | X       | X         | X         | X     | X  | X        | X             |
| <b>Governance</b>  |      |            |         |           |           |       |    |          |               |
| logging, tracking and auditing of interactions and usage |      | X          | X       |           | X         | X     | X  | X        |               |
| reflect organisational structure                         | X    | X          |         | X         |           | X     | X  | X        |               |
| support compliance for providers and customers           | X    |            | X       | X         | X         | X     | X  | X        |               |
| compliance with regional or country-specific regulation  |      |            | X       | X         | X         |       |    |          | X             |
| <b>Flexibility</b>                                       |      |            |         |           |           |       |    |          |               |
| changing apps, infrastructure components                 | X    | X          | X       | X         | X         |       |    |          |               |
| changing organisational structure (VO, BVN)              |      | X          |         |           |           |       |    |          |               |
| rapidly varying workloads                                | X    | X          | X       | X         | X         |       |    |          |               |
| dynamic reconfiguration of devices                       | X    | X          | X       | X         | X         |       |    |          |               |
| adaptation to different markets, regulatory regimes      |      |            | X       | X         | X         |       |    |          | X             |

Error! Reference source not found.: **Research Challenges vs. Business Scenarios (continued)**

## **5.2 Functional & Commercial Issues**

Traditional grid systems focus on isolated batch jobs while virtual-machine based grids address complete systems to be submitted. However, Business Grids focus more on interactive applications with a low response time. Furthermore, individual applications are not completely decoupled, in the sense, that they are executed as part of business processes or coexist with other collaborating applications.

### **Data Management**

Storage demands and capabilities are increasing very rapidly. Terabyte capacity hard drives are already available. Applications with requirements for petabyte storage are beginning to emerge in science, medical imaging and digital media. The need to comply with regulation (e.g. Sarbanes Oxley) is driving businesses towards large-scale storage of all relevant financial records, including email. Data needs to be managed throughout its lifecycle. Different policies for retrieval, assured immutability, confidentiality, privacy and compliant deletion may need to be applied at the level of individual items within a collection of many billion, and may change over time. Data and storage access is an essential part of many applications. Business Grids must be able to offer well-defined storage and data management services that can support these applications. Data must be available in a timely way to applications to avoid performance bottlenecks. In outsourcing or collaborative scenarios, flexible access controls must be offered. Many of these considerations will have implications on the type and configuration of the underlying storage systems. Data management systems need to be able to handle heterogeneous underlying resources and apply them effectively to support business processes and applications.

### **Applications Development**

As an approach to maintain the rate of improvement in available computing power, major vendors (Intel, AMD, and IBM) have all recently moved towards multicore processors where several processor cores are linked within the same chip. This offers benefits in computing power and also in power dissipation, which is becoming increasingly important. However, programming multicore systems to take full advantage of their capacity requires changes in the way software is written. Software needs to be written to exploit the concurrency inherent in new processors. Similar changes in software development are also required to ensure that applications run efficiently on Business Grid infrastructure as this becomes the standard deployment environment for enterprise applications.

### **Network Connectivity**

As Business Grids develop, the role of networks to interconnect resources in different locations becomes increasingly important. These networks can have very varied characteristics with significant implications for application performance. Applications will increasingly be built from a number of concurrently executing components – whether these are Web or Grid services or parts of an application built for multicore or multiprocessor hardware. Communication patterns between these components play a vital role in determining end-to-end performance. Relevant networks may include high-speed cluster interconnects, local area networks ranging from megabit to gigabit speeds, wide-

area networks with a wide range of bandwidth and latency and eventually intermittently connected, low bandwidth wireless networks. In addition to physical network characteristics, communication middleware plays an important role. This must be appropriate both for the application and also for the underlying networks. An effective Business Grid needs to be able to match the requirements of a particular application to the resources available so that acceptable performance can be achieved. Heterogeneous network connectivity and communication patterns have played a relatively minor role in most current Grid deployments.

### **Accounting**

Though many grid systems provide basic means for accounting, this typically does not allow associating accounting data with related business activities or decisions. This significantly restricts the cost transparency of IT operations. Solutions for precise accounting across all layers of an IT infrastructure are required so that TCO (total cost of ownership) calculations can be used as an effective tool in capacity planning. Appropriate accounting at business process level will also allow business value to the customer to be made clear.

### **Service Level Agreements**

SLAs in current Grids typically relate to technical properties of the solution rather than being expressed in terms of the business requirements of the customer. This makes it difficult for the customer to know whether a particular SLA will actually meet his needs, as well as limiting the flexibility of the service provider and hence increasing operational costs. Reliable translation of business properties to technical properties and vice versa is required.

### **Environmental Issues**

Environmental issues are rapidly becoming very important for ICT infrastructure. Demand for computing capacity continues to increase rapidly with a corresponding increase in energy requirements for IT hardware and associated cooling systems. The Green Grid is a consortium which has recognised the importance of energy efficiency in data centres both for business and the environment – identifying it as the most significant issue facing technology providers and their customers today. The cost of energy is projected to exceed 50% of total IT budget within the next few years and security of supply could also become a problem. The solution to this will involve both introduction of more efficient hardware and data centre architectures, and integrated management solutions that take into account thermal conditions and energy consumption. Control of energy usage will be an important feature of an IT infrastructure and being able to demonstrate high efficiency should encourage use of Business Grids over standalone deployments.

The research challenges introduced in this section are most important for the range of hosting scenarios but also increasingly important for the (hierarchical) enterprise scenario.

### **5.3 Dependability**

In today's systems dependability requirements are typically satisfied with a static solution and most often only at the level of infrastructure resources (e.g. the number of redundant nodes assigned for a certain activity). Characteristics are not derived from application level requirements and consequently their economic costs and benefits are hard to quantify.

Business Grids aim for dependability levels appropriate to the needs of individual customers. Consequently, the most important research challenge in this area is the automatic mapping of customer requirements to the hardware level and the aggregation of resulting costs so that different approaches to providing dependability can be compared. While cost awareness is highly relevant for all business scenarios, complete automation of the requirement mapping is of particular relevance for hosting scenarios where the provider needs to offer business value to his customers as efficiently as possible.

Another research challenge is on harmonizing traditional and virtual-machine based grid technologies for supporting autonomic behaviour (i.e. system management with a minimum of human interference) via so-called self-\* mechanisms (e.g. self-configuring, self-healing, self optimizing) which aim at ensuring maximum service availability and performance when some components of the infrastructure or application fail..

### **5.4 Security**

At the moment, grid security mechanisms target traditional infrastructure resources (e.g. compute nodes, files, devices, .etc.) in a rather static way and do not consider the overlaying organizational structure. Enterprise security mechanisms are focused on organizational and user roles but make assumptions about the underlying infrastructure topology which is subject to change in grid environments.

Business Grids need to provide security mechanisms for possibly virtualized infrastructure resources (e.g. a virtual node or a distributed grid job) with a granularity and flexibility that allows the reflection of higher-level security zones such as a process group, a business process or organizational entities including departments, customers and partners. Consequently, Business Grids require advanced security models and policies that can accommodate both organizational structures and infrastructure topologies. This is most important for hosting scenarios, where systems process applications of competitors within one operational domain. In this context, complete isolation on all levels (application to infrastructure) is necessary. These challenges are synchronized with the ones stated by the European Security Forum for Web Services, Software and Systems (ESFORS) [33].

A second research challenge is how to enhance security at infrastructure level so that external threats (e.g. from the Internet) are optimally addressed. Such deeply integrated mechanisms may support traditional techniques such as network-level firewalls or might turn them even obsolete.

## **5.5 Performance**

Virtualisation involves hiding the differences between heterogeneous resources, across different resource types, between vendors and across time. It allows decoupling of computing hardware from applications and management systems. Hardware and software can then follow independent evolution paths since changes to one can have minimal effect on the other. These are clearly attractive features for a service oriented infrastructure as envisaged for Business Grids. However, use of a virtualised infrastructure increases management complexity because the way applications are mapped to hardware can now be variable. This makes it much more difficult to reliably predict specific performance metrics of the system in advance. This results in unpredictable costs for a given performance level, as the resources required to meet a SLA can only be estimated very roughly.

Scheduling mechanisms are typically restricted to one virtualization layer and not harmonized across layers, resulting in sub-optimal balancing of work loads. Performance estimation is necessary in order to apply advanced scheduling techniques. Advanced scheduling systems are necessary in order to allocate and reserve resources in advance (for co-allocation problems) and to enable the system to effectively apply pre-emption. Such advanced scheduling has to take into account the logical boundaries in hierarchical enterprises and in hosting scenarios.

A specific research challenge is on resource sharing in mass hosting environments, i.e. research in sharing compute, network and storage resources among hosting customers while still keeping them effectively isolated. Interactions between applications sharing the same resources are unpredictable in general and in a virtualised environment it will be hard to test all possible combinations in advance. Support for predictable isolation at the resource level is required.

## **5.6 Interoperability**

In today's grid-like systems, interoperability is restricted in two dimensions: First and in contrast to virtual-machine based grids, traditional grid systems require the specific engineering of applications to be "gridified". Second, different grid systems cannot easily be connected as they are based on different standards and use different interfaces.

Consequently, Business Grid research has to address the harmonization of traditional and virtual machine based grid capabilities to allow for executing existing business applications without further modifications. A second research area is on open standards that support the interoperability of different Business Grid flavours. This is especially important for the hierarchical enterprise scenario.

## **5.7 Manageability**

Management tasks are still a major cost driver in today's business systems. In particular, many management tasks are not yet extensively automated. Grid systems provide some support for automated management of infrastructure resources but typically follow a

narrow perspective that simply covers the management of resources as assets rather than looking at the overall business solution stack.

Infrastructure architectures and their management systems need to have the flexibility to incorporate new kinds of server and special-purpose devices alongside existing hardware. Virtualization technologies applied across many resource types (hardware, operating systems, middleware, applications, etc.) can provide abstractions and interfaces required for an integrated and automated approach to management. Realising this promise is a significant research challenge.

The traditional approach to systems management has relied on human intervention to manage complex situations. However, this is now becoming untenable in large enterprise deployments and will be even more so in future Business Grid scenarios. There is a need to monitor and control on timescales relevant to individual application sessions whose duration could be on the order of seconds. Control decisions, particularly in a virtualised infrastructure must be made more rapidly than manual systems can achieve. Management information will not, in general, be completely shared across administrative boundaries so there will be no central point where management decisions can be made with full knowledge of the system state. Automated and decentralised management decision-making is required to achieve the required speed of response, particularly in a large system.

Appropriate analysis and presentation tools are required to provide visibility of the business performance on appropriate timescales for human decision makers.

These challenges apply to all of our business scenarios. A specific research challenge for hierarchical enterprises involves concepts for mediation and conflict management in distributed environments. Hosting scenarios require special attention on remote management and mass automation support (e.g. cloning of customer systems).

## **5.8 Governance**

Today, enforcement of governance policies is poorly supported and if at all requires manual intervention by administrators. In particular, support for complex organizational setups (such as hierarchical enterprise) is almost non-existent.

An important research challenge is therefore the enforcement and tracking of policies at the infrastructure level. To this end, certain techniques for logging, tracking, and auditing of resources are necessary. Second, the automatic translation of business policies to policies at the infrastructure level is to be explored. A third issue is on automated mechanisms for enforcement and conflict resolution. These challenges apply to all business scenarios. However, the hierarchical enterprise scenario requires additional research on how to derive models and techniques to specify and reflect a hierarchical structure of policies. The corresponding models must be very flexible such that they can easily be adapted for the different enterprises. Finally, hosting scenarios require governance support for both providers and customers.

## **5.9 Flexibility**

Today, business decisions are often implemented in a fixed way, e.g. a fixed landscape design reflecting security zones or a static deployment of applications on resources. Flexibility as envisioned by Business Grids requires research in two main areas: the automation of information flows and management processes from business process to infrastructure, and the dynamic adjustment of infrastructure resources. As automation issues are already discussed in other sections we focus on resource topics. All of our scenarios require research in dynamic allocation and release of resources. This also includes migration mechanisms for supporting load balancing and scalability requirements. In contrast to eScience applications, the migration of business applications may also include migration of related application pools and data sources. Finally, research needs to investigate the interplay of migration and scheduling mechanisms.

## **5.10 Overarching challenges**

Finally, there are some overarching research challenges which cannot be directly derived from the listed business scenarios and business requirements. Those research challengers cover:

### **Direct contribution to business value**

Users of Business Grids should not care about the details of the supporting technology. Enterprise-wide Grids supporting multiple applications (and still more so, Grids that span multiple enterprises) need to offer well-defined functionality and performance, described in terms that make sense to users and at a predictable price. This will allow costs and benefits to be clearly quantified.

### **Reduction of the complexity of Grid technology**

There is a need for the complexity of Grid technology as perceived by users to be significantly reduced. Ideally, the infrastructure deployed to support their applications should become invisible, allowing them to concentrate on their main concerns. The inherent complexity of the technology will undoubtedly increase as Business Grids evolve and this complexity will need to be managed by system administrators or service providers. Management systems and tools will need to offer high levels of automation, appropriate levels of abstraction and user friendly interfaces if this is to be tractable.

### **Architecture driven solutions**

Both domain-specific and inter-domain enterprise grid scenarios require well architected platforms that create a fabric for business flows, the services that power them, and the software components that enable the services. Interworking within a well-governed, coherent and consistent framework is required to deliver characteristics such as security, dependability and performance end-to-end. The framework should ensure that the 'service ecosystem' is:

- well-governed (policy and rules driven, monitored by SLAs)
- well-balanced between the need of flexible business flows and mandatory technology processes
- well-orchestrated at the level of complex 'end-user' services

- well-integrated at the level of software systems powering core and derived services
- well-instrumented at the level of the technology stacks powering the software systems
- well-supported at the level of infrastructure.

Grid architectures will need to address these requirements, and include both business and technical aspects. Interoperable Grid service architectures specific to the business scenarios described above, will need to be developed.

## 6 Community Involvement

The aim of this section is to describe the open process that will be implemented to extend participation in the development of the NESSI-Grid SRA to external members of the consortium, mainly focusing on the relevant players and experts within the Grid Community.

The first section lists the relevant members of the grid community whose involvement will be sought. Three models for contribution are defined in the second section in order to obtain relevant inputs from the different types of contributor. The planning of the open process is described in the third section. Finally, the fourth section introduces the SOI-NWG (Software Oriented Infrastructure NESSI Working Group) as the instrument for the implementation of the open process.

### 6.1 Definition of the Relevant Members of the Community

This section defines relevant players of the Grid community whose participation in the SOI-NWG will be solicited as a means to provide feedback and contributions to the NESSI-Grid SRA. In the context of NESSI-Grid, Grid is defined as the adaptive service-oriented utility infrastructure for arbitrary business applications, primarily aimed at providing business flexibility in the most efficient way. Typically, business applications do not exist as independent executables but involve a complex technology stack, containing for example application servers, databases, other middleware components and other co-existing and cooperating business applications. In addition, usage patterns are often interactive or session-based. The scope of research and development in business grids covers the development of middleware that provides an ITC infrastructure to support business applications; from the basic services of the infrastructure to the support for process provisioning, monitoring, integration and outsourcing. That includes research on service computing, utility computing, virtualization, SLAs, stable and safe architectures data management, knowledge and analysis services, service flow description, dynamic VOs, ...

Contribution to the SRA is open to any individual (*individual contribution*) with relevant experience in the business grid area, i.e., it will not be restricted to NESSI members. In fact its promotion to any valuable player is one of the aims of the community involvement activity. Participation of experts from Industry is of special importance and so invitation for participation will be submitted to business oriented working groups, such as the Enterprise Grid Requirements Working Group at OGF. It is also important to count on the participation of experts with a clear view of the state-of-the-art and the challenges in the major technological components of a Grid solution, such as the coordinator of the technical groups in concertation task 1 of European projects.

Moreover, there are groups of interest (no legal entities) in the grid community; whose feedback may provide great value to the document. It is understood that in this case (*groups of interest contributions*) the contributors act as representatives of their corresponding groups of interest. The following list is not complete and should be considered as a guide:

- **Research Projects.** Large grid-related projects, such as FP6 IPs. NextGRID, SIMDAT, AKOGRIMO, XTreemOS, BEinGRID and BREIN will be encouraged to participate in the process. Other ongoing STREP and SSA projects, such as GridCOMP, A-Ware, ..., will be also invited to contribute.
- **Infrastructures.** European Grid infrastructures, such as EGEE and DEISA, and regional Grid infrastructures, such as D-Grid, UK NGS and NorduGrid, will also be encouraged to participate.
- **Middleware Solutions.** Main Grid OSS communities, such as the Globus Alliance, and middleware projects, such as UNICORE, gLite, GRIA, OMII, GCM/ProActive, ..., will be also encouraged to participate. Other middleware solutions for utility computing, virtualization, SLAs, management, knowledge and analysis services, service flow description, dynamic VOs, etc. will be invited to contribute.

## 6.2 Contribution Models

Contributions can have any extension. Accepted contributions will imply that the corresponding contributor gets cited in an acknowledge section. Three approaches have been defined to provide feedback and contribute to the NESSI SRA:

- **Individual Contributions:** Experts from Industry, Research and Academia can contribute by submitting comments and/or change proposals completing the form provided in Annex A. Submissions will be sent to the editor chief. All accepted contributions will be included in the SRA document and the sources will be cited in an acknowledge section.
- **Group of Interest Contributions:** Representatives of the main groups of interest (research projects, infrastructures and middleware solutions) can contribute by submitting one of the surveys provided in Annex B, C and D, which have been designed to extract relevant information according to the type of project. Submission will be sent to the responsible for liaison with the grid community. The surveys will be analyzed and the results included in the SRA. The name of the representative and the contributing project will be cited in an acknowledge section.
- **Related Analysis.** Projects, such as BEinGRID, ECHOGrid or SIMDAT, and working groups, such as the OGF WG on Enterprise Grid Requirements and EU Concertation Tasks 4 and 5, can also contribute by submitting related analysis, surveys and interviews. Submission will be sent to the responsible for liaison with the grid community. This information will be analyzed in the SRA, and the source will be cited.

## 6.3 Implementation of the Open Participation Process

NESSI-Grid will follow an open process of consultation to collect inputs to the SRA from relevant members of the grid community.

### Community Involvement Process in the Edition of the Second SRA Version

#### PHASE A: Design and Development of the Open Process

- June 18: Development of a draft describing the open process for community involvement and distribution to the participants of the Service Oriented Infrastructure NESSI Working Group meeting to be held on June 21
- June 21: Presentation of the draft in the Service Oriented Infrastructure NESSI Working Group meeting and open discussion.
- July 5: Incorporation of the definitive open process for community involvement in the SOI-NWG web page and in the draft of the second SRA version
- July 15: Release of the draft of second SRA version

#### **PHASE B: Call for Contribution**

- July 15 – September 30: Period during which contributions to the draft of the second SRA version are requested. The NESSI-Grid project will put the resources involved in promoting and monitoring participation of individuals and groups of interest in this call for contribution.

#### **PHASE C: Analysis of Contributions**

- October 1 - October 7: Evaluation of the response of the community, incorporation of the individual contributions in the second SRA version and analysis of the contributions from the groups of interest and the related analysis in the SRA.
- October 8 - October 15: Publication of the analysis of the surveys and last draft of the SRA for public comment.
- October 31: Release of the second SRA version.

#### **Community Involvement Process in the Edition of the Third SRA Version**

The process for community involvement in the development of the third SRA version will be designed according to the results of the first community involvement process. The main target for the surveys will be the new projects funded by FP7 that will not be able to participate in the edition of the second version of the SRA.

### **6.4 SOI-NWG as Instrument for Open Participation**

The Service Oriented Infrastructure NESSI Working Group (SOI-NWG) will provide the umbrella under which the open edition and promotion of a widely agreed NESSI-SRA for business grids will take place:

- The SOI-NWG mailing list ([wg-service-oriented-infrastructure@nessi-europe.eu](mailto:wg-service-oriented-infrastructure@nessi-europe.eu)) will be used for open discussion on the contents of the SRA and to notify updates in the web.
- The SOI-NWG WIKI (<http://www.soi-nwg.org>) describes the open process adopted to develop the SRA and incorporates collaborative tools which support distribution of the subsequent versions of the SRA and workshop presentations as well as the contribution and participation of members of the community in the SRA development process.

## 7 Business and Market Indicators

### 7.1 Introduction

This section is going to be fully developed in version 3 of the SRA; this version will introduce its future contents. The aim of this chapter is to define a collection of market and business indicators, related to the Grid field, that help defining the SRA challenges and roadmap as well as monitoring the impact of its implementation.

This section is structured in two main parts:

- To find the right indicators the first premise is to define the target market from where we will extract them. Once determined, we will be able to identify the characteristics of this target market: the major players, the relationship among them, their functional needs, their priorities and get their statistics related to the use of grid-related technology.
- The definition of the business indicators, that is, those indicators which aim is to measure the impact of the SRA on the use of Grid technologies by the target market players.

Next subsections will elaborate each of these parts.

### 7.2 Target market and main players

Generally speaking, target market would be composed of all those stakeholders who may obtain benefit from deploying an infrastructure that allows looking for more computing resources to execute applications/services, either internally or externally to an administrative domain. Some stakeholders will ask for additional resources to execute their applications; other will provide/share them.

Identification of these players, the business/academic sector they belong and thus their activities, allows gathering their needs and derive the functional requirements how business grids can help to achieve them. This is reflected in the business scenarios section of this document.

#### Target market - sectors

Target market could be classified in three main sets of stakeholders (see [69])

- **Academia and research:** emphasis is on collaborative working and utilization of resources for discrete processes that require considerable processing power.
- **Public Sector:** a major user of high power computing. Some of the applications they use with grid technology are predictions and forecasts (whether models, population growth, etc.) in applications combining statistical and quantitative analysis, military applications and e-Government and e-Health
- **Commercial enterprises:** Main drivers in Grid adoption are improving performance -which allows a significant reduction of computing time and thus the possibility of doing new things, new services and reduce time to market-, cost reduction and also competitive concerns [70].

Drilling into target commercial enterprises, main functional requirements can be obtained from the following sectors and applications:

- Energy (for oil and gas for exploration)
- Finance/insurance/real estate (securities and brokerage –especially for stock/ portfolio analysis and risk management)
- Aerospace and Automotive (for collaborative design and modeling)
- Life sciences (particularly in pharmaceuticals)
- Media/entertainment (to generate digital animation)
- Architecture (engineering and construction)
- Electronics (design and testing)
- Manufacturing (inter/intra-team collaborative design, process management)
- Utilities (to improve efficiency while dealing with peaks and valleys in utilization)
- Telecommunication Operators (mainly processing and analysis of big amount of data)

An important input for the SRA is the identification of how SOI-related technology can improve the solution for the main needs of the above sectors (i.e. for manufacturing, how SOI can influence in the speed of the product chain and in the product margin; for services, how can improve the capacity utilisation; or for knowledge, how can improve image and reputation, competence and know-how).

Furthermore, looking to the short, mid and long-term needs and expectations of these different sectors will provide the basis for establishing priorities in the SRA and adjust the roadmap accordingly.

### Target market - Main players

Looking to the different sectors that are sensible to benefit from grid technology, we can abstract the different generic players who have an active role in the market and are present in one or more of the above sectors [69]:

- **Middleware providers**, in particular lower layer towards the infrastructure and grid application and utility
- **Application providers**, in particular modularized applications that can be used on a grid
- **Hardware providers**
- **Grid Systems Integrators**
- **Network providers**, e.g. offering servers for hiring, or in case when the mobile world is involved, the Telco company is providing its infrastructure
- **Content providers** - Content creator, content aggregator, content distributor
- **Service providers** - Grid service provider, retail service provider, access provider, ...
- **Payment providers**
- **Users** –Business and private users, government and science who can use the grid , provide resources for the grid or even both.
- **Regulatory bodies**, like standard bodies, and governments who provide the rules

- **Other Influential entities** as media, consultants, other information sources, (press, Web portals, professional events)
- **Identity providers** as Certification Authorities.

These players and the sectors they belong are the basis to define the business and market indicators that are introduced below.

### **7.3 Indicators**

The purpose of these indicators is to have a snapshot of the use of grid technology in certain moment in time and to follow its evolution by getting their value periodically. This evolution can show us the impact on the market of the implementation of the SRA. In what follows we introduce the list of proposed indicators that will be refined in further versions of the SRA.

#### **Adoption Dynamics**

Different industrial sectors adopt technologies at different rates. There has already been large-scale adoption of grid technologies by many financial and engineering companies. Penetration into public sector, retail and general consumer sectors has been much less so, if at all. The adoption dynamics of each sector will differ because their business requirements differ, but this indicator will reflect a number of these dynamics such as the number of sectors adopting business grids, the speed of adoption with individual sectors, the increasing speed of adoption in sectors adopting later, etc.

#### **Emergence of New Vendors**

The belief is that the development of business grids will give rise to new companies selling hardware, software and services to both implement the grids themselves as well as implement new services using these business grids. This indicator will reflect the number of new commercial organisations that start trading in areas pertaining to business grids.

#### **Interest from Current Vendors**

Just as new companies will form to take advantage of the business opportunities around business grids, so existing vendors of hardware, software and services will adopt technologies and business models to take advantage of these opportunities too. This metrics will reflect the number of new offerings of hardware, software and services offered by existing companies (those existing prior to the formation of NESSI) to address the opportunities arising from business grids.

#### **Behaviour of Big Companies**

Big company behaviour basically falls into one of two main categories. There are those big companies that will be providing business grids – whether this is providing the components to build them, providing the grids themselves as utilities, etc. - and those who are using them internally. Indications related to the former will be covered by the previous indicator (Interest from current vendors). This indicator will reflect the latter. A possible measurement for the success of this might be the percentage of their internal infrastructure that is in a business grid.

### **Standards and Ontology Resources**

Interoperability of business grid components from different providers will only be possible through the widespread adoption of standards. One of the reasons that commercial grid implementations are much wider than those grids implemented with a 'standards-based' approach is predominantly down to a lack of a set of standards and consequently a lack of software that implements these standards. This indicator will reflect the number of agreed and ratified standards for business grids that have been implemented by products from multiple vendors.

### **Emergence of New Consulting Companies**

Just as the development of business grids will give rise to new companies selling hardware, software and services to both implement the grids themselves as well as implement new services using these business grids, there will be business opportunities for organisations consulting in this area. This indicator will reflect the number of new commercial organisations that start trading to provide consultancy pertaining to business grids.

### **Emergence of New Applications, Architectures and Components**

The belief is that the development of business grids will give rise to new applications, architectures and components (be they hardware, software or services). These will be used to undertake new business challenges or to address business challenges in new and innovative ways. This indicator will reflect the number of these business solutions that simply could not have been addressed without the implementation of business grids.

### **Publications**

There are many academic publications today with grid-related content. There are very few, if any, non-academic publications directly aimed at the business user of these technologies. As business grids become more established as platforms, the number of publications will undoubtedly increase. This indicator will reflect the number of business-centric, non-academic publications around business grids, their implementation, use and management.

### **Seminars and Conferences**

There are many academic seminars and conferences today with grid-related content. There are very few, if any, non-academic conferences / seminars directly aimed at the business user of these technologies. As business grids become more established as platforms, the number of these will undoubtedly increase. This indicator will reflect the number of business-centric, non-academic conferences around business grids.

### **Analyst and Media Attention**

There is already a considerable amount of analyst and media attention on grid computing. More correctly, this interest has existed in the past and is now starting to tail off as grid has been somewhat overtaken by newer technologies which are currently perceived as being 'hot'. This indicator will reflect the number of media and analyst articles that are written about all aspects of business grids.

### **Amount of grid-enabled applications**

Business grids are only of interest if they can run applications. Some of these applications will be new. Others will be implementations of existing (legacy) applications that can both run on, and take advantage of a business grid. This indicator will reflect the number of business applications, both commercial and open source that can run on a business grid.

### **Evolution of users (nodes) of grid middleware, grouped by business or academic**

As business grids are adopted by commercial organisations, the number of nodes running grid middleware or the number of users of grid middleware (whether directly or indirectly) will increase. This metrics is a simple reflection of the number of nodes with “business grid middleware” installed on them or the number of (direct and indirect) users of “business grid middleware”.

### **Evolution of other technologies related to “SOI”: SOA, WS, ...**

Business grids build upon many technologies, standards etc. from other areas of IT. Without these items being in place to be ‘re-used’ by business grids, there will be a requirement for business grids to ‘reinvent the wheel’ and provide similar functions themselves. This is both wasteful and time-consuming. As such, these other technologies and standards need to evolve to support the needs of business grids. This indicator will reflect the progress made towards delivering these underlying and complementary technologies and standards, as well as reflecting the modification or extension of existing technologies and standards to better support the needs of business grids.

### **Usage of any common platform, joint testbeds, repositories etc. that are created for the purpose of fostering the implementation of business grids**

Whilst most commercial organisations are likely to either purchase the components and build their own business grids or buy commercial services from other commercial organisations, there may be a proportion of organisations that will consider an open source or ‘community’ approach to building a business grid. To facilitate these, repositories of open source business grid software, testbeds, common platforms, etc. are going to be needed. This indicator will reflect the number of these entities and the numbers of commercial companies actively using them.

## 8 Conclusions and Outlook

This document has set out a general vision for grid infrastructures used in business environments.

Based on a variety of short-, mid- and long-term business scenarios and requirements detailed research challenges have been derived. These challenges result from three major sources:

- **Societal requirements:** most important here are issues on data management (both for compliance reasons but also as “brain” of an organization), accounting, SLA management and environmental sustainability.
- **Technical trends:** most important here are application development for advanced hardware environments (e.g. multicore) and better integration of network characteristics into applications and architectures.
- **Non-functional requirements:** these cover the full variety of issues, such as dependability, security, performance, interoperability, manageability, governance, and flexibility.

Future versions of this document will feature a detailed roadmap for the identified challenges. As a first indication and input to this, the following figure represents the discussed business scenarios and their dependencies. The Enterprise scenario is set as basis out of which other scenarios can be stepwise developed according to three dimensions: organizational complexity, technical reach and degree of service enablement.

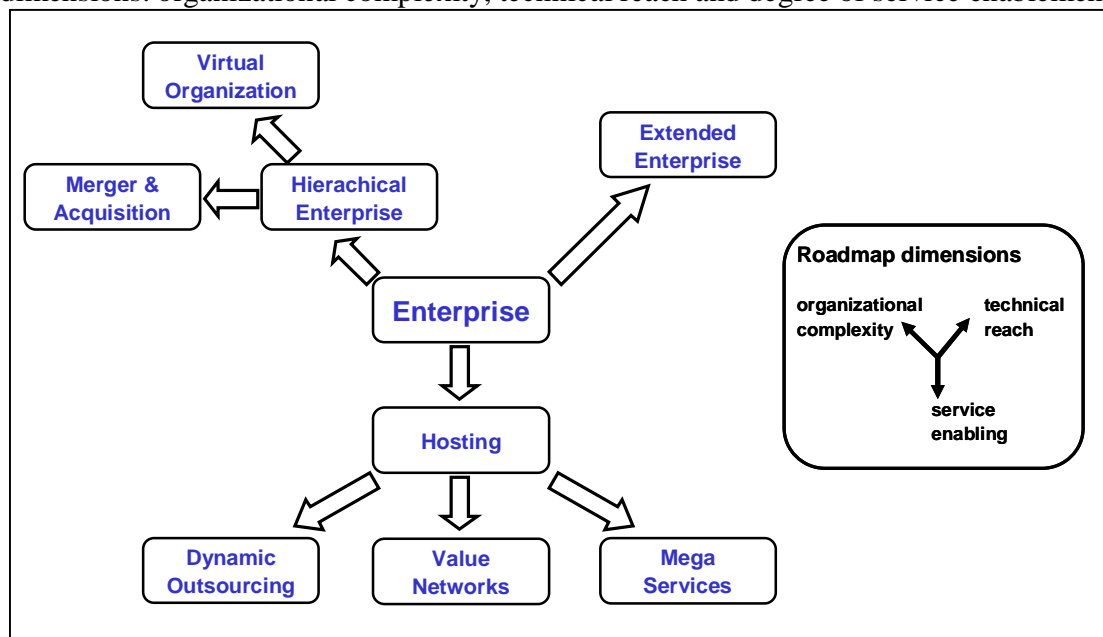


Figure 3: Roadmap for business scenarios.

Though Business Grids do not directly create new application types or business models, their impact on the further evolution of the service economy cannot be underestimated. As a general-purpose service-oriented infrastructure they will become the backbone for

highly flexible, service-based interactions, where business needs and IT capabilities are transparently reconciled.

This document is a work-in-progress document. Community feedback from a variety of channels and domains will be used for complementing all aspects of this SRA, in particular refining and/or complementing on business scenarios, state-of-the-art and research challenges. Version 2.0 of this SRA, including the consolidated input from all possible community members is planned for end of October 2007.

Based on that consolidated and comprehensive overview, a detailed roadmap analysis will be done towards version 3. This will also include recommendations for researchers, industry and policy makers.

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## ANNEX A: Sample of Contribution Form for Individual Contributors

The Service Oriented Infrastructure NESSI Working Group ([www.SOI-NWG.org](http://www.SOI-NWG.org)) is defining the NESSI Strategic Research Agenda on new generation of ITC infrastructures (NESSI-Grid SRA). In this context, business Grid is envisioned as the adaptive service-oriented utility infrastructure for business applications, which will become the general ICT backbone in future service oriented economies.

The aim of this template is to collect the feedback of relevant experts in the Grid community on the draft of second version of the NESSI-Grid SRA (v1.5). Thank you for participating in this survey. Your feedback is important in helping us improve future versions of the NESSI-Grid SRA. Please be concise and specific.

### CONTRIBUTOR

|               |
|---------------|
| Name:         |
| Organization: |
| E-mail:       |

#### 1. Overall Comments on the SRA

|  |
|--|
|  |
|--|

#### 2. Specific Comments and Amendments on Sections

*Copy the next table for each section. Comments have to be accompanied by an amendment proposal. An amendment proposal will be produced by copying the amended text and introducing changes under change control.*

|                        |
|------------------------|
| <b>Section Number:</b> |
| Comment                |
|                        |
| Amendment              |
|                        |

|                        |
|------------------------|
| <b>Section Number:</b> |
| Comment                |
|                        |
| Amendment              |
|                        |

## ANNEX B: Sample of Survey Form for Research Projects

The Service Oriented Infrastructure NESSI Working Group ([www.SOI-NWG.org](http://www.SOI-NWG.org)) is defining the NESSI Strategic Research Agenda on new generation of ITC infrastructures (NESSI-Grid SRA). In this context, business Grid is envisioned as the adaptive service-oriented utility infrastructure for business applications, which will become the general ICT backbone in future service oriented economies.

The aim of this template is to collect the feedback of relevant grid application projects on the draft of second version of the NESSI-Grid SRA (v1.5). Please notice that you, the contributor, act as representative of a research project and not as an individual contributor himself. Thank you for participating in this survey. Your feedback is important in helping us improve future versions of the NESSI-Grid SRA. Please, be concise and specific.

|  |
|--|
| <p><b>CONTRIBUTOR</b><br/>                 Name:<br/>                 Organization:<br/>                 E-mail:<br/>                 Project:</p> |
|--|

### PART A: BUSINESS SCENARIOS

1. What is your opinion on the relevance and timeline of the business scenarios described in the SRA?

| Scenario                | Relevance  | Timeline  |
|-------------------------|--|---|
| Enterprise              | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Hierarchical enterprise | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Hosting                 | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Extended enterprise     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Dynamic Outsourcing     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Mergers & acquisitions  | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Virtual organisations   | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Value networks          | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Mega Services           | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |

2. Does your project consider other scenarios apart from those described in the SRA?. Please briefly describe the new scenario.

|  |
|--|
|  |
|--|

3. What is the relevance of the business scenarios in your specific project?, What is the percentage of use cases in your project that could be represented by each business scenario?

| Scenario                | Relevance  | Percentage of Use Cases  |
|-------------------------|--|--|
| Enterprise              | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Hierarchical enterprise | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Hosting                 | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |

|                        |  |  |
|------------------------|--|--|
| Extended enterprise    | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Dynamic Outsourcing    | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Mergers & acquisitions | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Virtual organisations  | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Value networks         | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Mega Services          | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |

**4. For those scenarios relevant to your specific project, please indicate if your use cases exhibit other requirements apart from those described in the SRA for the scenario**

| Scenario                | Specify other Fundamental Requirements |
|-------------------------|--|
| Enterprise              |  |
| Hierarchical enterprise |  |
| Hosting                 |  |
| Extended enterprise     |  |
| Dynamic Outsourcing     |  |
| Mergers & acquisitions  |  |
| Virtual organisations   |  |
| Business value          |  |
| Mega Services           |  |

**PART B: STATE OF THE ART**

**5. Indicate the middleware solutions used to implement the scenarios and, if any, the infrastructures used to support them. Please also briefly describe if your project is developing enhancements to the middleware**

| Scenario                | Middleware | Infrastr. | Enhancements |
|-------------------------|------------|-----------|--------------|
| Enterprise              |            |           |              |
| Hierarchical enterprise |            |           |              |

|                        |  |  |  |
|------------------------|--|--|--|
| Hosting                |  |  |  |
| Extended enterprise    |  |  |  |
| Dynamic Outsourcing    |  |  |  |
| Mergers & acquisitions |  |  |  |
| Virtual organisations  |  |  |  |
| Value networks         |  |  |  |
| Mega Services          |  |  |  |

**PART C: RESEARCH CHALLENGES**

**6. Please indicate research challenges not described in the SRA resulting from your project.**

| Categories                     | Specify other Research Challenges |
|--------------------------------|-----------------------------------|
| Functional & Commercial Issues |                                   |
| Dependability                  |                                   |
| Security                       |                                   |
| Performance                    |                                   |
| Interopeability                |                                   |
| Manageability                  |                                   |
| Governance                     |                                   |

|                        |  |
|------------------------|--|
|                        |  |
| Flexibility            |  |
| Overarching Challenges |  |

## ANNEX C: Sample of Survey Form for Infrastructures

The Service Oriented Infrastructure NESSI Working Group ([www.SOI-NWG.org](http://www.SOI-NWG.org)) is defining the NESSI Strategic Research Agenda on new generation of ITC infrastructures (NESSI-Grid SRA). In this context, business Grid is envisioned as the adaptive service-oriented utility infrastructure for business applications, which will become the general ICT backbone in future service oriented economies.

The aim of this template is to collect the feedback of relevant grid infrastructure projects on the draft of the version of the NESSI-Grid SRA (v1.5). Please notice that you, the contributor, act as representative of a infrastructure and not as an individual contributor himself. Thank you for participating in this survey. Your feedback is important in helping us improve future versions of the NESSI-Grid SRA. Please be concise and specific.

|  |
|--|
| <p><b>CONTRIBUTOR</b><br/>                 Name:<br/>                 Organization:<br/>                 E-mail:<br/>                 Project:</p> |
|--|

### PART A: BUSINESS SCENARIOS

1. What is your opinion on the relevance and timeline of the business scenarios described in the SRA?

| Scenario                | Relevance  | Timeline  |
|-------------------------|--|---|
| Enterprise              | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Hierarchical enterprise | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Hosting                 | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Extended enterprise     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Dynamic Outsourcing     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Mergers & acquisitions  | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Virtual organisations   | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Value networks          | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Mega Services           | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |

2. Does your infrastructure support other scenarios apart from those described in the SRA?. Please briefly describe the new scenario.

|  |
|--|
|  |
|--|

3. What is the relevance of the business scenarios in your specific infrastructure?, What is the percentage of use cases that your infrastructure is currently supporting in each business scenario?

| Scenario                | Relevance  | Percentage of Use Cases  |
|-------------------------|--|--|
| Enterprise              | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Hierarchical enterprise | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Hosting                 | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Extended enterprise     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |

|                        |  |  |
|------------------------|--|--|
| Dynamic Outsourcing    | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Mergers & acquisitions | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Virtual organisations  | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Value networks         | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Mega Services          | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |

**PART B: STATE OF THE ART**

**4. For those scenarios supported by your infrastructure, indicate the middleware solutions used. Please also briefly describe if your project is developing enhancements to the middleware**

| Scenario                | Middleware | Enhancements |
|-------------------------|------------|--------------|
| Enterprise              |            |              |
| Hierarchical enterprise |            |              |
| Hosting                 |            |              |
| Extended enterprise     |            |              |
| Dynamic Outsourcing     |            |              |
| Mergers & acquisitions  |            |              |
| Virtual organisations   |            |              |
| Value networks          |            |              |
| Mega Services           |            |              |

## ANNEX D: Sample of Survey Form for Middleware Solutions

The Service Oriented Infrastructure NESSI Working Group ([www.SOI-NWG.org](http://www.SOI-NWG.org)) is defining the NESSI Strategic Research Agenda on new generation of ITC infrastructures (NESSI-Grid SRA). In this context, business Grid is envisioned as the adaptive service-oriented utility infrastructure for business applications, which will become the general ICT backbone in future service oriented economies.

The aim of this template is to collect the feedback of relevant grid middleware projects on the draft of the second version of the NESSI-Grid SRA (v1.5). Please notice that you, the contributor, act as representative of a grid research project as not as an individual contributor himself. Thank you for participating in this survey. Your feedback is important in helping us improve future versions of the NESSI-Grid SRA. Please, be concise and specific.

|  |
|--|
| <p><b>CONTRIBUTOR</b><br/>                 Name:<br/>                 Organization:<br/>                 E-mail:<br/>                 Project:</p> |
|--|

### PART A: BUSINESS SCENARIOS

1. What is your opinion on the relevance and timeline of the business scenarios described in the SRA?

| Scenario                | Relevance  | Timeline  |
|-------------------------|--|---|
| Enterprise              | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Hierarchical enterprise | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Hosting                 | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Extended enterprise     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Dynamic Outsourcing     | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Mergers & acquisitions  | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Virtual organisations   | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Value networks          | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |
| Mega Services           | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> Never <input type="checkbox"/> Short <input type="checkbox"/> Medium <input type="checkbox"/> Long |

2. Does your infrastructure support other scenarios apart from those described in the SRA?. Please briefly describe the new scenario.

|  |
|--|
|  |
|--|

3. What is the relevance of the business scenarios in your middleware solution?, Can the scenario be implemented by the last release of your technology?

| Scenario                | Relevance  | Grade of Implementation  |
|-------------------------|--|--|
| Enterprise              | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Hierarchical enterprise | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |

|                        |  |  |
|------------------------|--|--|
| Hosting                | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Extended enterprise    | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Dynamic Outsourcing    | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Mergers & acquisitions | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Virtual organisations  | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Value networks         | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |
| Mega Services          | <input type="checkbox"/> None <input type="checkbox"/> Low <input type="checkbox"/> Medium <input type="checkbox"/> High | <input type="checkbox"/> 0% <input type="checkbox"/> 25% <input type="checkbox"/> 50% <input type="checkbox"/> 75% <input type="checkbox"/> 100% |

**PART B: STATE OF THE ART**

**4. For those scenarios relevant to your middleware solution, please indicate the requirements that are not currently met by your middleware and if you are planning to provide such missing functionality.**

| Scenario                | Unmet Requirements |
|-------------------------|--------------------|
| Enterprise              |                    |
| Hierarchical enterprise |                    |
| Hosting                 |                    |
| Extended enterprise     |                    |
| Dynamic Outsourcing     |                    |
| Mergers & acquisitions  |                    |
| Virtual organisations   |                    |
| Value networks          |                    |
| Mega Services           |                    |

## ANNEX E: Contributors

This document has been provided by the NESSI-Grid consortium as well as numerous community contributions.

| Expert              | Country | Affiliation & Main contribution                                     |
|---------------------|---------|---|
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| Elies Prunés Soler  | ES      | ATOS Origin, NESSI-Grid: business scenarios and business indicators |
| Eric Madelaine      | FR      | INRIA, NESSI-Grid: state-of-the art                                 |
| John Easton         | UK      | IBM, NESSI-Grid: Basic model, business indicators                   |
| Juan José Hierro    | ES      | Telefonica, NESSI-Grid: community involvement                       |
| Kumardev Chatterjee | BE      | Thales, NESSI-Grid: architectures                                   |
| Mike Fisher         | UK      | BT, NESSI-Grid: research challenges                                 |
| Wolfgang Theilmann  | DE      | SAP, NESSI-Grid: overall lead and business scenarios                |

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