Small or medium-scale focused research project (STREP)

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Research & Education and Cloud Industry Partnership in Europe

RECIPE

Small or medium scale focused research project (STREP)
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Proposal abstract

Infrastructure as a Service (IaaS) or Resource Clouds are the most basic and essential form of cloud systems as most other cloud capabilities are built on them. Several national and international initiatives and pilots have appeared with the aim of deploying IaaS clouds tailored to specific industry sectors such as Research and Education (R&E). Today, different public and private IaaS providers apply different models, heterogeneous cloud architectures, incompatible protocol stacks and proprietary interfaces that limit the technical interoperability between clouds, lock-in customers with technology, and slow down the evolution of the open marketplace and real competition in the cloud industry. RECIPE targets the Research Networks (NRENs) and cloud industry to be able to deliver cloud services to campuses in a seamless way. Becoming acquainted with efficient use of cloud facilities is not without difficulties. RECIPE aims at both a) integrating the campus infrastructure with the cloud as well as b) harmonising and federating various (private and public) Resource Cloud services to bridge the current gap between education and cloud industry. RECIPE designs a resilient, secure, and trusted reference Inter-cloud Architecture (IA), proposes a consistent, harmonised, and interoperable Cloud Carrier Software Stack (CCSS), implements prototypes for the necessary functions, runs a service pilot with carefully selected private and public IaaS clouds (provided by the project consortium partners), and demonstrates the benefits of the inter-cloud carrier model with some pre-selected key e-science platforms and applications on top. RECIPE will deliver a set of comprehensive small reports, best practice documents, pre-standardization recommendations, as well as open source software prototypes and pilot services (i.e. recipes). These recipes will be publicly available for the benefit of both the European R&E community and cloud industry to ensure the sustainability of the results.

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1.1 Concept and objectives

1.1.1 Project concept

Cloud is one of the leading paradigms that keeps Information and Communication Technologies (ICT) stake-holders excited nowadays as it changes the traditional way in which different services and/or resources are operated, managed, and accessed with a profound impact on business practices. Infrastructure as a Service (IaaS) clouds (or Resource Clouds) are the most basic - and at the same time most essential - form of cloud systems, since most other cloud capabilities can be built upon their resource virtualisation facilities.

As “The Future of Cloud Computing, Opportunities for European Cloud Computing Beyond 2010” [cloud] report states: “Resource clouds are of particular commercial interest not only with the growing tendency to outsource IT so as to reduce management overhead and to extend existing, limited IT infrastructures, but even more importantly, they reduce the entrance barrier for new service providers to offer their respective capabilities to a wide market with a minimum of entry costs and infrastructure requirements. In fact, the special capabilities of cloud infrastructures, such as more specialized IT infrastructure knowledge, allow providers to experiment with novel service types whilst reducing the risk of wasting resources.”

However, the current IaaS cloud landscape is very heterogeneous. Customers are experiencing a plethora of competing, largely unfulfilled promises from various network and service providers about being “open” and that networks can seamlessly “share services” between providers. In reality, different vendors and commercial cloud service providers apply different models, incompatible cloud architectures and protocol stacks, as well as proprietary interfaces that limit the technical interoperability between clouds, lock-in customers with technology, and slow down the evolution of the open marketplace and real competition in the cloud industry where the market has been mostly a monopoly so far. The various public (i.e. open) and private (i.e. closed) cloud service offerings are not just technically inconsistent, but in most of the cases administratively and legally separate and inconsistent too.

In parallel with the commercial uptake, several national and international cloud initiatives and pilots appeared in the past years with the aim of deploying cloud services tailored to specific industry sectors such as Government or the scientific Research and Education (R&E) community. Though these initiatives have sound technical objectives, cloud users cannot see real convergence, and coherence among them. For example, several IaaS clouds have been built up by the National Research and Education Networks (NRENs) mostly based on similar disciplines and open technologies (e.g., OpenNebula, OpenStack). However, virtual infrastructure entities such as virtual machines, virtual storage capacities, and virtual network segments can rarely be shared among them.

On the ever-growing landscape of cloud industry, NRENs are in a good position to cope with the challenges of the R&E sector and act as an intermediary (either a cloud provider or cloud carrier/broker) aggregating Higher Education (HE) user demands and service needs on the scientific application front-end and technology-agnostic commercial cloud offerings on the service back-end. NRENs can also help both the cloud industry (especially start-up cloud SMEs) to sell services and resources in the education environment and the higher education institutes to get more and better services from industry.

Desktop applications (i.e. educational and/or scientific software) are becoming more and more pervasive, running on different platforms and network-connected devices (e.g., smart phones/tablets used by students) supporting portability and mobility of data and processes at the application level. We believe that the cloud-awareness must be built into the key e-science applications and platforms used by the typical HE users; so that the application/platform itself is able to request the appropriate Resource Cloud service (IaaS) or do seamless roaming across cloud infrastructures. The necessary information sub-system and interfaces must be designed and developed in order to ensure that the application or platform can discover and configure the underlying cloud resources’ attributes.

The key points of the RECIPE project's concepts are as follows:

1) RECIPE focuses on the European R&E community (primarily served by the NRENs and being a playground for start-up cloud SMEs) as its targeted user group, with special focus on the Higher Educational (HE) use of Resource Clouds (and not the large scientific users).

   We believe that the next generation of European scientists must be cloud-enabled; so they are able to seamlessly access a wide variety of cloud services and resources already in the phase of their education. For the worlds of education and research, which are always global, the way in which scientific data is stored and distributed as well as computing is executed between inter-institutional (i.e. disciplinary-centric) groups is proving particularly challenging. These challenges can only be addressed by a resilient, secure, and trusted Inter-cloud Architecture (IA) as well as a consistent, harmonised, and interoperable Cloud Carrier Software Stack (CCSS) built on open standards.

2) RECIPE targets both the National Research and Education Networks and Cloud industry SMEs and aims at:
   a) seamlessly integrating the campus infrastructure with the cloud, and
   b) harmonising and federating various (private and public) Resource Cloud services, in order to satisfactorily address the aforementioned challenges that the HE users are currently facing and to bridge the current gap between education and the cloud industry.

   This IaaS cloud integration and harmonisation must be done, not only on the technical level (i.e. federated access, exchange of virtual infrastructure entities, storing metadata/encryption keys separate, running virtual instances in the cloud within the user IP address space, etc.), but also on the business processes level (i.e. orchestration that defines the policies and service levels through automated workflows for service offers, purchases and provisioning among multiple stakeholders, enabling providers to optimize efficiency, maximize flexibility, etc.).

3) RECIPE focuses on the Resource Clouds (or IaaS clouds) software stack and goes beyond the usual cloud computing aspects (i.e. computation cycles) to investigate other infrastructure cloud services such as storage and networking, which we consider equally important.

   The scientific application mobility and platform awareness will primarily be supported and demonstrated on the cloud infrastructure and management level (IaaS) validating our IA and CCSS proposals. Application portability and seamless access to various applications in the cloud will also be demonstrated at the PaaS and SaaS levels, respectively (e.g., the information sub-system developed for IaaS-PaaS interworking, and the open interfaces (APIs) developed and service composition and orchestration worked out for IaaS-SaaS interworking).

4) RECIPE takes a two-step approach with developing open source early software prototypes and then implementing pilot services to create an open, inter-cloud experimental environment in order to demonstrate and disseminate the project results.

   We also produce a set of comprehensive small reports, best practice documents, and pre-standardization recommendations - we call them "recipes" - on all the lessons (technical and non-technical) that we learn. These recipes will be publicly available for the benefit of the whole European R&E community and cloud industry SMEs in order to ensure the exploitation of the results and the sustainability of the architecture.

1.1.2 Motivations and main ideas that led to the project

As a consequence of the current early stage of the heterogeneous IaaS cloud marketplace (Fig. 1), the majority of cloud industry offerings are not advertised to or not accessible by HE users (i.e. higher educational institute, university students, researchers, and staff). Usually, they can only be accessed by either the private (or hosted private) cloud of the home institution or the NREN that offers them, or by the public cloud service (e.g. Amazon EC2 or S3) that the institutional or campus policy allows them to use (although many other cloud offerings may be close to them, but not available to them). From the campus infrastructure point of view, most of the cases clouds are considered as external entities. This conflicts with the security policies at many of the campuses which allow HE users to store "sensitive" data only on resources owned by the university itself. Similar issues may happen when considering other use cases for cloud offerings in various public or private organisations. They could potentially benefit from the scalability and elasticity of public clouds, but in case of business critical applications it is often prohibited by the organisation, company or user domain policies. The obvious examples are the storage and processing of medical data in non-trusted, public clouds or the handling of national security-related data by cloud providers based in the US, India or China.

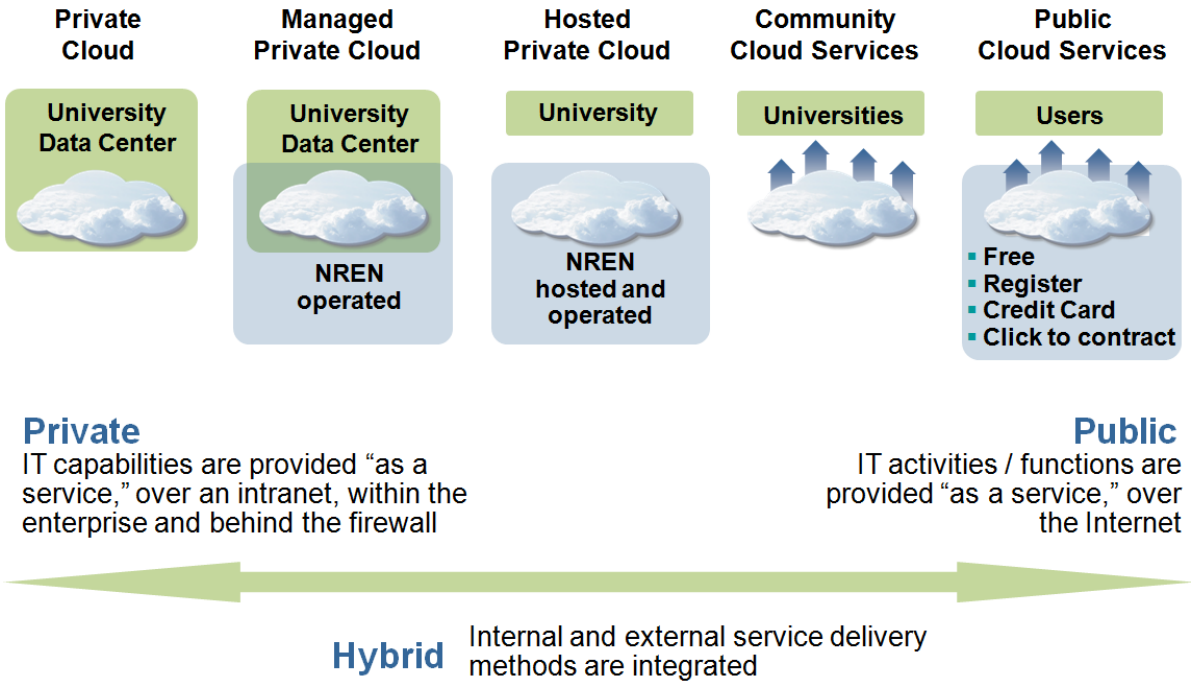


Fig. 1 Public and private cloud industry space
Source: VMWare

The obvious need for university students and staff to be able to access 'the network' seamlessly regardless of their home institution and current location led to the flagship service of NRENs called eduroam [edu]. eduroam (education roaming) is the secure, world-wide roaming access service that allows students, researchers and staff from participating institutions to obtain Internet connectivity across number of campus WiFi infrastructures using their home credentials. eduroam is independent on the current wireless network implementation, access point vendor, internet access provider (either telco or cableco), etc.

Regarding the IaaS clouds, the R&E community today is faced with technical and non-technical barriers to seamlessly access various cloud services (e.g. to share virtual resources among different cloud infrastructure providers) in a technology-agnostic way like eduroam does. Ideally, the choice among the number of public and private cloud offerings would just be a simple match between the application's (customer's) needs and the cloud's features. Unfortunately, it is not that simple as of today (Fig. 2).

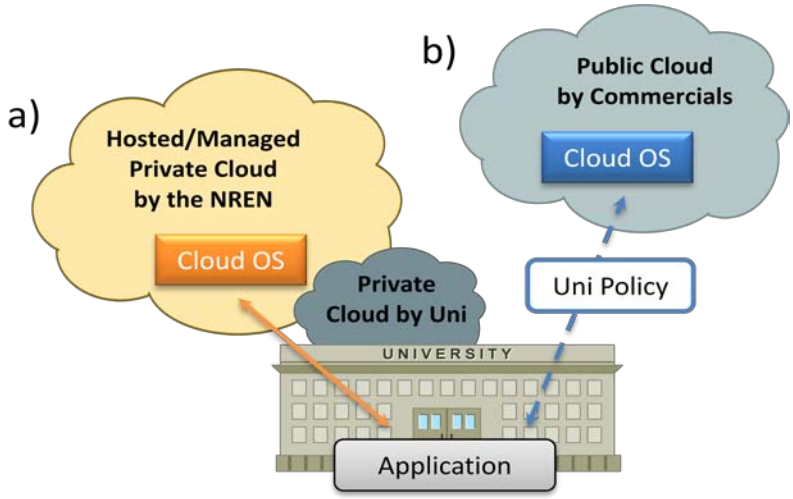


Fig. 2 Today, HE users typically can access a) the private (or hosted/managed private) cloud provided by the home institution or NREN and/or b) the public commercial cloud service (if it is allowed by the policy)

Analysing the campus environment – one that is very well known by the NRENs – it was discovered that most universities have a principle of doing things at a local level; within the university most departments have one or two IT staff and some of the larger ones run e.g., their own email systems or web servers. As the famous Oxford colleges' example [oxford] illustrates, many of the colleges want the servers that they run to be on their network (within the firewalls, own address space) and not in a central location. In some cases there are genuine security concerns (particularly in medical research where security could be a condition of grants). For some researchers, there is just a need to protect their assets.

Beside the technical and privacy concerns, one of the biggest challenges is to select the appropriate charging and business model for outsourced university IT operations. Commercial IaaS cloud providers widely apply the "contract free, pay-as-you-go" business model that works well for individual users but not for university IT departments or campuses as customer. They have to make their IT budget plan a year in advance (that is easy to do if the infrastructure is owned by them) and cannot accommodate dynamically changing, mostly operational cost (OPEX) components depending on the random needs of various students' projects. University IT most likely have fixed budget, particularly if it is a research grant, and they want to know that that the costs will be stable [oxford]. Other public institutions and organizations face similar blocking issues preventing them from using public cloud offerings. In the case of HE, NRENs are in a position to play the role of a financial clearing house for federated campuses, significantly reducing the data transfer costs (in and out of the cloud), and pave the way for multiple commercial cloud providers (especially start-up cloud SMEs) to be able to address and serve the R&E community.

Ii is important to note that, from the Cloud Provider point of view, RECIPE's ecosystem differentiates between the *Cloud User* (i.e. the HE student, researcher and staff) and the *Cloud Customer* (i.e. the university or campus IT department). In some cases only the legal department is allowed to sign contracts, whereas the IT department is responsible for the technical aspects; this only makes the situation even more complex. From the Cloud User point of view, the university or campus IT department can act as a *Cloud Provider* and can also seamlessly deliver/broker third-party cloud services to the users. The NREN can play multiple roles at the same time, such as the private Cloud Provider, commercial Cloud Broker (and a Cloud Customer to other providers) as well as the Cloud Carrier that is able to deliver the Resource Cloud services down to the campuses and HE users.

We believe that RECIPE will satisfy the need of HE users to freely roam between cloud providers using a technology-agnostic, standard-based cloud brokering function and common business layer that will make it technically, legally, and financially possible (Fig. 3) taking all the key players of the R&E sector into account.

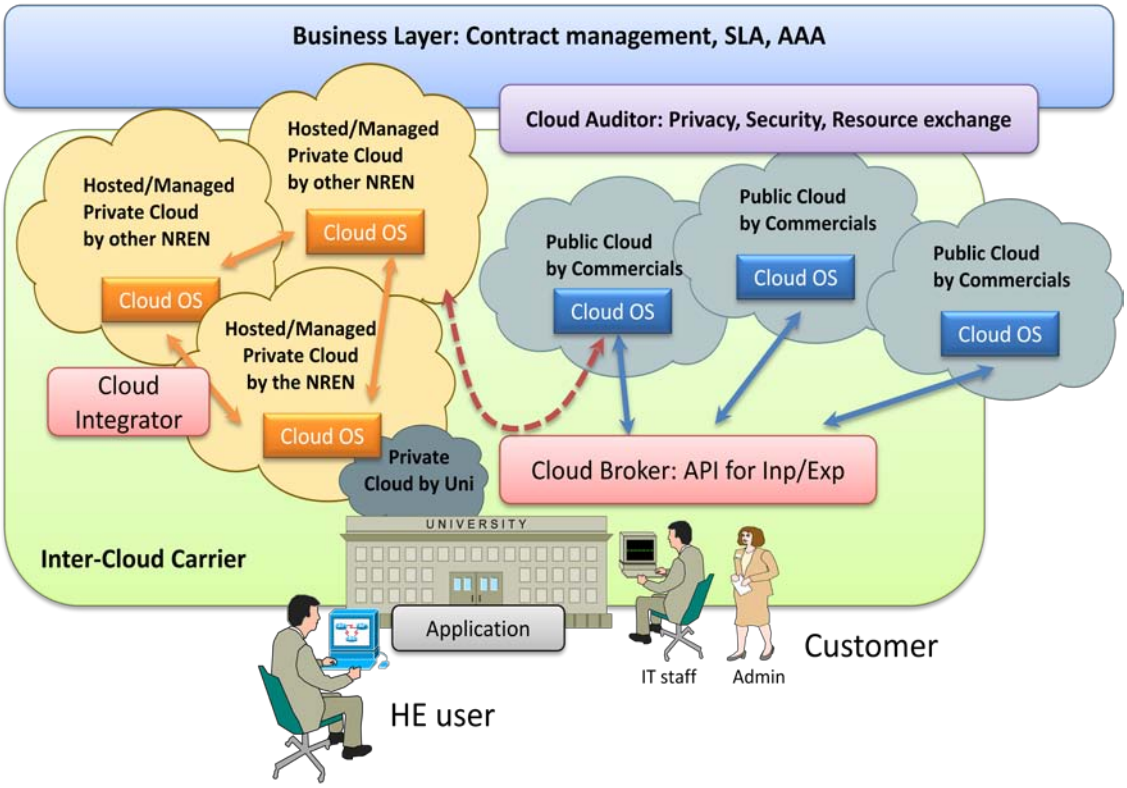


Fig. 3 Inter-cloud Carrier model:
Architectural components, roles, and responsibilities that facilitate HE users to get access to and roam around all the IaaS clouds potentially available to them

This project brings together the key advantages of the in-house private cloud (i.e. reducing the complexity, simplifying operations and maintenance, maximising privacy), the hosted/managed private cloud (i.e. dramatically lowering costs, redirecting investments into value-added opportunity), and the outsourced public cloud (i.e. enabling flexible, agile IT service delivery, meeting and anticipating the needs of the specific industry) models under one, single architecture. In the framework of the project we design a reference Inter-cloud Architecture (IA) and Cloud Carrier Software Stack (CCSS), develop prototypes, and run small scale pilots with carefully selected private and public IaaS clouds (provided by the project consortium partners) applying a (pre-selected) set of HE platforms as a service (PaaS) and reference e-science applications/software as a service (SaaS) on top to demonstrate our objective.

Pre-definition 1: Inter-cloud Architecture (IA)

> The Inter-cloud is an interconnected global “cloud of clouds” and an extension of the Internet “network of networks” on which it is based [intc]. The term was first used in the context of cloud computing in 2007 when Kevin Kelly opined that “eventually we'll have the intercloud, the cloud of clouds”. This concept is taken up by RECIPE and developed further to be tailored and applied to the R&E community needs. The Inter-cloud Architecture, however, raises many more challenges than solutions concerning federation, security, interoperability, vendors’ lock-ins, trust, legal issues, QoS, monitoring, and billing.

Pre-definition 2: Cloud Carrier Software Stack (CCSS)

> The Cloud Carrier Software Stack refers to a set of interoperable, both vertically (up and down the stack) and horizontally (from campus to cloud) harmonised, open source, software components that can be used by an organisation (primarily an NREN alternatively a cloud industry SME) carrying out resource cloud services to customers (university campuses) according to the Inter-cloud Architecture.

1.1.3 Scientific and technical objectives

It is well stated in the aforementioned Cloud Expert Group Report [cloud] of the Commission that: "Many aspects of clouds are still in an experimental stage where the long-term impact on provisioning and usage is as yet unknown. Furthermore, plenty of as yet unforeseen challenges arise from exploiting the cloud capabilities to their full potential, involving in particular aspects deriving from the large degree of scalability and heterogeneity of the underlying resources. … The technological aspects belong in particular issues related to: scale and elastic scalability; trust, security and privacy; handling data in clouds that is still complicated; … and automation of systems development and management. … On the other hand, non-technological issues play a major role in realizing these technological aspects and in ensuring viability of the infrastructures in the first instance. To these belong in particular: economic aspects; legalistic issues; and aspects related to green IT."

The RECIPE project addresses these challenges and particularly addresses two of the Expert Group recommendations as follows:

- One recommendation says that "…the development of standards and a reference implementation would assist European SMEs in particular in ensuring their products and service offerings in the cloud environment have the widest possible market and customer acceptability." [cloud]

  The RECIPE project focuses on the European market and facilitates all the key players of the cloud industry to address the widest possible market, what concerns the R&E community. The NREN space is a challenging incubator of the reference implementations of the new proposals and paves the way towards exploiting results in a sustainable way.

- Another recommendation says that "… maintaining an open source approach for research results and cloud infrastructure support tools ensures uptake and simplifies adaptation to different environments. The European open source movement should thereby work strongly together with industry to support commercial cloud based service provisioning." [cloud]

  The RECIPE project consortium consists of Research Networks (NRENs), cloud industry SMEs, and academic (university, research institute) participants in close partnership that aims at prototyping and piloting the inter-cloud reference architecture based on open source software components and documentation.

The main objectives of the RECIPE project can be summarised as follows:

1. To design and prototype a resilient, secure, and trusted Inter-cloud Architecture (for public and private IaaS clouds) and a harmonised, consistent, interoperable and open source Cloud Carrier Software Stack (i.e. vertical integration) built on relevant standards.
    a. Focus on the HE use of IaaS clouds (i.e. University/Campus IT department as customer and HE student, researcher and staff as end-user) however, bearing in mind other possible applications of the proposed model.
    b. Consider the interoperation/integration between private Resource Clouds (IaaS) provided by NRENs as well as the harmonisation and federation between those private and other public IaaS clouds provided by commercial cloud industry.

2. To integrate and harmonise the existing campus infrastructure seamlessly with the cloud (i.e. horizontal integration) in order to bridge the current technical and non-technical gaps between the education sector and cloud industry.
    a. Do the integration at the technical level (i.e. exchange, import/export of virtual infrastructure entities, store metadata/encryption key separate from the data, run virtual instances in the cloud under the user IP-space, etc.)
    b. Do the harmonisation at the business processes level (i.e. orchestration that defines the policies and service levels through automated workflows for service offers, purchases and provisioning among multiple stakeholders, etc.)

Additional objectives of the RECIPE project can be seen as follows:

1. To prototype the necessary architectural components to be recommended by an integrated campus-cloud infrastructure, and pilot the complete scientific workflow that can be adopted by R&E.
    a. Develop and demonstrate new business models, operational workflows and resource provisioning methods that define new roles e.g., Cloud Carrier with Cloud Broker/Aggregator, Cloud Customer (not user), etc.
    b. Use the NRENs infrastructure that provides a flexible experimental environment and take a set of key e-science applications/platforms of HE users into account for demonstration purposes.
    c. Design and prototype a Business Layer on top of the inter-cloud services in order to enable automated provision and invocation of infrastructure service components among multiple providers, to optimize flexibility and efficiency (i.e. to create a market place).

2. To define and prototype the Cloud Carrier Software Stack and the associated operational models that allow interactive services negotiation, validation, and characterisation.
    a. Experiment with an enhanced Service Delivery Framework (SDF) for multi-provider cloud service integration and provisioning as well as a federated SLA (Service Level Agreement) management during the whole services/infrastructure lifecycle.
    b. Develop appropriate SLA mechanisms, security disciplines, trust frameworks, legal policy, billing and accounting practices for brokered cloud services.
    c. Formalize a shared European policy for HE among the IaaS cloud service providers and customers.

3. To enhance security and trust by introducing well-established security disciplines in Resource Clouds such as AAI.
    a. Investigate the main security concerns such as content ownership, data security and trust.
    b. Propose a SAML/Shibboleth based security framework with con-federated AuthN (eduGAIN support) and with special focus on AuthR and Accounting sub-systems.
    c. Define common security services interface for IaaS cloud integration with platforms and applications. We understand that data security issue might be a blocking factor for up-taking even private clouds - depending of course on disciplines, awareness, etc.

4. To build up a trusted European network of academic (i.e. NREN) and industrial (i.e. cloud SME) IaaS providers with mutual quality and reliability measures.
    a. Catalyse the knowledge and best practice collection and exchange among service providers, service brokers and users.
    b. Support the less cloud-aware institutions (in the R&E sector) to take over the knowledge worked out by the European cloud pioneers and offer cloud services built upon the same disciplines.
    c. Facilitate standardization activities; either use currently available standards or boost widely accepted practices toward standardization.
    d. Produce a set of comprehensive small reports, best practice documents, and pre-standardization recommendations - we call them “recipes”.

5. To define use cases and pilot a complete service workflow with the set of flagship open source e-science platforms and applications running on top of the reference Inter-cloud Architecture.
    a. Design and implement the necessary information sub-system and interfaces in order to ensure that the application/platform is aware of the underlying cloud resources’ attributes.
    b. Demonstrate use cases, applied business models, and a complete real-life service workflow from application to infrastructure (e.g., mobility of educational courses, in particular, laboratory and computational setups).
    c. Decide upon which IaaS applications (e.g., dependent on latency issues) can be moved to an IaaS cloud provider which uses green power and air cooling and experiment with applications that are less latency dependent and could be moved to a more environmental friendly (i.e. green) IaaS cloud in a potentially far-away location.

1.1.4 Objectives relate to the topics addressed by the call

Topics addressed by the call	Projects activities related to the topics
Intelligent and autonomic management of cloud resources, ensuring agile elastic scalability. Scalable data management strategies, addressing the issues of heterogeneity, consistency, availability, privacy and supporting security.	**Intelligent and autonomic management of cloud resources** The Inter-cloud Architectural components proposed and prototyped (i.e. Cloud Carrier/Broker components together with the cloud information subsystem/registry and key application APIs) allow the intelligent and automated selection of IaaS cloud services as well as autonomic management/allocation of cloud resources to platforms and software on top. **Availability** The multi-provider based inter-cloud carrier model addresses the higher level of availability thanks to the increased redundancy of resources and enables to offer higher level of SLAs. Applications' robustness can be achieved by making them cloud-aware (e.g., they will explicitly store multiple data replicas in the cloud-backed storage spaces) or providing the abstract cloud interfaces that hide the reliability mechanism and don't require application modification (e.g., transparent data replication to multiple clouds). **Consistency, privacy, and security** Data and application consistency is addressed by applying appropriate mechanisms at the trust borders, such as cryptography (encryption, integrity control, keys handling) as well as data (replication, erasure-coding, etc.) and resources redundancy techniques.
Technologies for infrastructure virtualisation, cross platforms execution as needed for service composition across multiple, heterogeneous environments, autonomous management of hardware and software resources.	**Infrastructure virtualisation, cross-platform execution** Architectures, technologies and techniques for IaaS cloud interoperation/harmonisation will be proposed in order to seamlessly exchange resource cloud entities among different Cloud Providers exploiting: • cloud federations, inter-cloud services • improved trans-domain network and storage services • enhanced, and leveraged cloud security framework **Service composition, across multiple heterogeneous environments** RECIPE focuses on service orchestration rather than service composition. We don't create new services as combination of others; just select the appropriate ones from the service portfolio according to the applications' profile. However, the application profile can be dynamically changed while the application is running. Orchestration defines the policies and service levels through automated workflows, provisioning, and change management. This creates an application-aligned infrastructure that can be scaled up or down based on the needs of each application.

	Autonomous management of hardware and software resources Orchestration also provides centralized management of the resource pool, including billing, metering, and chargeback for consumption. We define an orchestrator as the entity that manages complex inter-cloud processes and handle exceptions.
Interoperability amongst different clouds, portability, protection of data in cloud environments, control of data distribution and latency.	**Interoperability amongst different clouds** On the one hand activities around loose cloud integration will focus on architecting IaaS services, for example a cloud broker, and cloud resource information sub-system that will allow cloud users to transparently access the different IaaS cloud services offered by autonomous cloud providers. On the other hand a deeper level, tight cloud integration will also be considered investigating how different cloud entities (virtual machines, virtual network segments, virtual disk slices and cloud data stores) can be transferred among the different cloud domains. The beneficiaries of tight cloud integration are not merely the primary cloud user communities, but also the cloud provider communities, i.e. NRENs, commercial providers, and campus cloud providers responsible for sustaining the infrastructure. In both cases, data exchange, data access interface and distribution mechanisms will be developed in order to address • portability • protection of data in cloud environments, especially at trust borders • control of data distribution and latency in aggregate cloud. **Protection of data in cloud environments** In the context of cloud interoperability, the integrated campus-cloud infrastructure allows the separation of metadata and encryption keys or cryptographic digests from the data, so that they can be stored locally on campus while the data can be stored in the cloud protected against illegal access or unwanted modification. We understand that encrypted data must be decrypted for computation in the cloud and so that can be somehow scanned, stolen from the memory or altered and thus made inconsistent. However, there are some technical best practices on how to protect the computation environment to make it more difficult or impossible and organisational solutions that minimise the risks of such abuses and these approaches will be investigated and disseminated.
Seamless support of mobile, context-aware applications.	**Mobility** The mobility is meant by application data and process portability from one cloud provider to the other. The Inter-cloud Architecture enables roaming of applications and users among different cloud providers (e.g., metadata and mechanisms needed to seamlessly run in different private and potentially public clouds will be experimented). **Context-aware applications**

	The context-aware application is meant by the profile that is based on the actual use of the application and determines the set of available cloud offerings to be chosen. A cloud information sub-system will be prototyped to exchange information between the cloud infrastructure and the platform (not the operating systems) running on top.
Energy efficiency and sustainability for software and services on the cloud.	**Energy efficiency** Resources consolidation and high level of virtualization enables energy usage optimisation (e.g., suspending inactive VMs by the cloud middleware or releasing extra data replicas unused for defined period of time). Energy efficiency is also supported by the possibility that the application can roam around the actually most energy-efficient, green resource clouds. The cloud broker function can decide upon which IaaS applications (e.g., dependent on latency issues) can be moved to an IaaS cloud that uses green power and air cooling. The automated selection of green resources can be supported by the Service Registry. **Sustainability for software and services** Sustainability of services is guaranteed by the portability between different private clouds as well as among private and public cloud offerings. In a larger context, NRENs and cloud industry SMEs ensure the sustainability of the software components designed and prototyped by the project adopting them into their own cloud infrastructure.
Architectures and technologies supporting integration of computing and networking environments; implications of Cloud Computing paradigm on networks.	**Integration of computing and networking** The campus network infrastructure and resources will seamlessly be integrated with the access network and resources in the cloud. **Networking for clouds** Research Networks can act as Cloud Carriers and able to provide the necessary virtual network instances to deliver cloud services to customers in an integrated way. Virtual networking mechanisms for private clouds will be examined and harmonised among multiple private cloud providers and NRENs. Best practices in this area will be documented.
Open Source implementations of a software stack for Clouds.	**Open source implementations** The selected NRENs' private cloud stacks are open source based implementations as well as the project facilitates the interoperability with commercial public cloud offerings in an open way (i.e. open APIs). All the project software developments will be available under an open source licence.

1.2 Progress beyond the state-of-the-art

The cloud environment is developing very rapidly. Although it is best known for cloud computing, the cloud paradigm extends to a range of services. The term “cloud computing” means different things to different people and type of institutions. It is often used to loosely describe a broad range of activities, ranging from outsourcing a specific activity to a single external provider (which many would argue is not cloud computing) to delivering a set of services from the cloud in such a way that users are not even sure where their data is being housed or where it is being processed.

Obviously, the cloud concept is still changing and it is hard to find a definition for clouds. One comprehensive definition could be: Clouds are a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized SLAs [def].

The set of features that most closely resemble the minimum cloud definition would be ease of use (typically via a web interface), scalability, pay-per-use utility model, and virtualization.

1.2.1 Cloud industry state-of -the-art and advances brought by RECIPE

The “Cloud Computing: Public Consultation Report” [cons], published by the European Commission in December 2011 illustrates very well the state-of-the-art of the cloud industry and the main challenges ahead. Some of the report’s findings are highlighted below, in order to show how RECIPE addresses the key issues.

- All respondent groups agreed that rights and responsibilities are unclear in cross-border situations.

The EU legal framework within which clouds must be implemented confuses and creates uncertainty in the respondents to the consultation. There is a widespread need for clarification on rights, responsibilities, data protection and liability, especially in cross-border situations. RECIPE will investigate an integrated cloud service scenario across various borders that has never been piloted and examined before in a consistent way:

a. Institutional borders can be crossed by seamlessly integrating the campus infrastructure with the cloud,
b. National borders can be crossed by harmonising the existing Resource Cloud back-end offerings provided by the NRENs for the R&E community, and finally
c. The R&E community’s border can be crossed by brokering with commercial public cloud providers.

In all the cases the appropriate rights and responsibilities of the various actors at both sides of the borders must be clarified.

- Considering this level of uncertainty, 135 individuals consequently feel that guidelines and checklists on model terms for contracts would be useful (compared with 35 individuals who did not).

The question asked of respondents was, “From your perspective, would it be useful if model Service Level Agreements (SLA) or End User Agreements (EUA) existed for cloud services so that certain basic terms and conditions could easily be incorporated into the contractual agreements?". The need of having model contracts for SLAs and EUAs at European level is a widely shared opinion among all respondent groups [cons].

That is exactly what RECIPE project addresses with its recipes. Recipes will be a set of comprehensive small reports, best practice documents, and pre-standardization recommendations along the line of the recommendation above. These recipes (separate from the project deliverables) will publicly be available for the benefit of both the European R&E community and the cloud industry.

- The public sector can play a role in stimulating the use and take-up of cloud computing.

"By being early adopters of cloud technologies – including via pre-commercial procurement – public authorities can educate the private sector about the benefits of the cloud and encourage private sector uptake. In this regard, as in all areas of procurement, [this organisation] encourages public authorities to be technology neutral and to choose the best technology or service for the particular need…" [cons]

"Pan-European infrastructures such as GÉANT for networking and EGI for computing have allowed different resource providers to collaborate directly. This collaboration has significantly improved communication between the various providers and created a framework in which appropriate standards and best practices can emerge. The public sector should look to existing infrastructures (where possible) as a mechanism to continue the push towards practical standards and best practices." [cons]

The public sector, as cloud computing adopters, could set the requirements for standards in security, interoperability and data portability; thus, stimulating rapid deployment. RECIPE project consortium has four NREN participants (NIIF – Hungary, PSNC – Poland, SURFnet – Netherlands, and GRNET – Greece), SMEs associated to the public sector (TERENA) and cloud industry (Flexiant – United Kingdom, Vrijheid.net – Netherlands), cloud-aware equipment vendor (Cisco – technical advisor) as well as university and research laboratory members. The project participants believe that the composition of the consortium is appropriate to be able to leverage on the existing NREN infrastructures and mechanisms, do the early adaptation of the Inter-cloud Architecture and Cloud Carrier Service Stack proposals within the NRENs' domain, do the demonstrations and service pilots for typical HE users, and finally push the developments towards SMEs and cloud industry (including practical standards and best practices taken up by cloud SMEs first) for exploitation and sustainability.

Another report issued by the European Commission in November 2011 summarises the "Industry Recommendations" [ind]. The report presents the 10 key recommendations from the select industry group to the European Commission on the orientation of a Cloud computing strategy for Europe, and proposes some actions for the European Commission and Industry. They are organised by: legal framework related recommendations and actions, market related recommendations and actions, and technical related recommendations and actions. We selected only one recommendation per each area to illustrate the advances brought by RECIPE.

- Concerning the legal framework one industry recommendation says that: Promote the Digital Single Market to encourage efficient cross border Cloud Services [ind].

It has already been recognised that the Digital Single Market is a key driver for productivity and competitiveness in Europe, which will allow firms in all sectors to exploit the potential of ICT that a digital single market would offer. RECIPE believes that (once the multi-provider, inter-cloud infrastructure is created) HE users need the freedom to roam around cloud providers thus, a technology-agnostic, standard-based cloud brokering function and common business layer must be worked out to make it technically, legally, and financially possible.

- One market related recommendation is to: Investigate further the creation of voluntary and industry led mechanisms of enhancing trust and security [ind].

RECIPE proposes new business and relational models and operational/provisioning workflows that define new roles in the cloud reference architecture (we call it Inter-cloud Architecture). A service delivery framework for multi-provider cloud service integration and provisioning as well as a federated SLA (Service Level Agreement) management during the whole services/infrastructure lifecycle will be proposed.
RECIPE enhances security and trust by introducing well-established security disciplines in Resource Clouds such as AAI, encryption and integrity control of data, etc.

- The most relevant technical recommendation by industry puts an action to: Foster interoperability and data portability in the Cloud [ind].

Indeed, one of the main objectives of RECIPE is to integrate and harmonise the campus infrastructure seamlessly with the cloud (i.e. horizontal integration) in order to bridge the current technical and non-technical gaps between the education sector and cloud industry. This will ensure the necessary data portability especially for HE users (just like their networked device portability is already ensured by eduroam [edu]).

1.2.2 Research & Education community state-of-the-art

In this section we describe the state-of-the-art in the R&E sector that is not as widely researched and known as the commercial cloud industry trends. It is also explained how RECIPE goes beyond the state-of-the-art and fosters R&E and cloud industry partnership.

It is not only the private sector that is creating new opportunities in the field of clouds, but funding bodies and R&E networks are also playing a critical role in the transformation of the future computing. The recent announcements by Internet 2 in the US [int2], SURFnet in the Netherlands [surf], and JISC/JANET in the UK [jisc] to broker commercial cloud services for researchers are great examples of this trend.

In the current climate of fiscal constraints funding bodies (such as the European Commission in Europe, National Science Foundation in the US, as well as the national governments) are looking for industry "partnerships", rather than simple "partners" in order to accelerate commercialization of academic research. Moving research computing, storage, etc. to commercial clouds will enable an entirely new eco-system of industry and research applications and tools. Some believe that commercial clouds are much better suited for the needs of the R&E community as they allow virtually unlimited scaling as the needs of the researcher increase. When a university or research community provisions a private cloud they are constrained in their ability to scale by the funding renewal cycle of the granting councils. Private or community clouds may look cheaper but that is because researchers rarely see the true cost of operating a cloud. Also there is an incredible amount of innovation occurring in the commercial space and prices are continually dropping.

A brokered commercial cloud service allows NRENs to get large discounts and provide a blanket license for all institutions in terms of privacy and security etc. NRENs can also implement policy engines to insure that some compute tasks and data storage is done only domestically. RECIPE sets the roles and responsibilities for a Cloud Carrier to be able to broker commercial cloud services for campuses in an integrated and harmonised way.

The Internet2 announcement [int2] of brokering commercial cloud services from HO, Box and SHI is the start of a major trend that will transform computing at universities and eventually businesses in the US. This is likely to be the first of many announcements on "above the net" services from Internet2. Moving university IT departments and researchers from the traditional "client-server" mindset to delivering services from the cloud will enable new applications and services at much lower cost. This will create new business opportunities for NRENs and small businesses. This will not only provide potential new service revenue for NRENs, but also has the potential to significantly reduce overall costs to universities' IT department.

This is very much along the lines of JANET/JISC and SURFnet initiatives in Europe. Brokering commercial cloud services seems to be an ideal service offering for R&E networks as they generally manage the federated authentication systems and collaborative tools such as SURFconext, COmanage, COIP, etc. to facilitate use of these clouds. As well, Open Lightpath Exchanges will enable large data file transfers to and from major commercial cloud providers.

The Dutch research network SURFnet has started to investigate how institutions can have resources in the Netherlands (brokered or federated IaaS cloud services via SURFnet) as well as have them available via other commercial cloud offerings outside the Netherlands [surf]. For that reason, SURFnet has been collaborating with GreenQloud – a company based in Iceland with a focus on doing their operations "truly green". GreenQloud and SURFnet make this integrated cloud easily available by obtaining credentials via the national federation (SURFfederatie), and also allowing people to work in groups that can span beyond university borders. In the data transport field, SURFnet also works on a direct lightpath between the

Netherlands and Iceland. Eventually, this setup will make it possible for a Dutch university, to connect to their own VM's in Iceland as if they are running in their own LAN (and IP-space).

SURFnet, as a RECIPE consortium partner, will bring this service pilot concept into the project for further development that can ensure the seamless integration of campus infrastructure even with a remote cloud. SURFnet also expects new, prospering business cases to be developed in which they can broker IaaS cloud services from existing market parties, preferably as green as possible.

Regarding the business model, there are interesting new trends towards creating "a common market space" for NREN and university cloud offerings. For instance, a very innovative Canadian start-up called Enomaly is offering a service called SpotCloud (http://spotcloud.com/) which allows IT departments to sell spare compute cycles into the global cloud market. SpotCloud may be an ideal opportunity for university IT departments and research groups to earn a little additional money and familiarize themselves with the advantages of commercial cloud services. Universities, generally, have seasonal loads on their servers and so have long periods of underutilized servers that could be offered up to SpotCloud. It is also a great opportunity for small business to experiment using and offering cloud services. RECIPE will investigate the new business models and opportunities that might be created by prototyping and piloting the Inter-cloud Architecture and the Cloud Carrier Software Stack components on top of the RECIPE experimental infrastructure.

1.2.3 RECIPE's progress beyond state-of-the-art

As was already mentioned before, our project focuses on the specific scenario that is the HE use of IaaS clouds. In this scenario our main objective is to prototype the necessary architectural components (Fig. 4) to be recommended for an integrated campus-cloud infrastructure (following the Inter-cloud Architecture) and to pilot the complete scientific workflow (using the Cloud Carrier Software Stack) that can be adopted by this industry segment. Note however, that both IA and CCSS can be applied to other segments where multiple IaaS clouds integration is necessary.

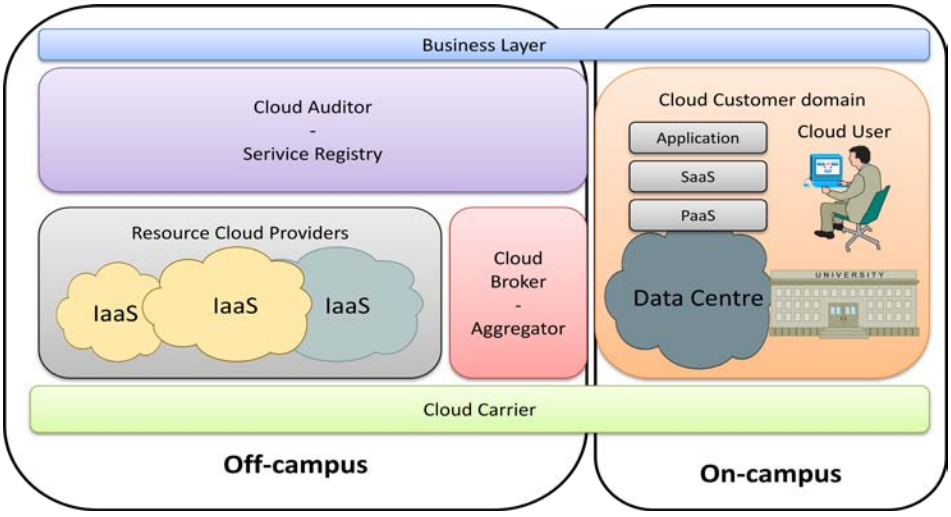


Fig. 4 Inter-cloud Architecture (campus-cloud integration) built on Cloud Carrier concept

In our scenario, the Cloud Carrier that primarily provides the connectivity and data transport to the cloud is typically the NREN (and the pan-European backbone network GÉANT). Today, both traditional IP connectivity and static/dynamic connection (i.e. bandwidth on demand / lightpath) services are available in the NRENs' portfolio. Most of them do (commercial) peering via Internet Exchanges or very recently Open Lightpath Exchanges and facilitate campus networks to deliver network services seamlessly all the way down to the desktop. In some cases, the campus network policies have been changed/relaxed toward the NREN to deliver connection services (bypassing boarder routers and other middle-boxes) seamlessly to the end users. NRENs are in the best position to play the role of Cloud Carriers and deliver connectivity services from campus sites to the academic/research and commercial clouds.

In addition to this, the Cloud Provider can also be the NREN, or a commercial third party cloud provider, or both of them at the same time. If the NREN owns and operates its IaaS cloud the Cloud Carrier and Cloud Provider roles overlap. If the NREN has no IaaS infrastructure but delivers commercial or any third party Resource Cloud service to the customer it may have a Cloud Broker (or Reseller, Aggregator) function in place that is integrated with the Cloud Carrier.

The Cloud Customer is the university or campus IT department having (some sort of) private resource cloud (on top of their local data centre) and also willing to outsource some IT operations into a distant cloud. Therefore, they are very keen on integrating their local infrastructure with the cloud to be able to e.g., use their own IP address space and stay behind their firewalls in case of cloud computing, or store metadata, encryption keys and digests locally in case of data storage in the cloud. Cloud Customers are represented by UvA (consortium partner) as well as the University of Szeged and the National Technical University of Athens (third-parties) in the project. They require the seamless integration of infrastructures and business processes adapted to their scientific workflow. The Cloud User is the HE student, researcher and staff on campus working with scientific applications that can automatically request for the appropriate Resource Cloud services.

Typically, the Cloud Broker/Aggregator and Cloud Auditor roles/functions are not yet realised/implemented in this scenario as it is recommended by the conceptual reference model of NIST [nist]. RECIPE project aims at prototyping some of these functions (within the NRENs Cloud Carrier domain that provides a flexible experimental environment) taking the aforementioned set of key e-science applications of HE users into account. The NREN environment also ensures the exploitation of the results and the long term sustainability of the software enhancement in the NREN's production cloud.

Regarding the Cloud Broker, the service intermediation/orchestration function will be piloted. An intermediation broker provides a service that directly enhances a given service delivered to one or more service customers, essentially adding value on top of a given service to enhance some specific capability. The federated access to commercial cloud services is an example to such an enhancement. The project focuses on service orchestration rather than service composition. (We don't create new services as combination of others; just select the appropriate ones from the service portfolio according to the applications' profile. However, the application profile can be dynamically changed while the application is running.) Orchestration in this sense refers to aligning the business request with the applications, data, and infrastructure. It defines the policies and service levels through automated workflows, provisioning, and change management. This creates an application-aligned infrastructure that can be scaled up or down based on the needs of each application. Orchestration also provides centralized management of the resource pool, including billing, metering, and chargeback for consumption. We define an orchestrator as the entity that manages complex inter-cloud processes and handle exceptions. Since an orchestrator is valuable in the fulfilment, assurance as well as billing processes, in their most advanced service aware incarnations should be capable of adjustments based on feedback from monitoring tools.

Regarding the Cloud Auditor, the necessary audit and service registry functions will be prototyped. These will perform the independent assessment of cloud service components in order to determine the possibility of the potential cloud domain harmonisation and common Service Level Agreements.

In addition, the aim is to implement a Business Layer on top of the proposed Inter-cloud Architecture. This layer creates the appropriate market place for the R&E community to exploit the benefits of demand aggregation, centralised framework contract management, and automated purchase mechanisms in the context of IaaS cloud services. In the area of software (scientific application) licensing and business processes, in the recent years, NRENs have been putting efforts into aggregating the academic demands at the national level and successfully negotiate discounted prices (or free academic releases) for various commercial software products to be used by the education community. NRENs are in the best position to play the role of a "buying syndicate" or financial clearing house for the education community and provide the necessary business advances for the whole industry segment.

Although RECIPE builds on the role that the NRENs can play in the cloud services delivery chain towards campuses, the project also advances the state-of-the-art of the cloud market in general to be exploited by

other industry segments (such as public administration use cases), thanks to the fact that the Inter-cloud Architecture is based on standard recommendations and the Cloud Carrier Software Stack is open-sourced, well-documented, and tested.

1.2.4 Open source cloud initiatives and EC-funded projects relevant to RECIPE

Today, a plethora of cloud infrastructure stacks exist and numerous open source projects are developing their own stack as we speak. RECIPE will not create yet another Resource Cloud stack but rather build upon the existing ones and open up the cloud space for campuses offering an Inter-cloud Architecture (IA) and a comprehensive Cloud Carrier Software Stack (CCSS) for seamless integration of infrastructures across domains.

Below, we list some of the cloud infrastructure stacks that are relevant to the work of RECIPE:

Eucalyptus (http://www.eucalyptus.com/): The Eucalyptus project aims to bring a similar level of functionality of the Amazon Web Service Cloud to public and private environments. It is designed to be application programming interface (API)-compatible with Amazon's EC2 platform. This means that a company evaluating EC2 can use freely available software on freely available operating systems to build a compatible test lab. That same company, once they are an Amazon customer, can then use Eucalyptus for development work before moving to Amazon. Eucalyptus can support resource management in private and public cloud services. The software is under the GPL licence.

Sheepdog (http://www.osrg.net/sheepdog/): Sheepdog is a Cloud storage system for the Linux Kernel-based Virtual Machine (KVM) that provides highly-available block level storage volumes in KVM clusters. The Sheepdog project originated at NTT Laboratories in Japan. Sheepdog scales to several hundred nodes, and supports advanced volume management features such as snapshot, cloning, and thin provisioning. Sheepdog is still under active development so it may not be widely deployed in hosting environments, let alone private clouds, but it is definitely one Cloud project to watch.

Ganeti (http://code.google.com/p/ganeti/): Ganeti is a virtual server management and cluster tool for Xen and KVM hypervisors developed and hosted by Google. Clouds can be created and managed with Ganeti's suite of apps and virtual machines can be recovered in the event of physical machine failures. Ganeti scales from one to 40 physical nodes and can do live migration of virtual machines across and between clusters. Support for Ganeti is available through the public mailing lists under GPL licence.

OpenStack (http://www.openstack.org/): Founded by Rackspace Hosting and NASA in 2010, OpenStack is a global collaboration of developers and cloud computing technologists producing the ubiquitous open source cloud computing platform for public and private clouds. The project aims to deliver solutions for all types of clouds by being simple to implement, massively scalable, and feature rich. The technology consists of a series of interrelated projects delivering various components for a cloud infrastructure solution. Their mission is to enable any organization to create and offer cloud computing services running on standard hardware and create a large ecosystem that spans cloud providers [ost]. OpenStack now has quite a number of software companies involved in its ecosystem. OpenStack offers the promise of do-it-yourself clouds in a secure, private test lab before moving to either private cloud or public cloud, along with insight into the real security issues behind cloud computing and IaaS. OpenStack is offered under the Apache Licence.

OpenNebula (http://www.opennebula.org): Initiated in 2005, OpenNebula is the open-source industry standard for data centre virtualization, offering the most feature-rich, flexible solution for the comprehensive, complete management of virtualized data centres to enable on-premise IaaS clouds in existing infrastructures. OpenNebula interoperability makes cloud an evolution by leveraging existing IT assets, protecting your investments, and avoiding vendor lock-in [one]. Clouds can also be federated for even more scalability. Commercial support is available under the Apache Licence.

OpenNebula is the result of many years of research and the interaction with world leading industrial and academic organisations in cloud computing. OpenNebula is being enhanced in the context of several EU-funded flagship international projects in cloud computing to address the requirements of business and research use cases from leading IT organizations across multiple industries. The results of the projects listed below are relevant to RECIPE too:

- RESERVOIR, main contributor with significant impact on OpenNebula's design and innovative features, coordinated by IBM.
- StratusLab, coordinated by Centre National de la Recherche Scientifique
- BonFIRE, coordinated by Atos Origin.
- 4CaaSt, coordinated by Telefónica I+D

In the context of RECIPE, it can be said that OpenNebula is mature, proven, and works very well. It has been used by NIIF (the Hungarian NREN participating in RECIPE) creating their Resource Cloud and has been considered by university IT departments and research institutions in the R&E community. It offers a community ecosystem that is complex and useful but can easily be tailored to the specific needs. From the ecosystem one can install a graphical interface, alternate schedulers, and many install automation tools.

OpenStack Compute called Nova (the part of OpenStack that compares with OpenNebula) is immature at the moment. In the long run, it may compare favourably with OpenNebula, but it has to catch up. The OpenStack philosophy is to use as few tools as possible that are independent from the client's existing environment. This is different from OpenNebula that provides a reasonably rich set of dedicated tools, including a command line environment and a browser-based user interface. That is why OpenStack is easier to start with (just need to set it up) whereas OpenNebula requires more development knowledge and experience. It also implies that OpenStack is rather supported by cloud industry (such as Cisco, the technical advisory third-party to RECIPE) and OpenNebula is instead better supported by the public research and development community (well-represented in RECIPE).

We can also mention that Ganeti has been open sourced by Google and it is now used as a cloud manager in GRNET’s (the Greek NREN participating in RECIPE) IaaS cloud. The feasibility study of the potential interoperation of the Ganeti-based cloud with the OpenNebula stack is a challenge for RECIPE. Beside the open source cloud stacks we can mention the dedicated commercial cloud stacks such as Eucalyptus Enterprise Editon, VMware vCloud Director, Citrix XenCloud, RedHat Cloud Foundations or Flexiant Extility. Additionally, Flexiant (participating in RECIPE as a consortium partner) offered their Extility cloud stack for the RECIPE to further investigation and potential integration.

We have mentioned RESERVOIR as one of the flagship EC projects contributing to OpenNebula and we would also like to list some additional projects from the previous Software & Service Architectures and Infrastructures calls that RECIPE is planning to cooperate with:

SLA@SOI is delivering and showcasing an open SLA Management Framework that provides holistic support for service level objectives – enabling an open, dynamic, SLA-aware market for European service providers. It allows SLAs to be managed autonomously throughout the service lifecycle, spanning the entire services stack from the business layer through to infrastructure. SLAs can only be consistently managed if all the different stakeholder perspectives and service layers are consistently interlinked and managed.

> RECIPE will use the outcome of SLA@SOI and experiment with an enhanced Service Delivery Framework (SDF) for multi-provider cloud service integration and provisioning as well as a federated SLA (Service Level Agreement) management during the whole services/infrastructure lifecycle. We will work out appropriate SLA mechanisms, security disciplines, trust frameworks, legal policy, billing and accounting practices for brokered cloud services. Moreover, we will formalize a shared European policy for HE among the IaaS cloud service providers and customers.

The **4CaaSt** project aims to create a PaaS Cloud platform which supports the optimized and elastic hosting of Internet-scale multi-tier applications. 4CaaSt embeds features that ease programming of rich applications

and enable the creation of a business ecosystem where applications from different providers can be tailored to different users, mashed up and traded together.

> RECIPE focuses on the IaaS Cloud platform integration and uses PaaS only for demonstration purposes. 4CaaSt can be considered as a use case for RECIPE adding PaaS on top of RECIPE and interfacing with a resource cloud information sub-system proposed by RECIPE.

Cloud4SOA focuses on resolving the semantic interoperability issues that exist in current Clouds infrastructures and on introducing a user-centric approach for applications which are built upon and deployed using Cloud resources. To this end, Cloud4SOA aims to combine three fundamental and complementary computing paradigms, namely Cloud computing, Service Oriented Architectures (SOA) and lightweight semantics.

> RECIPE also focuses on interoperability issues that exist in current clouds infrastructures but not only on the semantic level. RECIPE dives down deep into the various cloud stacks and puts the Cloud Carrier into the middle of the provisioning lifecycle equipped with the necessary cross-platform Software Stack. We also extend the dimensions of interoperability; dealing with cloud infrastructures in deferent domains (e.g., campus domain, NREN domain, public domain).

VISION Cloud is introducing a powerful ICT infrastructure for reliable and effective delivery of data-intensive storage services, facilitating the convergence of ICT, media and telecommunications. This infrastructure will support the setup and deployment of data and storage services on demand, at competitive costs, across disparate administrative domains, while providing QoS and security guarantees.

> Cloud storage is one of the main use cases for RECIPE and therefore VISION Cloud will be monitored very closely in order to determine the potential collaboration areas.

The **OPTIMIS** project will enable an open and dependable Cloud Service Ecosystem that delivers IT services that are adaptable, reliable, auditable and sustainable (ecological and economical). The key goal is to allow organizations to automatically and seamlessly externalize services and applications, to trustworthy and auditable cloud providers. This ecosystem will give rise to a strengthened European ICT industry able to meet key societal and economical needs.

> RECIPE's "cloud service ecosystem" is based on strict security disciplines with mutual quality and reliability measures. We will investigate the main security concerns such as content ownership, data security, and trust. The security audit aspect is one of the most important aspects from RECIPE point of view. We understand that data security issue might be a blocking factor for up-taking even private clouds – depending of course on disciplines, awareness, etc. – therefore we set our priorities differently from OPTIMIS but will consider the expansion of their toolkit for independent gauging of trust, reliability, power and cost.

The **CONTRAIL** project will design, implement, evaluate and promote an open source system in which resources that belong to different operators are integrated into a single homogeneous Federated Cloud that users can access seamlessly. CONTRAIL will vertically integrate an open source distributed operating system for autonomous resource management in Infrastructure-as-a-Service (IaaS) environments, and high level services and runtime environments as foundations for Platform-as-a-Service (PaaS).

> As we referred to in the SpotCloud initiative in Canada earlier, it is an emerging paradigm in the R&E community that an organization (i.e. university IT departments) should be able to be both a Cloud *provider* when its IT infrastructure is not used at its maximum capacity, and a Cloud *customer* in periods of peak activity. In RECIPE, once an integrated campus-cloud experimental infrastructure has been created, we will experiment with a matrix of shared roles and responsibilities among the various players of our ecosystem (e.g., university IT department, NREN, public cloud provider, etc.). The experiences of CONTRAIL can be used as valuable input to RECIPE.

The **mOSAIC** project aims to develop an open-source platform that enables applications to negotiate cloud services as requested by their users. Using the Cloud ontology, applications will be able to specify their service requirements and communicate them to the platform via an API. The platform will implement a multi-agent brokering mechanism that will search for services matching the applications' request, and possibly compose the requested service if no direct hit is found.

> RECIPE's objectives seem to be similar to mOSAIC's aims, but we are adding two new aspects to the picture. One is our tightly coupled, harmonised cloud scenario that provides unique opportunities to both the Cloud Provider and the Cloud Carrier for monitoring and managing the Resource Cloud more efficiently than in case of the loosely coupled, brokered scenario. The second aspect is the integration of the campus infrastructure with the cloud, so that the cloud is not considered as an external, remote entity but an integrated part of the campus infrastructure.

Last but not least, RECIPE will obviously leverage on the results of the NREN's flagship project GN3 as well as planning to provide feedback (migrate efforts after RECIPE's mandate) to the potential follow-up projects of GN3 (i.e. GN3+ or GN4) in the area of clouds.

GN3 is the third term of the successful **GÉANT** network and project that lie at the heart of the EU's e-Infrastructure strategy. Co-funded by the European National Research and Education Networks (NRENs) and the European Union (EU), the project seeks to shape the Internet of the future through the pan-European GÉANT network and a portfolio of advanced services for the research and education community.

A Study on the Prospects of the Internet for Research and Education (ASPIRE) has been initiated by GN3 [asp]. One of its key topics is the cloud for R&E. The ASPIRE study concluded that:

"The pricing models of some commercial cloud providers ... enable end-users to compute results from their data in a fraction of the time it took using traditional approaches of owned hardware. The instant availability of these elastic services may encourage end-users to by-pass community computing centres thus avoiding large capital investments and long lead times to satisfy their requirements. Cloud service providers are leveraging their internal investments … with massive economies of scale involving tens of thousands of servers. It would therefore be impossible for the R&E community to compete head-to-head with such providers on such things as providing vanilla storage or compute services. Some service providers charge for the volume of data shipped into and out of their cloud. For data intensive applications these costs could be prohibitive unless some agreement can be reached. A possible solution would be to peer with the cloud providers at open access points on the NREN networks, hence minimising the data movement costs." [asp]

> Indeed, the Inter-cloud Architecture and Cloud Carrier model, proposed by RECIPE, enables NRENs and cloud industry SMEs to deliver cloud services to campuses in an integrated way. Becoming acquainted with efficient use of cloud facilities is not without difficulties. Since cloud services are not yet fully standardised learning how to use one suppliers cloud services, does not mean that it is a simple matter to move to another. NRENs could provide value to the community by developing independent best-practice guides – just like the objective of RECIPE is to provide these "recipes".
>
> Moreover, cloud service providers sell portfolios of services driven by their marketing strategies. If requirements fall outside of this portfolio it is unlikely that single institutions will have sufficient negotiating power to get what they want at an economic price. NRENs could operate as a trusted and knowledgeable broker on behalf of the community; securing the best services at the best prices. The added values could be: federated access, high levels of security and privacy, guaranteed geographic storage location, and high transmission speeds without a volume charge.

1.2.5 Recommendations towards standardisation

OGF - Open Grid Forum

The RECIPE project partners are active in a number of OGF working groups and search groups. In particular, UvA and PSNC are co-chairing (together with ESnet) Infrastructure Services On-Demand Research Group (ISOD-RG) which is currently focuses its activity on the analysis and definition of the existing Infrastructure as a Service (IaaS) cloud models and implementations and their evolution to the generic Inter-cloud Architecture. The ISOD RG will provide a forum to present the project results to wider industry and research community, on the other hand the project will benefit from the OGF community experience in developing interoperable cloud and Grid services.

In particular, RECIPE will contribute to the ongoing ISOD-RG research and BCP document on infrastructure services provisioning models, architectures, systems and standards. This may include the architecture and business model for campus-based cloud access and federation, the Cloud NaaS Broker model, and other aspects developed in the project.

UvA is also involved in such working groups as NSI-WG (Network Service Interface WG) and NML-WG (Network Markup Language WG) which propose two important components for building interoperable network and cloud infrastructure based on industry and research community accepted standards.

It is intended that ISOD RG will provide use cases and recommendations for development of upper layer service frameworks for a number of currently running related initiatives at OGF, such as NSI WG, NML WG, OCCI WG, CDMI at SNIA, and will review standardization work done by the ITU-T and TeleManagement Forum (TMF) for possible adoption by the OGF user community.

The Open Cloud Computing Interface (OCCI) was developed by OGF and is becoming widely accepted as interface for requesting cloud infrastructure resources. It allows defining required computing and storage resources however, it defines network connectivity in a quite simple way. OCCI provides a good basis for interoperability, integration and portability therefore RECIPE is planning to use OCCI as basic cloud services interface and will extend it with the necessary functionality to allow better network services definition and management. The expected extensions will include network topology and QoS extension, security services configuration, and services lifecycle management.

NIST - National Institute of Standards and Technologies

NIST is a standardisation body of the U.S. Department of Commerce and (founded in 1901). NIST standards are internationally accepted, in particular, NIST contribution to the shaping modern cloud industry since their definition of the cloud in 2008.

UvA (Yuri Demchenko) is one of the active contributors to the discussion on the definition of the Cloud Computing Reference Architecture (CCRA) and the standards roadmap which are currently published as Draft SP 800-145: The NIST Definition of Cloud Computing, and Draft SP 800-146: Cloud Computing Synopsis and Recommendations. Current and future UvA involvement in NIST community activities on cloud standardisation will provide a good bi-directional exchange of information and allow RECIPE to disseminate project results to the international community.

TMF - TeleManagement Forum

The TeleManagement Forum (TMF) is the world's leading industry association focused on enabling best-in-class IT for service providers in the communications, media, defence and cloud service markets. The TM Forum provides business-critical industry standards and expertise to enable the creation, delivery and monetization of digital services. The TM Forum brings together the world's largest communications, and technology companies, providing an innovative, industry-leading approach to best practices and standards, along with wide range of support services including benchmarking, training and certification. Many TMF developments have been proposed to the ITU-T standardisation activity in the area of telecommunication

networks management. TMF is currently working on the cloud services management to cover such topics as Cloud Business Process Framework, Cloud Service Definitions and Cloud Billing.

UvA has applied for complimentary TMF membership as an educational institution which will provide full access to existing TMF documents. UvA has experience of working with TMF documents and contributing to their practical implementation, in particular, UvA together with partners (in such projects as GEYSERS and GN3 JRA3 Composable Services) proposed extensions and a profile of the TMF Services Delivery Framework (SDF) for on-demand infrastructure services provisioning and services lifecycle definition.

RECIPE will contribute to further SDF profiling and related cloud TMF activities. The project finding and experience will be submitted to corresponding TMF Interest Groups and contributed to relevant documents.

IETF - Internet Engineering Task Force

Cisco (Klaas Wierenga) is an advisor to the RECIPE Technical Management Committee. He co-chairs the Application Bridging for Federated Access Beyond web (ABFAB) Working Group at the IETF. ABFAB is relevant to RECIPE's federated Inter-cloud Architecture proposal. Especially those Resource Cloud components that requires federated access but goes beyond simple web interfaces (e.g., federated SSH access to network resources).

Cisco will ensure the mutual communication and information exchange between RECIPE project and the IETF ABFAB Working Group.

1.3 S/T methodology and associated work plan

Work Package 1 (WP1) is dedicated to the overall management of the project and the dissemination activities carried out in the technical work packages. The overall approach to project management and dissemination (WP1) is described in Section 2.1 and Section 3.2, respectively.

The main technical work is broken down into four technical work packages (WP2-5). Last but not least, Work Package 6 (WP6) deals with the demonstrations of the project results (i.e. software prototypes, pilot services) as well as the potential exploitation and long term sustainability of the developments.

Among the technical work packages, WP2 targets the survey, analysis and definition of the potential architecture (i.e. Inter-cloud Architecture) and its basic components that is in line with the technical objectives of the project. WP2, led by the academic partner UvA, is broken down into three tasks: T2.1 – Functional definition of the RECIPE architecture for cloud and campus infrastructure convergence and end-to-end services delivery; T2.2 – RECIPE architecture implementation models, interfaces and protocol definition; T2.3 – Federated Cloud Service Delivery workflow.

The outcome of the preliminary architecture study will be fed into WP3 that addresses the RECIPE framework for cloud interoperability, campus integration, and orchestration. This technical work package is the backbone of RECIPE and will deliver the software prototypes (i.e. the Cloud Carrier Software Stack) as well as develop the pilot services in the Inter-cloud Architecture. In principle, it takes a two-step approach: a) developing open source early software prototypes, and then b) implementing pilot services to create an open, inter-cloud experimental environment in order to demonstrate and disseminate the project results in WP6. WP3, due to its complexity, is led by the NREN partner NIIF with the help of PSNC. It is broken down into four tasks: T3.1 – Loosely coupled IaaS cloud scenario; T3.2 – Tightly coupled IaaS cloud scenario; T3.3 – Standardization and policies; T3.4 – Inter-domain security framework and image repository for pilot services.

WP3 will work closely together with WP4 that concerns the business layer, scientific workflow and process integration for an integrated campus-cloud ecosystem. It takes into account the basic architectural and technical considerations of WP2 and WP3 and proposes a Business Layer on top of the architecture especially tailored to the R&E community. WP4, led by the research organisation FORTH, is broken down into four tasks: T4.1 – Cost modelling for migrating applications to integrated cloud services; T4.2 – Business models study and automated business processes; T4.3 – Platform for scientific workflow execution; T4.4 – Best practices and recommendations.

At the major milestones of the technical work packages RECIPE will produce a consistent set of small reports, best practice documents, white papers, and pre-standardization recommendations - we call them “recipes” - on all the lessons (both technical and non-technical) that we learn. These recipes will be publicly available (as part of the project dissemination activity) for the benefit of the whole European R&E community and cloud industry SMEs in order to ensure the exploitation of the results and the sustainability of the architecture.

WP5 targets the usability evaluation of the IaaS software prototypes, and the necessary platform and application interface definitions towards PaaS and SaaS to be demonstrated in WP6. Based on the preliminary requirements from the demonstration planning activity WP5 will perform the feasibility check of the architecture implementation, do the black-box testing, and the usability testing from a HE user point of view. WP5, led by the cloud industry partner Flexiant, is broken down into three tasks: T5.1 – Feasibility check and baseline black-box usability testing; T5.2 – Secondary black-box testing; T5.3 – Usability testing from a user perspective.

WP6 plans and performs the project demonstration activity and ensures the exploitation of the results (i.e. how the software prototypes can be used/adopted to environments such as the NRENs’ production cloud or an industry SME’s cloud) and the sustainability of the developments after the mandate of RECIPE (i.e. migrating efforts to NRENs/TERENA or the follow-up project of GN3). WP6, led by the NREN partner

GRNET, is broken down into three tasks: T6.1 – Demonstration cases and supporting infrastructure for early prototypes; T6.2 – Demonstrations plan and delivery; T6.3 – Exploitation and sustainability.

1.3.1 List of Work Packages

Work package No	Work package title	Type of activity	Lead partic no.	Lead partic. short name	Person-months	Start month	End month
WP1	Project management and dissemination	MGT	1	TERENA	21	1	24
WP2	Architecture survey, analysis, and feedback	RTD	8	UvA	67	1	22
WP3	Framework for cloud interoperability, campus integration and orchestration	RTD	2 and 3	NIIF and PSNC	140	1	24
WP4	Business layer, scientific workflow and process integration	RTD	9	FORTH	58	1	24
WP5	Usability evaluation, platform and application interface	RTD	7	Flexiant	62	6	22
WP6	Demonstrations, exploitation and sustainability	DEM	5	GRNET	55	6	24
	TOTAL				403		

The high-level relationship among the work packages is shown in Fig 5.

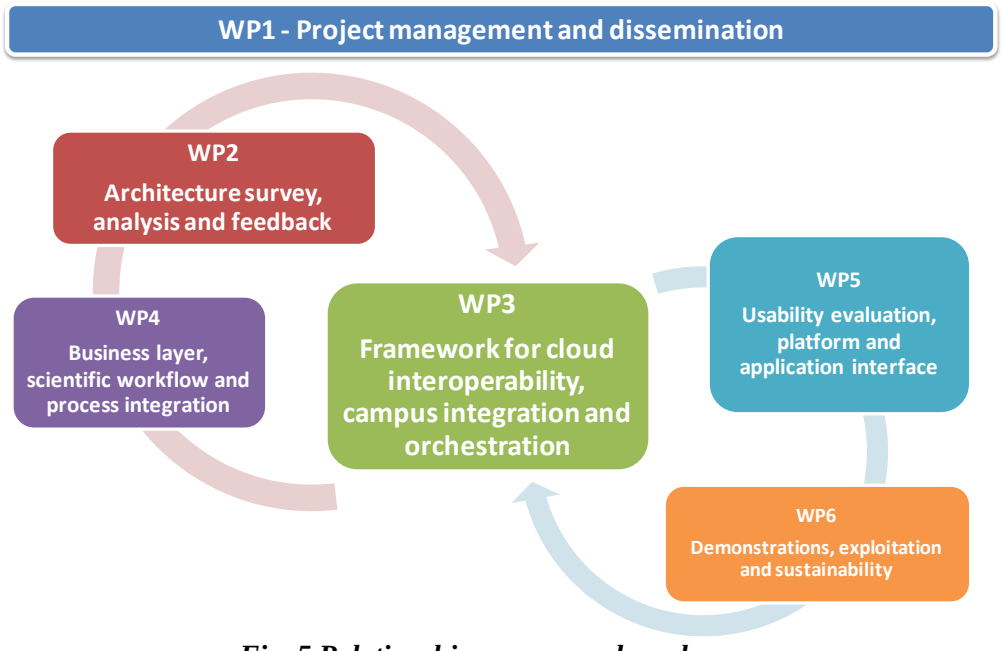


Fig. 5 Relationship among work packages

1.3.2 List of Deliverables

Del. no.	**Deliverable name**	**WP no.**	**Nature**	**Dissemi-nation level**	**Delivery date**
D1.1	Project presentation	WP1	R	PU	1
D1.2	Final Project Report	WP1	R	PU	24
D2.1	Use cases analysis, requirements collection and architecture development recommendations	WP2	R	PU	6
D2.2	RECIPE architecture definition for cloud and campus infrastructure convergence and end-to-end services delivery, initial interfaces definition	WP2	R	PU	9
D2.3	Architecture refinement, interfaces update based on feedback from other WPs	WP2	R	PU	15
D2.4	Final RECIPE architecture update	WP2	R	PU	22
D3.1	Loosely coupled cloud scenario - early prototype	WP3	P	PU	10
D3.2	Loosely coupled cloud scenario - prototype and pilot service implementation	WP3	R	PU	14
D3.3	Security model and standardization roadmap	WP3	R	PU	15
D3.4	Tightly couple cloud scenario - early prototype	WP3	P	PU	17
D3.5	Tightly couple cloud scenario - prototype and pilot service implementation	WP3	R	PU	20
D3.6	Shared inter-domain repository and pilot service implementations	WP3	R	PU	24
D4.1	Cost modelling tool	WP4	P	PU	6
D4.2	Architecture of automated business processes and scientific workflow execution	WP4	R	PU	12
D4.3	Prototypes of automated business process for cloud resource provisioning	WP4	P	PU	20
D4.4	Platform for scientific workflow execution	WP4	P	PU	20
D4.5	RECIPE overall business model	WP4	R	PU	22
D4.6	Best practices and recommendations	WP4	R	PU	24
D5.1	Initial feedback on baseline results	WP5	R	PU	14
D5.2	Results of the follow up testing and expert review	WP5	R	PU	18
D5.3	Usability evaluation of RECIPE by industry	WP5	R	PU	22
D6.1	Demonstration plan	WP6	R	PU	10
D6.2	Demonstration cases and supporting infrastructure for early prototypes	WP6	R	PU	12
D6.3	Report on delivered demonstrations	WP6	R	PU	23
D6.4	Exploitation and sustainability	WP6	R	PU	24

1.3.3 List of Milestones

Milestone number	Milestone name	Work package(s) involved	Expected date	Means of verification
M2.1	Preliminary RECIPE architecture definition	WP2	M6	Preliminary architecture design is fed into WP3 and WP4
M2.2	RECIPE architecture and interfaces definition	WP2	M15	RECIPE architecture is finalised and the interfaces between the main functional components are defined.
M2.3	Final RECIPE architecture release and recommendation for future implementers	WP2	M22	All feedback and experiences from other work packages are incorporated and the final RECIPE architecture is issued. Recommendations for architecture improvements are proposed.
M3.1	Loosely coupled cloud prototype	WP3	M10	The key software components of the loosely coupled cloud integration scenario are prototyped, and ready to be demonstrated and used for orchestrating pilot services.
M3.2	Shared security model in production	WP3	M15	Shared in-depth security model is properly implemented, and documented.
M3.3	Tightly coupled cloud prototype	WP3	M19	Crucial software components of the tightly coupled cloud integration scenario are prototyped, and ready to be demonstrated and used for orchestrating pilot services.
M3.4	Shared multi-domain disk repositories in production	WP3	M22	Shared disk repository is properly set up, documented, and different cloud management software implemented in different domains can use it.
M4.1	Cost modelling tool is ready (M6)	WP4	M6	The basic cost modelling to is ready to use.
M4.2	Platform for scientific workflow execution is ready	WP4	M20	The platform is ready to be demonstrated in WP6.
M4.3	Prototype for automated business processes is ready	WP4	M20	The prototype is ready to be demonstrated in WP6.
M5.1	Architecture feasibility check is complete	WP5	M10	Architecture is fit to run the planned demonstrations and use case(s) by analysing the requirements provided by D6.1
M5.2	Baseline black-box usability testing is complete	WP5	M14	Positive feedback from NREN users using the system with the results of the initial baseline results of the black-box testing.
M5.3	Secondary black-box testing is complete	WP5	M18	Secondary black-box tests are successful.
M6.1	Demonstration plan is ready	WP6	M10	Demonstration plan and schedule is realistic and in line with the major technical milestones.
M6.2	Demonstrations performed	WP6	M23	All the planned demonstrations are successfully performed and the further exploitation and sustainability of the project results are ensured.

1.3.4 Work package descriptions

WP1: Project management and dissemination
(Partners: **TERENA/Martel**, Flexiant, NIIF; M1 to M24)

Work package number	1	**Start date or starting event:**	M1			
Work package title	Project management and dissemination					
Activity type	MGT					
Participant number	**1**	2	3	4	5	6
Participant short name	**TERENA /Martel (leader)**	NIIF /USZ	PSNC	SURFnet	GRNET /ICCS	Vrijheid
Person-months per participant	**18**	1	0	0	0	0
Participant number	7	8	9			
Participant short name	Flexiant	UvA	FORTH			
Person-months per participant	2	0	0			

Objectives

To perform the overall project management of the RECIPE consortium, so that the contracted commitments are produced on time and within budget as well as to coordinate the dissemination activity of the project and its external relations.

Description of work

WP1 will first establish the routines for the internal project management, including regular reporting by all partners, and the overall coordination of activities, financial- and technical- planning and control.
It will then ensure that the overall project contractual requirements are met in accordance with the time schedule and budget, and be the contact point of the project to the Commission and the FP7 community. The overall project management will be achieved by applying the established routines in conjunction with the GA, based on valued inputs from the TMC. Any amendments to the Grant Agreement will also be managed by WP1.

The management structure adopted for the project is described in Section 2.1. The project dissemination activity will also be managed by WP1 and coordinated by Flexiant with the help of NIIF. The actual dissemination work will be carried out in the corresponding technical work packages as it is described in Section 3.2.

T1.1: Establishing the project management and dissemination procedures
In this Task, partners will be reminded of the scheduling, resource allocation, responsibilities, etc. The kick-off meeting will be planned, where explanations will be made of the contractual and administrative issues and payment procedures, and e-mail lists, etc. will be established. During the kick-off meeting the formal organisation of the project structure will be finalised, including the managing bodies, i.e., the General Assembly (GA) and Technical Management Committee (TMC).

T1.2: Performing the project management duties
In this Task the overall project management activities will be performed. Details of the applicable management procedures are contained in Section 2.1.

T1.3: Coordinating the project dissemination activity
In this Task, a procedure for the consortium to follow for all aspects that are related to communication and

dissemination, and a means for information to be documented and kept up to date will be established and implemented. This Task then collates all the information ready for use in publications and newsletters, etc. A public communication strategy of the project towards various target groups will also be prepared. The actual production of the printed materials (such as leaflets, information sheets, posters, banners for demonstrations, etc.) will also be done under this task.

Role of partners

This WP will be led by TERENA with the administrative support of Martel, as in-house consultant. The major functions and responsibilities of the RECIPE project management (done by TERENA) will be:

- Overall performance monitoring and control of all activities.
- Coordination of interfaces between the activities.
- Documentation and configuration control including change management.
- Resource and finance control of the entire project.
- Risk identification and mitigation control.
- Meeting and conference coordination.

The dissemination activity (led by Flexiant with the help of NIIF) will

- Ensure that the project documentations (i.e. recipes, news items, information sheets, etc.) are consistent and up to date.
- Coordinate the project scientific dissemination activity (publication of conference papers, presentations, posters, etc.) and public communication (news items).
- Create and maintain the project website (hosted and maintained by TERENA)
- Produce printed materials (done by NIIF)
- Work out and implement the communication strategy of the project towards various target groups (e.g., users such as campus people, customers such as university IT departments, European Commission as funding body, standardisation bodies, and last but not least the cloud industry).

Deliverables

D1.1: Project Presentation (M1, R, PU)
This deliverable is a public description of the project in terms of main goals, key issues technical approach and achievements. It is intended for publication on the Websites of the Commission and the project.

D1.2: Final Project Report (M24, R, PU)
A Final Project Report will also be produced at the end of the project to summarise in a public document the major results and achievements of the project and this will conclude the project's technical work.

Milestones

The regular management reports to the Project Officer, including the Periodic Project Reports (PPRs) produced prior to each Project Review, may create specific decision pints in the project considered as milestones in WP1.

WP2: Architecture survey, analysis and feedback
(Partners: **UvA**, NIIF, PSNC, GRNET, Flexiant, FORTH; M1 to M22)

Work package number	2	**Start date or starting event:**	M1		
Work package title	Architecture survey, analysis and feedback				
Activity type	RTD				
Participant number	1	2	3	4	5	6
Participant short name	TERENA /Martel	NIIF /USZ	PSNC	SURFnet	GRNET /ICCS	Vrijheid
Person-months per participant	0	10	8	0	16	0
Participant number	7	**8**	9			
Participant short name	Flexiant	**UvA (leader)**	FORTH			
Person-months per participant	5	**22**	6			

Objectives

To propose a general architecture for campus-based cloud services delivery model (i.e. the Inter-cloud Architecture). Such an architecture that allows consistent integration of the cloud infrastructure (e.g., provisioned by an NREN on-demand) with the campus infrastructure in order to seamlessly deliver end-to-end services to campus (group users and/or individual users) including the provisioning of value added services (e.g., federation as a service) from NRENs to campuses.

The following main architectural components will be proposed and defined:

- NREN and campus network management system for delivering cloud services with guaranteed network QoS and provisioned on-demand (what can be implemented as a Cloud Carrier model/functionality).
- Federated inter-cloud brokering system.
- NREN-based network management system (that can be configured to manage multiple network infrastructure segments).
- Reference architecture model and interfaces for tight cloud integration supporting the interchange of virtual entities, including VMs and their images, virtual network segment, disk slices and cloud data storage elements and data repositories.
- Federated security and access control infrastructure providing user access from home organisations
- Security-services and mechanisms to ensure secure data storage and handling.

The following objectives will be realised:

- Surveying the existing IaaS clouds in Europe, in particular offered by commercial providers, as well as those built and provided by NRENs
- Architecture definition for campus based cloud services delivery and convergence with NREN and campus infrastructures;
- Inter-cloud Architecture definition and proposal for the horizontal and vertical interoperability model;
- Structural and interfaces analysis and open standards compliance;
- Feedback to industry on new sustainable models for services provisioning/delivery to NREN users.

Description of work

WP2 will analyse some pre-defined use cases (selected from the current and potential future cloud service portfolio exposed to NRENs and campuses by various stakeholders) in order to define the basic requirements

for the Inter-cloud Architecture proposed by RECIPE. This work package will also survey the different European IaaS clouds, their architecture, their interfaces, and identify similarities and differences among them as well as identify blocking factors that stop a coordinated and harmonized provisioning of cloud services to the Cloud Customers on campus as well as in other cases where the client needs aggregation and cloud offerings brokering could be beneficial. This work package will be in charge of following up corresponding industrial technology trends.

The main stakeholders are considered as follows: Commercial cloud providers; NRENs acting as private cloud and/or transport network providers with dedicated resources and services (including federated identity management); Cloud Carriers that can optionally also deliver value added services; Organisations with their own campus infrastructures; and finally users.WP2 will propose novel operating models and procedures for different type of clouds integrations combining resources from both cloud providers and NRENs or campuses. The convergence scenarios for cloud provisioning via NREN and campus network will be investigated. This work package will also define the required interfaces and protocols for reliable and secure data/information exchange and provisioned infrastructure management between all involved entities and systems. Additionally, the work package will deal with the potential use of Service Level Agreement (SLA) and select/recommend appropriate infrastructure description language for hybrid cloud and NREN/campus infrastructure description.

The preliminary WP2 architecture survey results will be fed into WP3 and WP4 developments as well as the prototypes of those work packages will be fed back to WP2 in order to cross-check them against the industrial technology trends via several iteration rounds.

T2.1: Functional definition of the RECIPE architecture for cloud and campus infrastructure convergence and end-to-end services delivery
This Task identifies and describes a comprehensive set of use cases, scenarios and potential operational models to drive end-to-end cloud services delivery. Information will be gathered from former and existing projects (e.g., RESERVOIR, GEYSERS, GN3, SAIL, and CONTRAIL) and from partners' national cloud initiatives such as GRENT's Okeanos, NIIF cloud, PSNC cloud computing and storage, SURFNet's project on brokering cloud offering etc. Publicly available industry scenarios and use cases will also be investigated. The basic functional and non-functional requirements for the RECIPE architecture components, considering objectives such as scalability, extensibility and data handling and storage security, will be sketched by this task, but further refinement must be done within the respective work packages WP3 and WP4.

Moreover, this task is also to define the architecture for cloud and campus infrastructure convergence for end-to-end services delivery. It proposes services and mechanisms for inter-domain and compatibility considerations with legacy domains. In particular it focuses on:

- Definition of the requirements and challenges in inter-domain scenarios in RECIPE
- Interworking between cloud provider, NREN and campus legacy domains to provide integrated resources for users/applications
- Cloud brokering and cloud integration mechanisms supporting the cross-domain access to and interchange of virtual entities, e.g. VMs and their images, virtual network segment, disk slices and cloud data storage elements and data repositories
- Consistent security infrastructure and AAA service provisioning mechanisms between different RECIPE actors/domains and legacy infrastructure/network domains
- Security-related architecture components that ensure secure data storage and handling
- End-to-end service provisioning mechanism in multi-domain environments, which is backward compatible with legacy network domains.

T2.2: RECIPE architecture implementation models, interfaces and protocols definition
This Task will define the model and methods to allow consistent information exchange between different domains, layers and actors of RECIPE architecture and service provisioning environment. According to the information exchange model functional requirements of the interfaces between all entities will be defined. Finally, this task will define the information exchange model and interface between users, resource

owners/providers, service providers, network operators. Federated infrastructure/resource management and access control, as well as applications or services running on the infrastructure are important design factor in this task to enable guarantied and controlled end-to-end service provisioning/delivery based on user application requirements.

T2.3: Federated cloud service delivery workflow
This Task will propose a cloud service delivery workflow including the lifecycle management of an integrated cloud, transport network, and campus infrastructure. Such a workflow will support infrastructure servicers and mechanisms for user applications and data synchronisation.

Role of partners

UvA will provide the leadership of WP2 and put the main effort on defining the Inter-cloud Architecture that will address the main problems in delivering end-to-end services to campus users via NRENs. UvA will coordinate architecture development with other partners in WP3 and WP4 in order to propose advancements to current practices and assure the technology transfer to industry. UvA will use its expertise in clouds and security to define necessary architecture security services and mechanisms to ensure consistent security in the provisioned infrastructures.

GRNET will contribute to the survey of existing IaaS clouds in Europe. Participate in the use case analysis. Contribute to the Inter-cloud Architecture definition bringing the experience from the provision of the pre-production Okeanos cloud IaaS service currently running at GRNET.

FORTH will contribute to the architecture development, use cases analysis, interfaces definition and liaison with other WPs.

NIIF will work on the survey of existing IaaS clouds in Europe, participate in the use case analysis and contribute to the Inter-cloud Architecture definition bringing the experience from the cloud service provision in Hungary.

PSNC will contribute to the use cases and requirements analysis, architecture and interfaces definition as well as clouds services delivery framework developments basing on PSNC experience with the computing cloud resources and services management software development (Campus Services & Computing Cloud) and storage cloud (National Data Storage) architecture design, software development and deployment.

Flexiant will help to follow up on the industrial technology trends and give feedback in several iteration rounds.

Deliverables

D2.1: Usecases analysis, requirements collection and architecture development recommendations (M6, R, PU)
To provide selected use cases analysis that will be used for defining general requirements and recommendations to RECIPE architecture development and proposing main operational models for cloud, NREN and campus integration. Providing this deliverable at early stage of the project will ensure the common basis for all other WPs research and development.

D2.2: RECIPE architecture definition for cloud and campus infrastructure convergance and end-to-end services delivery, initial interfaces defintion (M9, R, PU)
To propose RECIPE architecture for combining and converging cloud, NREN and campus infrastructures for end-to-end services delivery and consistent security. Recommendations for inter-layer and inter-provider interfaces defintion will aslo be included.

D2.3: Architecture refinement, interfaces update based on feedback from other WPs (M15, R, PU)
To incorporate experiences from the RECIPE services and tools development into the updated architecture. Interfaces will be updated and verfied for interoperability in inter-domain and multi-layer services delivery and consistency in inter-services and security context management.

D2.4: Final RECIPE architecture update (M22, R, PU)
To summarise all the project expereince at architectural level and suggest future developments and prossible recommendations for standardisation.

Milestones

M2.1 Preliminary RECIPE architecture definition (M6)
Preliminary RECIPE architecture design is being fed into WP3 and WP4.

M2.2 RECIPE architecture and interfaces definition (M15)
RECIPE architecture is finalised and the interfaces between the main functional components are defined.

M2.3 Final RECIPE architecture release and recommendation for future implementers (M22)
All feedback and experiences from other work packages are incorporated and the final RECIPE architecture is issued. Recommendations for architecture improvements are proposed.

WP3: Framework for cloud interoperability, campus integration, and orchestration

(Partners: **NIIF/USZ**, **PSNC,** SURFnet, GRNET/ICCS, Vrijheid, Flexiant, UvA, FORTH; M1 to M24)

Work package number	3	**Start date or starting event:**		M1		
Work package title	Framework for cloud interoperability, campus integration and orchestration					
Activity type	RTD					
Participant number	1	**2**	**3**	4	5	6
Participant short name	TERENA /Martel	**NIIF /USZ (Leader)**	**PSNC (co-leader)**	SURFnet	GRNET /ICCS	Vrijheid
Person-months per participant	0	**26**	**30**	28	28	5
Participant number	7	8	9			
Participant short name	Flexiant	UvA	FORTH			
Person-months per participant	8	12	3			

Objectives

To implement the RECIPE framework for cloud interoperability, campus integration, and orchestration. WP3 will deliver the software prototypes (i.e. the component of the Cloud Carrier Software Stack) as well as develop and implement the pilot services in line with the reference Inter-cloud Architecture defined by WP2.

WP3 objectives are as follows:

- To make a significant leap towards harmonized, and interoperable European infrastructure cloud incorporating different stakeholders e.g. commercial cloud providers, as well as NREN and campus network/cloud providers;
- To architect, and install high-level architectural components/functions, such as cloud broker or cloud information sub-system to allow HE users to have a uniform view on all cloud providers available to them;
- To work out, and apply technology enhancements that will allow IaaS cloud entities (e.g., virtual machines) to traverse, or be utilized among cloud provider domains (including domains managed by different hypervisors or administered by different entities);
- To boost the uptake of standardized cloud APIs;
- To develop an in-depth security model that will equip cloud entities with uniform, and technically feasible access model, thus enhance users trust on such infrastructures;
- To work out a shared, inter-domain virtual disk image storage, and image management system that store the virtual machine templates in order that the users can perform secured inter-domain operations over them.

Description of work

WP3 takes a two-step approach; it will develop open source early software prototypes and then implement pilot services to create an open, inter-cloud experimental environment passed to demonstrate and disseminate the project results in WP6. The tasks in WP3 will be performed in two basic integration scenarios:

- Activities around the loosely coupled cloud integration will focus on architecting IaaS service components such as cloud broker, and cloud resource information sub-system that will allow cloud users to transparently access the different IaaS cloud services offered by autonomous cloud providers.
- A deeper level of integration will also be considered, as activities around the tightly coupled cloud integration that will investigate how different cloud entities (virtual machines, virtual network segments, and also virtual disk slices) can either be transferred, or be utilized among the different

cloud domains. The beneficiaries of the tight cloud integration are not merely the primary cloud user communities, but also the cloud provider communities (i.e. NRENs, commercial providers, campus cloud providers) responsible for operating and administrating the infrastructure.

Besides the two different integration scenarios, efforts, such as architecting an appropriate security framework, or creating shared disk image repositories are also considered as relevant tasks in this work package.WP3, and RECIPE in general, has the obvious intention to leverage on the work and the results of previous projects (such as Reservoir, Stratuslab, or GN3). WP3 will develop mostly "glue-components" with re-engineering and re-using the existing software modules to be tailored to the specific needs of RECIPE, rather than creating new components from scratch.

T3.1: Loosely coupled IaaS cloud scenario
This Task will focus on the higher integration level that will hide structural and architectural differences of IaaS cloud implementations (domains) from the primary users by exposing a common set of IaaS cloud services, and thus providing uniform access. This task will architect a small layer of modular software that wedges between the primary user interface and the cloud management middleware components, and features services, like the cloud broker, the cloud information sub-system, i.e. an analogous of common Network Information System that will aid users to work seamlessly in an inter-domain cloud environment.
The software is meant to be minimal-intrusive, as it will use the already available APIs offered by the underlying cloud management software components within the domains. The primary scope of the task is focused on the four IaaS cloud domains operated by consortium partners, but we also plan to scale out this activity by submitting API-related recommendations to other European R&E stakeholders, and also to commercial IaaS cloud providers.

As a concrete example, in Task T3.1 Vrijheid.net will focus on an elastic Storage as a Service broker prototype across various cloud providers applying a pluggable storage back-end and elastic scaling of front ends and metadata stores. The cloud storage back-ends can include local campus data centres as well as Amazon S3, Flexiant, and other public clouds added on demand. The cloud backed storage will be available under an Apache open source license and fully built around open standards and open source.

T3.2: Tightly coupled IaaS cloud scenario
This Task will go beyond the brokering model and mostly investigate how the different cloud entities can either be transferred, or utilized among tightly integrated cloud domains. Based on the analytical work and the results of WP2 the task will focus on either the transferring or the cross-using possibilities of virtual entities such as virtual machines, virtual network segments, virtual disk chunks, and virtual operating system images. The following operations are targeted for implementation:

- the transfer of a complete virtual machine (or a set of virtual machines), along with machine descriptions, the transfer of image data from one cloud domain to the other one, and the experimentation on what temporary exchange formats to use (live-migration is not a priority, but will be thoroughly investigated);
- either the transfer or the inter-domain mapping of virtual network segments;
- either the transfer or the cross-domain use of virtual disk images;
- the realization of cloud backend storage solutions;
- the cross-domain use of virtual image repositories.

The early prototypes will implement the basic integration techniques such as virtual machines image conversion and domain borders traversal, solution for spanning the multiple domains with VLANs combined with virtual machine networking configuration tools, as well as sample techniques for transferring the virtual images, and accessing virtual image repositories. Pilot services on top of the integrated cloud infrastructure will be then made available in the penultimate project quarter for demonstrations in WP6. WP3 and WP6 will jointly ensure that the more mature combination of the virtual machine transfer/conversion, inter-domain virtual network, and storage provisioning technologies will be put into production (i.e. in the NRENs or industry SMEs' production cloud infrastructure).

T3.3: Standardization and policies
Standardisation in clouds is in it's infancy but is considered as highly important for RECIPE, as the proper level of interoperation can only be achieved by using standard communication interfaces and protocols among the different cloud domains. On the one hand, RECIPE will survey the landscape of available IaaS cloud related standards, or standard initiatives that might influence the further development, assess them based on their possible relevance, and apply/implement them if they are found to be appropriate. On the other hand, RECIPE will also support the work of standardization bodies by putting recommendations, implementing the early standards, and giving feedback on their production usage in order to be further refined by standardization working groups. Shared IaaS and resource management policies (establishing the legal as well as the organizational background behind virtual entity transfers) will also be worked out in this task. These policies will be represented by a set of agreements among various R&E stakeholders, not necessarily reflected by standardization bodies.

T3.4: Inter-domain security framework and image repository for pilot service
This Task will work out a security framework in details that can significantly increase the trust in cloud services. In practice, this task will work out a set of solutions to create disk image repositories meeting such tight security and trust requirements. The security related work items are:

- Allowing virtual entities to be securely authenticated, authorized, accounted through the existing trust federations, replacing the typical central, mostly password file based authentication models;
- Creating a method that will help in describing cloud security messages, and will make them conform to security standards and best practices (e.g., SAML2 compatible solutions);
- Allowing virtual security related entities to be exchanged over multiple cloud domains;
- Revealing the most dreaded cloud-specific security risks, and offering reasonable enhancements over them;
- Exploiting encryption based technologies in virtual disk access;
- Working out security related best practices, adherence roadmaps to cloud operations models in use, and also security correspondence audits for the currently used IaaS clouds.

Concrete examples of security tasks are the integration of proprietary security XML tokens with extensive security context management functionality, and also the integration of WS-Security STS services. Disk images must be accessed from different cloud domains based on the same policies. The concept of safe image management will also be implemented, where the access to images repository is controlled (authenticated/authorized) and the integrity of the images can be checked.

Role of partners

WP3 will be led by NIIF, with the help of PSNC. NRENs (the research networks) participating in RECIPE are in the best position to deal with the integration of IaaS cloud resources with the network (as the major role of a Cloud Carrier). Commercial cloud providers are heavy weight users of the network infrastructure, therefore the collaboration with the network providers is a mutual interest. One approach to enable this interaction is described by the cloud workgroup of the TMForum. Among other interfaces this body describes the SLA interfaces and workflows. For the IaaS cloud broker of RECIPE (i.e. in case of the loosely coupled cloud scenario) it is important to consider the interaction with the network provider in order to receive more information about the backing network infrastructure. This integration could be done based on the results of the GN3 cNIS project where the Open cNIS software package (developed by PSNC and NIIF/USZ) is going to implement the necessary interfaces. WP3 will leverage on these results and enhance the software tool further to be applied to RECIPE.

The basis of the RECIPE cloud brokering pilot service will be the early cloud back-end storage prototype delivered by Vrijheid.net. This provides a broker with pluggable back-end, scalable front-end and metadata stores. The file system interface itself is implemented as a "pipe" and has metering, encryption and compression elements with a WebDAV front-end that works out-of-the-box with all major clients (seems to be ideal to start with). The main goal for Vrijheid.net in WP3 is to demonstrate, enhance and adopt the cloud

backed storage prototype to RECIPE by: using multiple cloud storage back-ends concurrently; using multiple Cloud Providers and Cloud Carriers to provide runtime switching of the relevant computing part of the infrastructure and testing elasticity in a hybrid cloud scenario, possibly utilizing the Cloud Carrier model. One of the key aspects of the cloud backed storage model proposed is that the distributed database also holds the server side encryption keys. It basically means that the campus security policy can be met (encryption keys and sensitive metadata can be stored locally on campus) while the data can be stored at various remote (public or private) cloud storage providers. This model therefore is considered as a proper candidate for campus-cloud infrastructure integration prototype.

Moreover, PSNC is interested mainly in working on solutions for virtual, cloud storage entities assuring mutual accessibility of storage entities among over federated IaaS clouds and mobility of these entities across the integrated IaaS clusters. PSNC is willing to collaborate on cloud-backed storage and brings the experience needed in this area, based on the development, deployment and operation of National Data Storage system, the storage cloud backed by pool of heterogeneous storage resources, both tape and disk media-based, accessed through virtual file-system interface developed using Linux FUSE library and multiple front-ends including SFTP, WebDAV, and GridFTP. PSNC is also interested in working on the other resource cloud aspects including VMs images, networks and disks migration/interchange necessary for assuring the tight IaaS integration.

UvA will contribute to WP3 with the development of the cloud interoperability framework, including supporting information model and inter-cloud/inter-layer interfaces definition, as part of WP3. Other contribution will include development of the federated security architecture and infrastructure for inter-cloud and cloud-campus integration. UvA has a cloud IaaS/PaaS test bed, which uses OpenNebula. They developed AAI services for on-demand infrastructure services provisioning based on ESB/OSGi and as domain based stand alone AAI server. Special features are provided for multi-domain AAI services interaction and during the whole provisioned services lifecycle.

GRNET aims to capitalize on the experience and competence that it has gained in the past from the provision of cloud services and the development efforts that it has put on the Okeanos and Pithos platforms. GRNET aims to bring the Okeanos platform to the RECIPE project rendering it as one of the core enabling software components for WP3, facilitating the provision of cloud services, and contributing with the development of project-specific services and APIs. GRNET can act both as a Cloud Provider offering hardware and software (Okeanos) resources, and as a Cloud Carrier with its role as NREN.

For SURFnet, failover and migration between (commercial and educational) clouds is important. A researcher could for instance by default use a local country cloud (that's probably the safest cloud), but dependent on security/legal/costs/etc decide to move his VM in a later phase to a commercial cloud. SURFnet's intention is to integrate the university LAN (i.e. campus network) with commercial IaaS vendors. For instance, HE users can boot-up new machines in the cloud while these machines are logically within their own IP address range.

Last but not least, Flexiant, as a commercial cloud provider in RECIPE, has mutual interest in both the loosely and tightly coupled cloud integration scenarios. They will focus on standardising interfaces and access methods, interoperability/portability (e.g., an import/export image tool that is required to manage migration between providers with different hypervisors), and data handling in an Inter-cloud Architecture.

Deliverables

D3.1: Loosely coupled cloud scenario - early prototype (M10, P, PU)
This deliverable will be a preliminary software prototype of the loosely coupled cloud scenario to be exposed to the Cloud Carrier Software Stack.

D3.2: Loosely coupled cloud scenario – prototype and pilot service implementation (M14, R, PU)
This document is meant to give an overview on how loose integration will be implemented over the different

IaaS cloud domains taking into account the seamless cloud-campus integration. It will highlight the already available cloud services supporting the loose integration, and also propose new inter-domain services, interactions among them and with cloud APIs. Recommendations, and further actions, will be identified on how to tune the current systems to adhere to the generic model worked out in WP2. The document will also check on the progress of realizing the pilot service implementation, highlighting challenges and issues met.

D3.3 Security model and standardization roadmap (M15, R, PU)
This is a combined deliverable summarizing steps made over the implementation of the in-depth security model laid down in WP2 deliverables, and also will give a survey over the landscape of available cloud-related standards, quasi-standards, best practices, and about their relevance. The standards roadmap will be updated by the end of the project continuously following up the on-going standardization efforts, and their realization within the project.

D3.4: Tightly coupled cloud scenario - early prototype (M19)
This deliverable will be a preliminary software prototype of the tightly coupled cloud scenario to be exposed to the Cloud Carrier Software Stack.

D3.5: Tightly coupled cloud scenario – prototype and pilot service implementation (M22, R, PU)
This deliverable will document the tightly coupled cloud prototype, as well as the experiences, and lessons learnt while prototyping the integrated infrastructure cloud. The document will thematically cover the transfer of virtual machines, the virtual machine exchange formats to be used, the virtual network transfer, and mapping possibilities, and also the cloud brokered storage regarding the virtual disk management. This deliverable will document the pilot tightly integrated infrastructure cloud services, and lessons and recommendations derived from piloting the integrated infrastructure clouds. The document will follow the same structure as the early prototype deliverable.

D3.6: Shared cross-domain repository and overview of implementations (M24, R, PU)
This document will introduce the shared inter-domain disk image repository service, while describing techniques, as well as best practices on how to achieve the mutual inter-domain use of such service, and what kind of transaction-like operations can be implemented. As security, data integrity, and validity will be extremely important concerns here, tests and experiments will be thoroughly reported.

Milestones

M3.1: Loosely coupled cloud prototype (M10)
This milestone indicates that the key software components of the loosely coupled cloud integration scenario (cloud broker, cloud information sub-system, etc.) are prototyped, and ready to be demonstrated and used for orchestrating pilot services.

M3.2: Shared security model in production (M15)
This milestone represents the point in time when the shared in-depth security model is properly implemented, and documented.

M3.3: Tightly coupled cloud prototype (M19)
This milestone indicates that crucial software components of the tightly coupled cloud integration scenario (i.e. virtual machine, virtual network, as well as virtual disk slice transfer technologies) are prototyped, and ready to be demonstrated and used for orchestrating pilot services.

M3.4: Shared multi-domain disk repositories in production (M22)
This milestone marks the point when the shared disk repository is properly set up, documented, and different cloud management software implemented in different domains can use it.

WP4: Business layer, scientific workflow and process integration
(Partners: **FORTH**, NIIF, PSNC, Flexiant, UvA; M1 to M22)

Work package number	4	**Start date or starting event:**	M1		
Work package title	Business layer, scientific workflow and process integration				
Activity type	RTD				
Participant number	1	2	3	4	5	6
Participant short name	TERENA /Martel	NIIF /USZ	PSNC	SURFnet	GRNET /ICCS	Vrijheid
Person-months per participant	0	12	14	0	0	0
Participant number	7	8	**9**			
Participant short name	Flexiant	UvA	**FORTH**			
Person-months per participant	2	2	**28**			

Objectives

To create a platform for integrating business and scientific workflow/processes with cloud infrastructure and services. The resulting platform will be itself offered as service enabling users to express typical, unmodified, scientific workflows. The underlying implementation will harmonize transparently to the user the execution of the workflows with cloud business processes related with soliciting and examining available service offers, purchases and provisioning among multiple stakeholders, optimizing long-running scientific workload execution statically or dynamically based on best price-performance points. WP4 is also targeting to create a business model behind the cloud services established, organizing the stakeholders of the infrastructure, understanding and clarifying their service offerings and pricing models, and working out a market, or semi-market model. This work package has the goal of empowering NRENs to play the role of a financial clearing house for federated campuses, significantly reducing data transfer costs (in and out from the cloud), and paving the way for multiple commercial cloud providers to be able to address and serve the R&E community. It is important to share a minimal set of disciplines on the European level regarding IaaS cloud provisioning. Mature policy elements and best practices can be moved toward the standardization level.

Description of work

T4.1: Cost modelling for migrating applications to integrated cloud services
This Task will focus on the development of cost models for the migration of users and applications to a cloud solution through RECIPE. The models will take into account any existing investment in infrastructure, support and skills and include the costs of migration to the cloud, impact on users and local support etc. and to make comparisons with in-house virtualisation. The modelling should ideally be based on historic evidence although it appears that there do not yet exist strong examples of real world cloud use – most cloud used in the private sector is for relatively small scale or newly developed services, and real examples of large scale migration from an internal infrastructure to a cloud infrastructure may be difficult to find. The model should include assumptions and indicate where future modelling has had to be used rather than historical evidence.

T4.2:Business model study and automated business processes
This Task will investigate the goal of empowering NRENs to play the role of a financial clearing house for federated campuses, significantly reducing data transfer costs (in and out of the cloud), and paving the way for multiple commercial cloud providers to be able to address and serve the R&E community. RECIPE will investigate changing the charging model for outsourced university IT operations from a “contract-free, pay-as-you-go” model suitable more for individual user to a more predictable (but still highly efficient) fixed-cost charging scheme. This task will also evaluate and harmonize the legal environments IaaS clouds are operating in and ensure legal restrictions are taken into account in any resulting business scenario.

Another focus of this task is the creation of automated workflows and business processes for soliciting and examining service offers, purchases and provisioning among multiple stakeholders, enabling providers to optimize efficiency, maximize flexibility, etc. The task will create a cloud service market place where service providers can advertise their service offerings and pricing, customers can dynamically query available cloud service offers, and appropriate value networks of service-providers can be formed by taking into account the available service levels and offered pricing, shifting demand to the most efficient service offers.

T4.3: Platform for scientific workflow execution
The focus of this Task is to ensure that standardized scientific workflows supported by Workflow Management Systems (WMSs) can be seamlessly executed over the RECIPE brokering service or federated environment combining in-house, private, NREN-hosted, or commercial cloud offerings. A standards-based open-source WMS will be used to transform abstract scientific workflow descriptions into concrete plans, which will then be decomposed into tasks to be executed over the RECIPE framework for cloud interoperability, campus integration, and orchestration (focus of WP3). The WMS will coordinate the workload throughout its execution and will use real-time information provided by Task T3.2 to target resource allocation decisions based on business considerations. The platform for scientific workload execution will be harmonized with automated business processes (the focus of Task T4.2), which dynamically examine available cloud service offerings and decide on the most cost-effective solutions.

T4.4: Best practices and recommendations
This task focuses on interface evaluation based on the outcome of WP2; collecting relevant standards and propagate their usage; setting up a standardization roadmap; evaluate currently used best-practices, evaluate them and aid them to converge to lifted up as standards; evaluating and harmonizing the policy environments, generalizing and harmonizing IaaS cloud policies; and transforming our experience with a novel business model into new policies and best practices.

Role of partners

FORTH will have the overall lead of WP4 and of Task T4.2. FORTH will contribute expertise with scalable infrastructure support for business process management, optimization of the deployment of scalable applications and services over heterogeneous Cloud computing providers, and cost modelling of data centre operations.

NIIFI will lead Task T4.3 and coordinate the overall federation and interoperability integration efforts of supported IaaS platforms along with its own OpenNebula based IaaS cloud solution.

PSNC will lead Task T4.1 and contribute its experience in top-down in-house and outsourced service costs calculation including hardware, software, computing room floor, cooling, utility, CPUs, RAM, network, storage as well as manpower, maintenance and end-user support, migration, education and business and personnel adaptation costs. These tools and methods can be adopted and exploited to the needs of tasks T4.1 and T4.2. PSNC will also contribute experience with scientific workflow engines such as Kepler (https://kepler-project.org/), the workflow orchestration engine for which PSNC develops modules (e.g. actors for) and provides support (training, installation, configuration and mgmt support) in projects e.g. EGI (currently), Euratom, Euphoria (in the past).

Finally, UvA will lead T4.4 best practices and standardization and Flexiant will contribute to that.

Deliverables

D4.1 Cost modelling tool (M6, P, PU)
This prototype will consolidate cost modelling analysis into a tool (such as excel or Eclipse worksheets) that can be used by practitioners into recommending concrete policy actions, such as whether it makes financial sense to move to an NREN-integrated, supported, and offered cloud solution vs. a standard non-NREN cloud

solution.

D4.2 Architecture of automated business processes and platform for scientific workflow execution (M12, R,PU)
This deliverable will describe the overall architecture of the automated business processes for managing appropriate cloud service offerings to maximize efficiency and flexibility. It will also describe the overall architecture of the standards-based platform to support scientific workflow execution over resources provided by the RECIPE interoperability layer. The deliverable has dependencies on deliverables from tasks of WP2 and WP3.

D4.3 Prototypes of automated business process for Cloud resource provisioning (M20, P, PU)
This prototype deliverable will comprise appropriate business workflows and a business-process execution language (BPEL) execution engine that supports their execution over the RECIPE service offering directory. This deliverable will leverage the cost modelling tool (D4.1) to ensure provisioning actions are always performed in the most cost-effective manner.

D4.4 Platform for scientific workflow execution (M20, P, PU)
This prototype deliverable will comprise a widely-deployed workflow management system and execution engine adapted to manage the deployment and execution of typical scientific workflows over the RECIPE interoperability layer.

D4.5 RECIPE overall business models (M22, R, PU)
This deliverable will outline novel business models supporting the viability of the RECIPE framework, and providing incentives for adoption by business customers, institutions, and academic and research users.

D4.6 Best practices and recommendations (M24, R, PU)
This deliverable will outline the results of the interface evaluation (based on the outcome of WP2) and all relevant standards, describing a concrete roadmap towards standardization. It will describe currently used best-practices and policy environments and the transformation of our experience with a novel business model into new policies and best practices.

Milestones

M4.1 Cost modelling tool is ready (M6)
The basic cost modelling tool is ready to use.

M4.2 Platform for scientific workflow execution is ready (M20)
The platform is ready to be demonstrated in WP6.

M4.3 Prototype for automated business processes is ready (M20)
The prototype is ready to be demonstrated in WP6.

WP5: Usability evaluation, platform and application interface
(Partners: **Flexiant**, NIIF, PSNC, UvA, FORTH; M6 to M22)

Work package number	5	**Start date or starting event:**	M6			
Work package title	Usability evaluation, platform and application interface					
Activity type	RTD					
Participant number	1	2	3	4	5	6
Participant short name	TERENA /Martel	NIIF /USZ	PSNC	SURFnet	GRNET /ICCS	Vrijheid
Person-months per participant	0	10	2	0	0	0
Participant number	**7**	8	9			
Participant short name	**Flexiant**	UvA	FORTH			
Person-months per participant	**24**	5	21			

Objectives

To evaluate the usability of the Inter-cloud Architecture and Cloud Carrier Software Stack in real life and give feedback to industry. WP5 will ensure the seamless operation of different runtime environments, ensure elasticity, scalability and fault tolerance with robust load-balancing and network infrastructure as well as cross platform functionality across differing hypervisors.

This work package will also deal with the users' perspective. WP5 will perform the feasibility check of the architecture implementation; do the black-box testing and the usability testing from a HE user point of view. It will refine and synthesize the application (SaaS) and/or platform (PaaS) requirements, analyze the current user interfaces (or APIs) from usability point of view, and would reveal the most prominent handicaps users might meet when using an IaaS cloud. The following tasks are considered:

- Performing continuous usability evaluation over the entire harmonization process in order to maintain continuous engagement with the targeted user community;
- Experimenting with e-science applications that can highlight the capabilities of the IaaS cloud federation, while offering a direct service to the user community.

Description of work

WP5 will evaluate the developments of the previous WPs by testing the developments as a useable product from the point of view of end users, IaaS and service providers. The WP will aim to go further than usability inspection by providing direct input from real users on how they use the system. This will be done by black-box testing and establish a baseline to measure efficiency, accuracy, recall, and emotional response from the user and also feedback issues and problems into the development life-cycle as well as using the FORTH stream-processing application as a use case as well as the storage characteristics of a system.

Interfaces between platforms developed by UvA and NIFF/USZ will be tested. This will ensure the developments are fit for the purpose set out in the RECIPE description of work. Ensure that it can be open sourced for the benefit of both the European R&E community and Cloud industry SMEs in order to ensure the exploitation of the results and the sustainability of the architecture, seamlessly integrating the campus infrastructure with the cloud and ensure that different vendors and commercial cloud service providers apply different models, incompatible cloud architectures and protocol stacks, as well as proprietary interfaces that limit the technical interoperability between clouds.

T5.1: Feasibility check and baseline black-box usability testing
Task T5.1 will ensure that the architecture is fit to run the planned demonstrations and use case(s) by analysing the requirements provided by D6.1 which will define technical requirements and necessary

infrastructure for hosting the demonstrations, ensuring convergence, coherence, consistency and harmonisation across NRENs and private/public clouds and that the planned integration of interfaces and tools are in place. Evaluate the usability of the Inter-cloud Architecture and Cloud Carrier Software Stack from an IaaS perspective and ensure the necessary API calls are in place and features such as portability and mobility of data and processes at the application level and establish a baseline.

T5.2: Secondary black-box testing
This Task will use the established baseline to measure improvements and also expert review as well as use case testing and establishing system characteristics for users.

T5.3: Usability testing from a user perspective
This Task will aim at refining the application level developments to promote seamless user roaming and negating lock-in and will also ensure the scientific and business process workflows can be used. Overall, this Task will ensure the earlier feedback has had the desired effect in the functionality.

Role of partners

Led by the cloud industry SME partner Flexiant, WP5 pre-selected some potential PaaS and SaaS use cases for the cloud customer domain to demonstrate our IaaS inter-cloud prototype with. WP5 will demonstrate e.g., the information sub-system that ensures the co-ordination (information exchange) between the cloud infrastructure and the platform (not the operating system) in order to optimise resource allocation in case of e.g., a JEE cluster that is not trivial. The list of pre-selected platforms (provided by the partners) is as follows:

- Java Platform, Enterprise Edition (JEE) runtime environment – provided by NIIF/USZ
- SURFconext, federated group manager platform that already includes applications – provided by SURFnet
- FP7 project GN3 GEMBus (Enterprise Services Bus) platform – provided by UvA
- Scalable stream-processing application platform as a service for stream-oriented applications – provided by FORTH

One level up, SaaS is represented by a set of pre-selected open source applications for demonstration purposes. Open interfaces will be implemented to expose the profile of the application according to its actual usage, mainly determined by the user's profile. The list of pre-selected applications is as follows:

- FileSender, large file transport solution – provided by the NREN community via TERENA.
- Cloud backed storage, easily accessible to end users – provided by Vrijheid.net
- Virtual Desktop Infrastructure (VDI) – provided by SURFnet
- Telenor EDH (e-Health for Digital Hungary) system, which is a complex telemedicine solution based on mobile phones – provided by NIIF/USZ

Note that the lists are non-exclusive; other platforms and applications may be put into the service portfolio as the project evolves.

Deliverables

D5.1: Initial feedback on baseline results (M14, R, PU)
Feedback from NREN users using the system with the results of the initial baseline results of the black-box testing.

D5.2: Results of the follow up testing and expert review (M18, R, PU)
Report on the results of the secondary black-box testing.

D5.3: Usability evaluation of RECIPE by industry (M22, R, PU)
Final analysis and results to gauge platform usability taking into consideration the scientific and business flows and checking all feedback has been incorporated to the system with the reported bugs fixed.

Milestones

M5.1 Architecture feasibility check is complete (M10)
Architecture is fit to run the planned demonstrations and use case(s) by analysing the requirements provided by D6.1

M5.2 Baseline black-box usability testing is complete (M14)
Positive feedback from NREN users using the system with the results of the initial baseline results of the black-box testing.

M5.3 Secondary black-box testing is complete (M18)
Secondary black-box tests are successful.

WP6: Demonstrations, exploitation and sustainability

(Partners: **GRNET**, NIIF, PSNC, SURFnet, Vrijheid, Flexiant, UvA; M6 to M24)

Work package number	6	**Start date or starting event:**		M6		
Work package title	Demonstrations, exploitation and sustainability					
Activity type	DEM					
Participant number	1	2	3	4	**5**	6
Participant short name	TERENA /Martel	NIIF /USZ	PSNC	SURFnet	**GRNET/ ICCS**	Vrijheid
Person-months per participant	0	10	6	10	**22**	1
Participant number	7	8	9			
Participant short name	Flexiant	UvA	FORTH			
Person-months per participant	1	5	0			

Objectives

To define and deliver demonstrations in various events in order to present the technical achievements of the project. Setup and maintain a minimal but feature complete federated IaaS cloud infrastructure that will be used for the demonstrations. Investigate possible exploitation potentials and pursue the long term sustainability and evolution of project results.

Description of work

The obvious way to assess the results and measure the success of RECIPE project is through its demonstrations. Furthermore, a crucial part of every endeavour that has a pre-defined end date is to ensure that the outcomes will sustain the lifetime of the project and will be further exploited leading to new products or projects. The goals of WP6 are twofold:

- To properly demonstrate the project results, and
- To devise an exploitation and sustainability plan for the various project assets

RECIPE will demonstrate the usefulness of the CCSS by running a service pilot with three in-house IaaS clouds (provided by NRENs), one public IaaS cloud (provided by a commercial partner), and optionally with other brokered public IaaS cloud instances (provided by other third parties) as follows:

- Campus cloud:
  - Private IaaS cloud pilot of UvA
- NREN clouds:
  - Hosted private IaaS cloud of NIIF
  - Hosted private IaaS cloud of PSNC
  - Educational public IaaS cloud of GRNET
- Commercial cloud:
  - Commercial public IaaS cloud of Flexiant
- Third party cloud:
  - Public cloud instances of Amazon S3 and/or EC2 (external to the consortium) under the current market circumstances. This may be subject to change as more providers challenge the dominant position of Amazon's Web Services.

Note that this list is non-exclusive; other IaaS clouds may be put into the portfolio as the project evolves.

T6.1: Demonstration cases and supporting infrastructure

This Task will be responsible to define the various scenarios that will better demonstrate the project results. In parallel the task will define technical requirements and necessary infrastructure for hosting them. It is anticipated that a number of NRENs participating in the project will provide the necessary physical resources

in order to be able to deploy a federated cloud service using the software and tools developed mainly by WP3. This team of resource providers will setup and maintain this infrastructure and coordinate with the demonstrations team in order to be available whenever this is required. The tasks will also decide whether this infrastructure is required to be constantly available or operate during the demonstrations.

T6.2: Demonstrations delivery
This Task will be responsible to actually deliver the demonstrations in high-profile venues. A small team will be setup among the participating partners and will be in charge to identify proper demonstration venues, travel to various events and run the demonstrations on site. These demonstrations will be obviously based on the demo cases outlined by Task T6.1 and exploit the infrastructure maintained by the latter.

T6.3: Exploitation and sustainability
This Task will start during the second year of the project with a clearly focused goal to define sustainability scenarios and possible ways to further exploit the concrete results of the project. The focus will be both on academic and research exploitation (campus IaaS clouds, federated production clouds by NRENs) but also industry exploitation. For the latter various business models have to be investigated that fit the profile of the involved partners. The questions that this Task will have to answer are:

- How the results can be exploited in different contexts and industry segments?
- How can external entities and third parties adopt the technical outcome of the project and use it for production? For example, will it be possible to setup a European NREN managed federated IaaS cloud that provides services to the academia and research? If so how this cloud can be further funded? What funding opportunities are available and how can the by pursued?
- Who will maintain the various assets of the project (technical or non-technical) and how these can be further evolved in order to satisfy additional requirements and be used in different use cases?

The main outcome of the task will be the exploitation and sustainability report (D6.4) that will be delivered at the end of the project.

Role of partners

GRNET as the leader of WP6 will define various subtasks and allocate necessary manpower from project partners. GRNET will also provide a demo Okeanos installation for the various testing and promotional activities of the project and participate in the definition of the exploitation and sustainability plan from the point of view of an NREN (this we expect to be lead by another partner, most probably TERENA as the umbrella body).

NIIF will contribute to WP6 with its IaaS cloud resources for demonstration purposes.

PSNC will participate in the team of resource providers that will setup and maintain the demonstration infrastructure as well as participate in the task about exploitation and sustainability.

Vrijheid.net will demonstrate the results described in WP3 with the consortium partners. The main focus will be the separation of metadata storage such as encryption keys from actual storage providers and runtime switching or growth (elasticity) of the computing part of the cloud backed storage SaaS. Flexiant will participate with its pubic cloud solution.

See the full list resources to be committed by the partners to demonstrations in Section 2.4.2

Deliverables

D6.1 Demonstration cases and supporting infrastructure (M10, R, PU)
This deliverable is to define the various scenarios that will demonstrate the project results. It will also

provide the input to WP5 on the technical requirements and necessary infrastructure for hosting the demonstrations, ensuring convergence, coherence, consistency and harmonisation across NRENs and private/public clouds.

D6.2 Demonstration plan (M12, R, PU)
This deliverable will report on the preliminary demonstration plan including target events, audience and potential pilot service to be demonstrated.

D6.3 Report on delivered demonstrations (M23, R, PU)
This report will summarise the demonstration set ups and results.

D6.4 Exploitation and sustainability plan (M24, R, PU)
This deliverable will elaborate on the exploitation of the results i.e. how the given software prototypes can be used/adopted to other environment (i.e. other than the RECIPE experimental environment that we are creating) for instance in NRENs' production cloud or in industry SME's cloud. It will also include the analysis of the potential sustainability scenarios i.e. how the project results will be maintained after the mandate of RECIPE.

Milestones

M6.1 Demonstration plan is ready (M10)
Demonstration plan and schedule is realistic and in line with the major technical milestones.

M6.2 Demonstrations performed (M23)
All the planned demonstrations are successfully performed and the further exploitation and sustainability of the project results are ensured.

1.3.5 Summary of effort

Partic. no.	Partic. short name	WP1	WP2	WP3	WP4	WP5	WP6	Total person months
1	TERENA	**18**	0	0	0	0	0	18
2	NIIF	1	10	**26**	12	10	10	69
3	PSNC	0	8	**30**	14	2	6	60
4	SURFnet	0	0	28	0	0	10	38
5	GRNET	0	16	28	0	0	**22**	66
6	Vrijheid	0	0	5	0	0	1	6
7	Flexiant	2	5	8	2	**24**	1	42
8	UvA	0	**22**	12	2	5	5	46
9	FORTH	0	6	3	**28**	21	0	58
TOTAL		*21*	*67*	*140*	*58*	*62*	*55*	***403***

A graphical presentation of the work packages, their Tasks and interdependencies is depicted in Fig. 6.

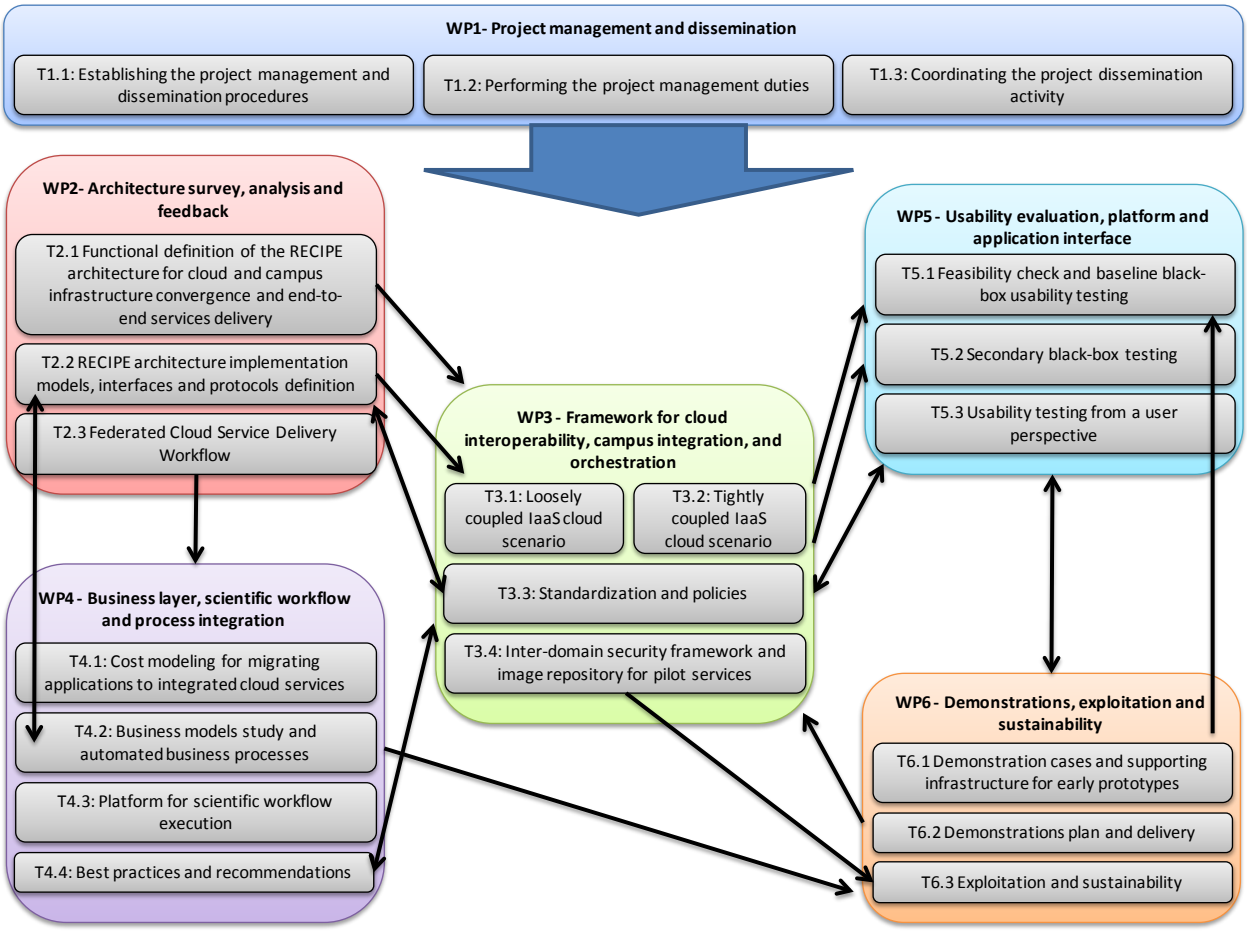
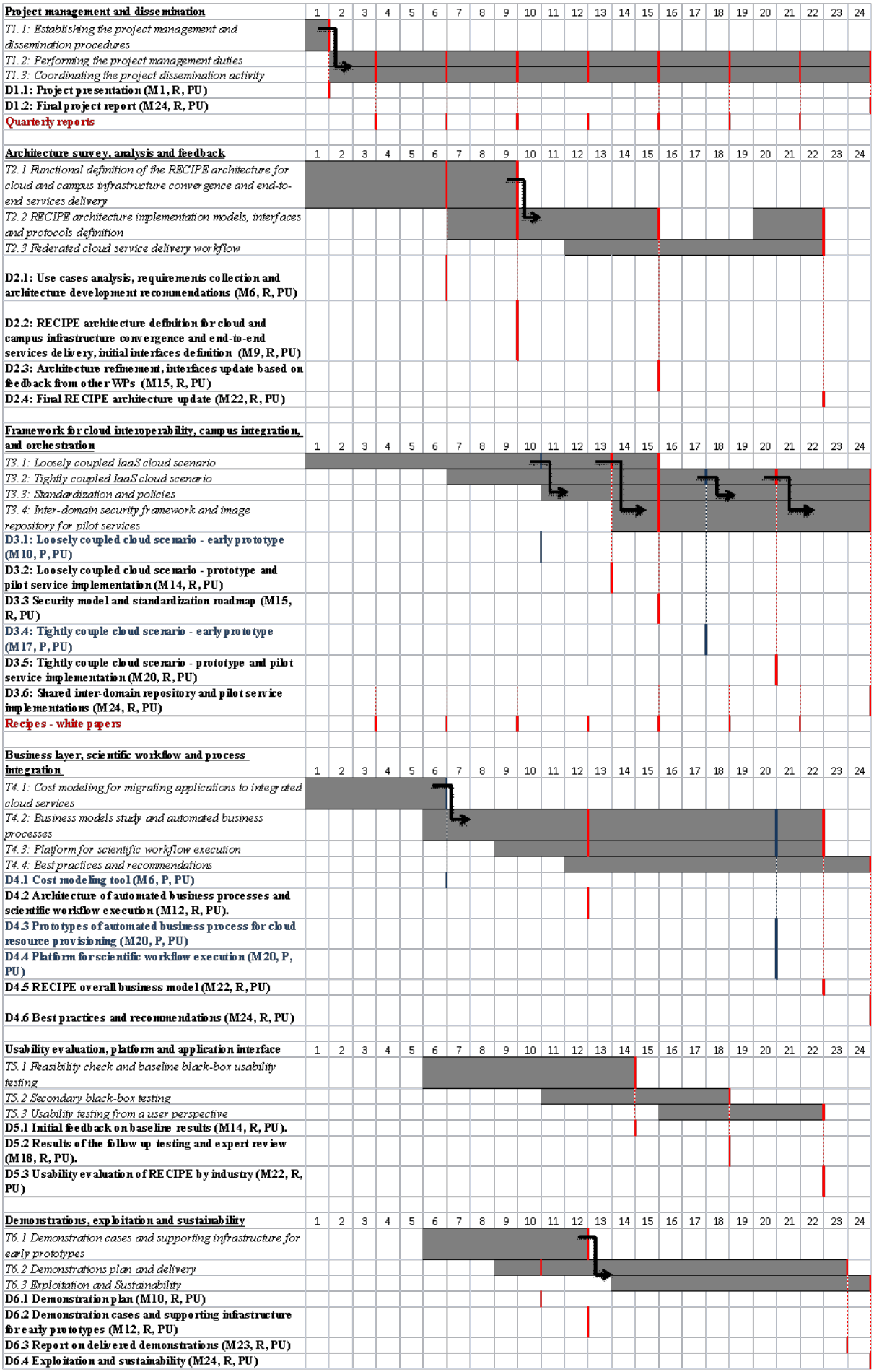


Fig. 6 Pert diagram of Work Packages and Tasks

A GANTT chart of the work packages, Tasks, Deliverables, and Recipes is shown below:


Project management and dissemination
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
T1.1: Establishing the project management and dissemination procedures
T1.2: Performing the project management duties
T1.3: Coordinating the project dissemination activity
D1.1: Project presentation (M1, R, PU)
D1.2: Final project report (M24, R, PU)
Quarterly reports
Architecture survey, analysis and feedback
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
T2.1 Functional definition of the RECIPE architecture for cloud and campus infrastructure convergence and end-to-end services delivery
T2.2 RECIPE architecture implementation models, interfaces and protocols definition
T2.3 Federated cloud service delivery workflow
D2.1: Use cases analysis, requirements collection and architecture development recommendations (M6, R, PU)
D2.2: RECIPE architecture definition for cloud and campus infrastructure convergence and end-to-end services delivery, initial interfaces definition (M9, R, PU)
D2.3: Architecture refinement, interfaces update based on feedback from other WPs (M15, R, PU)
D2.4: Final RECIPE architecture update (M22, R, PU)
Framework for cloud interoperability, campus integration, and orchestration
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
T3.1: Loosely coupled IaaS cloud scenario
T3.2: Tightly coupled IaaS cloud scenario
T3.3: Standardization and policies
T3.4: Inter-domain security framework and image repository for pilot services
D3.1: Loosely coupled cloud scenario - early prototype (M10, P, PU)
D3.2: Loosely coupled cloud scenario - prototype and pilot service implementation (M14, R, PU)
D3.3 Security model and standardization roadmap (M15, R, PU)
D3.4: Tightly couple cloud scenario - early prototype (M17, P, PU)
D3.5: Tightly couple cloud scenario - prototype and pilot service implementation (M20, R, PU)
D3.6: Shared inter-domain repository and pilot service implementations (M24, R, PU)
Recipes - white papers
Business layer, scientific workflow and process integration
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
T4.1: Cost modeling for migrating applications to integrated cloud services
T4.2: Business models study and automated business processes
T4.3: Platform for scientific workflow execution
T4.4: Best practices and recommendations
D4.1 Cost modeling tool (M6, P, PU)
D4.2 Architecture of automated business processes and scientific workflow execution (M12, R, PU).
D4.3 Prototypes of automated business process for cloud resource provisioning (M20, P, PU)
D4.4 Platform for scientific workflow execution (M20, P, PU)
D4.5 RECIPE overall business model (M22, R, PU)
D4.6 Best practices and recommendations (M24, R, PU)
Usability evaluation, platform and application interface
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
T5.1 Feasibility check and baseline black-box usability testing
T5.2 Secondary black-box testing
T5.3 Usability testing from a user perspective
D5.1 Initial feedback on baseline results (M14, R, PU).
D5.2 Results of the follow up testing and expert review (M18, R, PU).
D5.3 Usability evaluation of RECIPE by industry (M22, R, PU)
Demonstrations, exploitation and sustainability
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
T6.1 Demonstration cases and supporting infrastructure for early prototypes
T6.2 Demonstrations plan and delivery
T6.3 Exploitation and Sustainability
D6.1 Demonstration plan (M10, R, PU)
D6.2 Demonstration cases and supporting infrastructure for early prototypes (M12, R, PU)
D6.3 Report on delivered demonstrations (M23, R, PU)
D6.4 Exploitation and sustainability (M24, R, PU)

1.3.6 Significant risks, and associated contingency plans of the S/T work plan

The interoperability of IaaS clouds is the essence of RECIPE. However, providing the innovative interoperability solutions that assure the desired level of IaaS clouds integration and cover the necessary aspects of cloud service delivery chain requires the lowering of numerous barriers. The table below summarizes the risks associated to the scientific and technical work plan.

Risk	**Mitigation**
RISKS RELATED TO SOFTWARE/TECHNOLOGY:	
Problems while adapting the existing software components to the new model proposed by RECIPE. • Existing open source software components do not function well • No real acceptance of the model beyond the demo applications and platforms	The open source software development efforts committed by RECIPE project participants mostly in WP3 will ensure that the necessary software developments can be done. Technologies representing good technical compromises, commonly accepted best practices, or even standardized solutions will be preferred. Moreover, most of the software components to be used by RECIPE will be maintained by the project participants (NRENs and industry SMEs) that ensure the access and the proper expertise. Industrial correspondence will be audited by significant industrial partners.
Software prototypes are not mature enough to be put into production right away.	Proper test environment, and certification processes will be worked out to eliminate "last mile" effects being very common in the development cycles. NRENs can offer good power user communities who are technically literate enough, and also patient with initial problems to bridge the incubation periods.
Unexpected interoperability gaps appear between different Cloud Carrier functional model implementations.	Structurally different systems will be broken down to elementary structures and common functions, and similarities will be revealed. Causes of the gaps will be identified, and recommendations (recipes) will be formulated to make the mismatching systems to be more flexible, while not intruding into them.
Virtual entities cannot be migrated among different cloud implementations.	Though migration of virtual entities is a desirable project achievement, in case it is not fully possible, cross-domain virtual entity usage might be an auxiliary form of interoperability.
GENERAL RISKS:	
Difficult to recognize and address the real needs of the target user environment, campuses and industry.	RECIPE puts significant effort in analysing use cases, real-life scenarios and the definition of the Inter-cloud Architecture and the Cloud Carrier Software Stack. WP2 designs the architecture and provided/collects the feedback to/from industry. The risk can also be mitigated by applying short internal development cycles, continuous technology watch, and proper adjustments over the technical plan. RECIPE plans to use as much of the former project results as possible, and also to build on already available services.
Crucial follow-up on the ever changing needs of the environment, especially in the dynamic, rapidly evolving cloud industry.	Importantly, WP2 activities are repeated periodically enabling to keep eye on the changing situation and adjust the work during the project. Feedback coming from other work packages (WP5 on evaluation/exploitation, WP6 on demos) in taken into account by WP2 and influences the technical work in WP3 and WP4.
Inefficiency in communicating the requirements/design decisions and feedback within the consortium as well as the mainstream results.	Beside the formal deliverables and milestones less formal and more direct communication channels are assured. Most of the partners doing the technical work in WP3, WP4 and WP5, are also present in WP2. This assures quick and effective bi-directional information exchange, providing that requirements and design decisions are correctly understood while the conclusions on achievements and/or constraints, limits and problems met during the model and architecture implementation and integration are fed back to the designers. Moreover, market-driven stakeholders in the consortium will be representing business-oriented vision in the development,

	while university stakeholders the campus requirements.
Failure to reach the desired level of IaaS clouds integration on the technical level.	The integration of heterogeneous (hardware, software, model: private vs. private) IaaS clouds is difficult, and tight-integration is not easy to fully achieve in every situation, so RECIPE targets the IaaS interoperability from different levels in an incremental way: • it first develops and delivers solution for IaaS brokering which is more straightforward and less risky however provides lower level of integration and less interoperability-related features; • in parallel RECIPE addresses the tight IaaS integration, which is more complicated but provides higher level of integration, while requiring more technical problems to be solved (which increases the risk of failure). *Importantly, the two approaches don't lead to redundancy of efforts as both solutions are needed and can be used in parallel, i.e. brokering model for NREN's private clouds and SME's public clouds and tight integration for NREN's private clouds.*
Failure to propose coordinated and harmonized solutions and recommendations on legal, formal, organisational and technical levels.	RECIPE works in parallel at the formal, legal and organizational level and on the technology level. We provide the 'recipes', pre-standards and feed the worked-out model (Inter-cloud Architecture) to standardization bodies and organizations while developing the technical solutions (CCSS) that implements the model.
Integration failures resulting from different legal regulations applying to particular stakeholders, e.g. related to different regulations on data control and protection.	Particular stakeholders might come from different legal backgrounds: what is permitted in one country, it might be not in another. To mitigate such variety, legal control and harmonization will be initiated, set of the best practice will be collected and pre-standard recommendations will be proposed.
SOME RISKS DERIVED FROM IMPACTS	
Challenges in creating significant business opportunities.	NRENs, which play the role of Cloud Carriers, often operate in a semi-marketed environment where the customers pay for the services (either directly or indirectly), but, being technically literate, they can also use new services for free of charge. This environment allows services incubation between the direct development and fully market-driven use.
Contribute/influence the internal market of services in EU.	RECIPE invents the Inter-cloud Architecture and puts it on the way of standardization as well as implements the model as the open source Cloud Carries Software Stack which: • while being used inside the project, is tested, evaluated and demonstrated and catalyses the creation of the cloud service offerings market targeted to campuses, provided by semi-industrial NRENs and fully commercial SMEs (this is a small scale market contribution) • can be re-used in other situations, thanks to being evaluated and disseminates, e.g. for offering the services to public administration institutions from a given area, carried e.g. by particular, relevant ministry

2 Implementation

2.1 Management structure and procedures

TERENA is the Project Coordinator and the formal point with the Project Officer for all contractual matters. TERENA also provides the technical Project Manager. TERENA has taken a high profile role in many European research projects (see partner description in Section 2.2.1).

TERENA with the help of Martel (in-house consultant) carry out the project management in close cooperation with the members of the General Assembly (GA) and the Technical Management Committee (TMC). The GA comprises one nominated representative from each partner. It is the only project body that can make decisions on contractual matters, such as the budget, timeline, deliverables, shifts of person-months between partners, adding/deleting partners. The TMC comprises the Work Package (WP) Leaders, but other partners (such as Cisco, the industrial advisor third party of the project) may be invited to the meetings, depending on the topics to be discussed. WP Leaders will be responsible for the content and timely availability of project deliverables. A Consortium Agreement will be produced to formalise the voting rights within the GA, depending upon the topic to be decided, together with other aspects, such as the maximum delay for distributing the advance payment and the payments for subsequent cost claims, access rights (and whether or not any specific Background information will be withheld), confidentiality rules, handling of non-performing partners, settlements of disputes, etc. The Consortium Agreement will also provide guidance for the process of registering IPR, especially in cases where joint ownership is involved.

TERENA performs those coordination tasks defined in Art. II.2.3, which must be done by the Coordinator. These are to:

- maintain the Consortium Agreement
- administer the Community financial contribution regarding its allocation between beneficiaries and activities, in accordance with the Grant Agreement and the decisions taken by the consortium. The coordinator shall ensure that all the appropriate payments are made to the other beneficiaries without unjustified delay;
- keep the records and financial accounts making it possible to determine at any time what portion of the Community financial contribution has been paid to each beneficiary for the purposes of the project;
- inform the Commission of the distribution of the Community financial contribution and the date of transfers to the beneficiaries, when required by the Grant Agreement or by the Commission;
- review the reports from the project to verify consistency with the project tasks before transmitting them to the Commission;
- monitor the compliance by beneficiaries with their obligations under the Grant Agreement.

Martel (as an in-house consultant) will provide support on the Coordinator by operating a project office, which will assist TERENA in the day-to-day management of the project. This includes the management activities defined in Art. II.16.5 (but excluding those defined in Art. II.2.3, above, which must be performed by the Coordinator). Tasks to be performed by Martel include:

- the overall legal, ethical, financial and administrative management, including advising on the obtaining of the certificates on the financial statements,
- implementation of competitive calls by the consortium for the participation of new beneficiaries, where required by Annex I of the Grant Agreement,
- any other management activities foreseen by the annexes, except the coordination of research and technological development activities. These are expected to be:
    - assisting TERENA with the meetings (General Assembly, Plenary, WP Leaders, Project Reviews) by preparing the agendas, writing the minutes, and leading the administrative parts
    - ensuring an open flow of information within the project, for example:
        - informing partners of their responsibilities - and the timescales - for producing Deliverables and reaching Milestones
        - giving guidance on administrative and contractual issues

- collecting and collating progress reports
- assembling the Periodic Project Reports needed for the Project Reviews
- maintaining the Description of Work and preparing any Contract Amendments
- adding a level of quality of assurance in terms of validating the visible outputs, such as Deliverables, presentation material, papers, etc.

Martel is well suited to this role. Martel employees have taken responsibility in the past for giving such support for organisations, such as France Telecom, Cisco, Thomson (now Technicolor), Telefonica, Interoute, Aalto University, etc. (see Martel's description in Section 2.2.1).

2.1.1 Decision processes

The aim of the project management is to always achieve consensus on consortium contractual issues. If this is not possible, decisions will be made by a vote taken within the GA. The GA comprises one nominated representative from each partner, each having one vote. Issues that affect the allocation of duties or resources between partners will require a unanimous decision. For other decisions, a majority verdict will normally be sufficient. The details will be explained in the Consortium Agreement.

Technical issues will be decided by the Technical Management Committee (TMC), which comprises the WP Leaders and Cisco and industrial advisory of the project. The Project Manager (from TERENA) chairs both the GA and the TMC.

2.1.2 Information flow

The information that is exchanged inside the project or towards external bodies is:

- project planning and control information;
- technical information and deliverables;
- contributions to standardisation bodies and/or FP7 coordination groups.

The tools the project intends to use to circulate such information are:

- planning and reporting documents (wiki-based);
- technical contributions originated by the partners and deliverables:
- the Website (including public and private areas);
- e-mail distribution lists.

Beside the official General Assembly and Technical Management Committee meetings attended by the appointed people in-person, the project management will organise regular work package leaders' meetings as well as ad-hoc task leaders' meetings on-line using video and/or web conferencing tools. NIIF volunteered to provide dedicated video conferencing rooms for the project meeting purposes.

2.1.3 Organisation

The project is organised in 4 technical Work Packages (WPs 2-5), coordinated by the project management and dissemination Work Package (WP1). WP6 is designated for demonstrations, exploitation and sustainability. The project structure is represented by the diagram below, where management responsibilities exist at the project (Project Manager) and WP Leader levels. Other management responsibilities exist (Fig. 7), as described below:

GENERAL ASSEMBLY (GA)
The GA comprises one nominated representative from each partner. It is the only project body that can make decisions on contractual matters, such as the budget, timeline, deliverables, shifts of person-months between partners, adding/deleting partners. It will meet at least once every 4 months, and the meetings will be chaired by the Project Manager.

TECHNICAL MANAGEMENT COMMITTEE (TMC)
The TMC comprises all the technical and demonstration WP leaders, third-party experts and industry advisory, and is responsible for ensuring that the technical developments and general progress are well coordinated. The TMC is the formal place for the exchange of technical information between WPs and experts. TMC meetings will be held at least every 4 months, and the meetings will be chaired by the Project Manager. Interim WP meetings will be arranged independently.

WORK PACKAGE LEADERS
For each Work Package, a leader is responsible for the technical coordination. He/She reports to the TMC. The responsibility of each WP Leader is to ensure the activities of the WP proceed according to the project work plan. The WP Leader is responsible for the production of the relevant deliverables and may delegate parts of this responsibility to other WP participants.

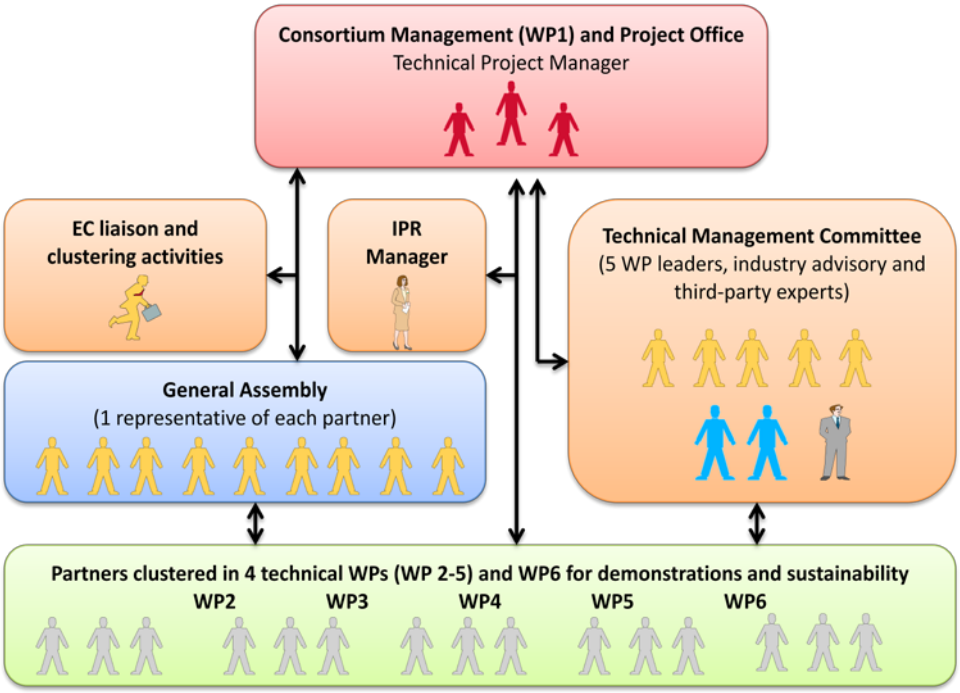


Fig. 7 Project structure

2.1.4 Planning, reporting and deliverable handling

Project planning and progress are documented in regular *Management Reports.* These *Management Reports* contain information on the achievements and the corresponding resources used. They are collected into a *Periodic Project Report* that is written prior to every project review. These documents are produced by Martel for checking by the Coordinator, and compiled from inputs from the individual partners.

Deliverables are the official outputs of the project. Their production is the responsibility of the WP Leaders. The Project Manager will give all the deliverables a final check for consistency and to check that the output is in-line with the general requirements of the project. Martel will also check the deliverables for quality.

2.1.5 Management of risks

Risk Management will be adopted to manage project issues and conflicts. During the initial start-up of the project, a risk assessment will be conducted to identify risks associated with both the business and technical aspect of the research. The project office, GA and WP Leaders will be involved in the assessment. This will establish a central risk register.

Risks will be assessed for their impact on the project and the probability of the risk materializing. The team will establish risk mitigation plans to reduce the impact and likelihood of the risk occurring, as well as action

plans to manage the risk should it arise. This integrated approach to risk management will enable the project office to control effectively the business, intellectual property, technology, people, management, environment and other implementation risks that may arise. Unresolved issues or conflicts impacting the project plan will be escalated to the appropriate body, project coordinator and then - if necessary - to the GA.

A first analysis of some key risks includes:

- Partners leaving the project
- Deliverables not being produced on time
- Milestones being missed
- Equivalent commercial products appearing on the market during the project lifetime

Some additional management risks are summarised in the table below

Risk	Action
High number of partners in a STREP proposal (especially the four NREN partners).	The management structure has been defined to be only in two levels (GA, TEC) with a technical/project coordinator to ensure the maximum agility and a tight coordination. The effort of each participant has been generally concentrated in few activities to ensure the best possibility to contribute. The higher number of partners than usual in case of a STREP project is due to the higher number of NREN participants in the consortium. However, these NRENs know each other very well and have been collaborating together for many years, so it can rather be considered as resiliency than risk.
Relatively low contribution from Vrijheid.net (6 PM).	Vrijheid.net is not the “token SME”! It is one of the three SME partners of RECIPE. The open source software development/implementation efforts are mostly concentrated in WP3. The partner (Vrijheid.net) with a low number of person months is in general contributing with some crucial software development work as the lead developer of the open source software. Most of the software tools won’t be developed from scratch but built on existing open source components. Having the lead developer in the consortium ensures the necessary level of expertise.
Relatively high number of efforts in one Work Package (WP3).	WP3 is the key work package of RECIPE carrying out the major software development and implementation work. It is necessary to be very well provided by the adequate human efforts.
Cloud industry SME participants pulls out due to the dynamically changing cloud business.	RECIPE consortium has two cloud industry SME partners and both of them have long-term engagements and working relationship with the NREN community. Potential substitution of an SME partner left can be managed by the extensive business contacts of the NRENs and TERENA in the area of networking and recently in the cloud sector too.
The development of the tools and specification for the Cloud Carrier Software Stack is too complex or time consuming.	The project will come up with a set of interoperable software prototypes that can fit into the Cloud Carrier Software Stack. Most of these prototypes won’t be developed from scratch, but existing software components will be enhanced, adopted, harmonised or developed further.
The standards evolve too fast for the project to keep in sync.	This risk can be significant in the area of clouds. Therefore, WP2 is dedicated to closely watch the standards as well as some of the WP3 and WP4 tasks in cooperation. The consortium participants and industry advisor (UvA, PSNC, Cisco, etc.) direct participation in various standardisation bodies (OGF, TMforum, IETF, etc.) supports this action. Moreover, RECIPE is only two-year long project although that might be a very long time in the rapidly evolving cloud industry space.

2.2 Individual participants

RECIPE project consortium consists of nine participants, of which four National Research and Education Networks, one university, two cloud industry SMEs, and two non-profit research organisations.

2.2.1 TERENA (with Martel as in-house consultant)

TERENA (http://www.terena.org) is the association of National Research and Education Networks in Europe. In 2012 the organisation counts 39 national members, two international members - CERN and ESA - and a number of associate members, including, DANTE, NORDUnet, and a few industrial organisations, which are normally highly involved in cooperation activities and projects with the research and education community. The mission of TERENA is to promote and participate in the development of high-quality international information and telecommunications infrastructure and services for the benefit of research and education. The activities of TERENA fall into four categories, which are the pillars of the organisation, and which are all ideally relevant to the RECIPE project.

- Fostering new activities: TERENA provides an environment for fostering new initiatives of the European research networking community.
- Technical Programme: TERENA supports joint European work in developing, evaluating, testing, integrating and promoting new networking, middleware and application technologies. TERENA brings together technical specialists from TERENA member organisations and the wider European research networking community in task forces and innovative collaborative projects.
- Knowledge transfer: TERENA organises conferences, workshops and seminars for the exchange of information between TERENA member organisations and in the wider research networking community, and to make them and the Internet community at large aware of relevant developments. TERENA also pursues the transfer of technical and managerial knowledge to less advanced networking organisations in the countries represented by the TERENA membership, both on a bilateral and on a multilateral basis.
- Promoting members' interests: TERENA represents the common interests and opinions of its member organisations in contacts with governments, funding bodies, industry and other organisations.

In recent years TERENA successfully coordinated the SEEFIRE (ended in 2006) SERENATE (ended in 2003) and SCAMPI (ended in 2004) projects. In addition, TERENA has been involved in information dissemination activities in various EC projects, including 6NET, EGEE, 6DISS, SEEREN and SEEREN2. TERENA was a contractor in the GN2 project, where, among other activities, it is responsible for the networking activities on NREN Development and Support, on the Foresight Study and on Coordination of RTD. Starting from 2009 TERENA is also involved in the GN3 as the leader of Networking Activity 3 on Status and Trends and Joint Research Activity 3 on Enabling Communities. Last but not least, TERENA is involved in FEDERICA and leading the Networking Activity 2 on Building and Consolidating the User Community, Networking Activity 4 on Dissemination and Training, and the Joint Research Activity 2 on Novel Paradigms and User Control.
TERENA will be the Project Coordinator of RECIPE and lead WP1 on “Management and dissemination”.

Key Personnel

Peter Szegedi (Project Development Officer). Peter is one of the Project Development Officers at TERENA who assist the Task Forces and contribute to technical projects. He received his MSc degree in Electrical Engineering at Budapest University of Technology and Economics (Hungary, 2002). He then worked towards a PhD at the Department of Telecommunications. He worked for Magyar Telekom (2003-2007) as a Research and Development Manager then he joined TERENA in January 2008. Mr. Szegedi participated in MUPBED project and he was the Joint Research Activity 2 and Networking Activity 2 leader of the FEDERICA project. He is the secretary of the TF-Storage, TF-Media, and TF-NOC task forces, as well as the technical organiser of the E2E Provisioning Workshop series at TERENA. Peter Szegedi will be the Project Manager of RECIPE.

Valentino Cavalli (Chief Technical Officer). Valentino is responsible for managing the TERENA Technical Programme, which provides a framework for international collaboration and innovation in computer networking areas, such as middleware, mobility, Grids, videoconferencing etc. Mr. Cavalli leads a team of project development officers who liaise with the broad European community and GÉANT3, the pan-European network backbone for research and education. In the past few years he has been involved in a number of projects addressing network connectivity and services to South East European countries, including a project to provide connectivity across the region (SEEREN) and a feasibility study on the acquisition of dark fibre by NRENs in the region (SEEFIRE). Valentino is currently responsible for an activity to support research and education networking in less advanced and emerging countries in Europe and close neighbouring regions. He has been working for TERENA since May 1999 and initially joined as one of the project development officers. Graduated in 1987, before joining TERENA he worked as Research Manager for an Italian IT company, where he was responsible for a number of projects under the European Commission Fourth Framework Programme.

Martel (http://www.martel-consulting.ch) will take responsibility for most of the day-to-day tasks in WP1 (Project Management) as an in-house consultant of TERENA. Martel will assist the Coordinator and manage all the administrative and contractual matters, the financial planning, and the general management and monitoring of the overall project. These are all areas in which Martel has a proven record with projects comprising consortia of a similar size. (See also in Section 2.1). Martel is a consultancy company, founded in 1996, which specialises in the management of international collaborative projects. Its employees have gained experience participating in European collaborative telecommunications research projects since 1988. The company is closely associated with the running of some of the largest collaborative R&D projects in the EU Framework Programmes related to information technology, telecommunications and the Internet.

Key Personnel

Martin Potts is the director of Martel GmbH. He has a degree in Electronic Engineering and has worked previously for British Telecom (UK) and Ascom (CH). In 1989, he participated in the RACE-I project R1022: Martin became the manager of the “follow-on” RACE-II project EXPLOIT (1992-1995) and the Chairman of the Project Line 8, in which all the projects active in the area of "Test Infrastructure and Interworking" were grouped. In the ACTS Programme, he was the Chairman of the Chain: "Global Network Interoperability", the Chain Group: "Network Level Interoperability and Management", and the Cluster of 8 IP/ATM projects. Mr. Potts managed the ACTS projects "EXPERT" and "DIANA", and the IST projects “CADENUS”, “SHUFFLE” and ADAMANT. He assisted Cisco in the management of the IST project “6NET”, Telefonica in the management of the IST project “EuQoS” and the Italian NREN GARR to manage the FP7 project FEDERICA. Mr. Potts is currently the co-ordinator for the FP7 project 6DEPLOY-2 (IPv6 deployment and support) and is assisting Technicolor in the management of the FP7 project FIGARO. He is also a member of the FIRE Support Action project FIRE STATION and the FI-PPP project INFINITY.

Dr. Monique Calisti is Senior Consultant and Project Manager at Martel GmbH. From 2002 until 2010 she worked for Whitestein Technologies being responsible for participation and technical contribution to various national and international research projects and several other activities, such as business development, consulting, scientific editing and publishing. In the last 15 years, she has been involved in several European projects (securing project affiliation, funding, management and technical contribution) and initiatives (expert reviewer, invited speaker at EU-organized workshops and events), she has been serving as a Programme Committee member of many international conferences and workshops. Dr. Calisti was a member of the Board of Directors for the Autonomic Communication Forum, ACF, and for several years, she has also been actively involved in the activity of the IEEE FIPA standardisation body, where she has been member of the Board of Directors from 2001 to 2004. Monique holds a Ph.D. in Computer Science from EPFL, and a Ph.D. in Telecommunications from the University of Bologna, Italy.

2.2.2 NIIF

NIIFI is the Hungarian National Research and Education Network (http://www.niif.hu) service provider, and has extensive experience in developing and operating data network facilities, as well as in services built over the network, such as distributed computing and data storage platforms, videoconferencing utilities, trust federations, and also cloud infrastructure. NIIFI offers these services to a wide user community in Hungary: around 450 higher education, academic, and research organizations.
NIIFI has been engaged with cloud development efforts for 2 years during that a self-made infrastructure cloud service has been established, and was transformed from a private infrastructure cloud to a community service. This platform is based on OpenNebula, KVM, and it contains several self-made components that extended the functionalities of the original software. Part of this infrastructure will also be offered as a incubator for putting any of the project achievements into practice. Having participated in such successful projects as in KnowARC, EGEE, EMI, PRACE, GN3, FEDERICA and HP-SEE, NIIFI has gained extensive experience in creating high-quality technical solutions, providing sustained IT services, offering best practices, and handling "last-mile efforts", i.e. on how to formulate the results into off-the-shelf products.

In the RECIPE project NIIFI will coordinate the cloud integration and interoperation activity, and will also contribute to any technical action items that are within this scope in other work packages, such as cloud structural analysis, and operations. Besides the technical contribution NIIFI plans to control exploitation and sustainability related efforts within the project too, being one of the core members of the sustainability backbone based on NRENs. NIIF will be the leader of WP3 on “Framework for cloud interoperability, campus integration, and orchestration”.

Key Personnel

Peter Stefan holds M.Sc. and Ph.D. in Information Engineering, and also a B.Sc. in Economics. Being a department leader Peter has gained almost 11 years of experience in infrastructure development, and operations over different IT services, such as high-performance computing platforms, distributed storage services, high-availability platforms, and also in IaaS cloud services. Peter has been involved in several national and international projects, having been standardization work package leader in KnowARC, task leader in GEANT, EMI, and HP-SEE, and also being activity leader and project leader in numerous national projects.

Szabolcs Szekelyi holds M.Sc. in Information Engineering from the Technical University of Budapest, and represents his 5-years of experience in distributed data storage, and cloud services in the project. Szabolcs has been the technical leader of NIIF Cloud initiative since the beginning, and had had significant contribution in developing corresponding data storage services.

Tamas Kazinczy holds M.Sc. in Information Engineering from the Technical University of Budapest. He has been working at NIIFI for 3 years during that time he was involved in developing a distributed storage management system based on NIIFI’s distributed storage infrastructure. Besides his development duties, he administers NIIFI’s PByte-scale distributed storage environment.

Tamas Devai holds B.Sc. in Information Engineering from the College of Kecskemet. He has been working for NIIFI for 3 years, mostly on the fields of web technologies.

Zoltan Kiss holds M.Sc. in Information Engineering from the Technical University of Budapest, and has been working for NIIFI for 3 years.

2.2.3 PSNC

PSNC is a Polish NREN operator (http://www.man.poznan.pl/), scientific HPC computing centre and R&D organisation. PSNC is affiliated to the Institute of Bioorganic Chemistry of the Polish Academy of Sciences and employs 250+ people in four departments. PSNC has a long experience in building the computing, data storage and network infrastructures as well as providing the services on top of them. PSNC provides the network connectivity (PIONIER Optical Internet, Eduroam), network services: Web, video-conferencing,

interactive HD-TV, CDN and many others as well as scientific HPC computing resources (300+ Tflops of computing power), Grid computing facilities, data backup and archival solutions, cloud computing and cloud storage to academic community in Poland. PSNC has experience in the distributed data management, gained among others during the design and development of the National Data Storage system [nds.psnc.pl], the innovative data storage cloud which holds the data in multiple distributed geographical sites and provides access to data through the transparent, virtual file system interface and front-ends on top including SFTP, WebDAV and GridFTP. The production deployment of NDS (Popular Archive Service of PLATON project [www.storage.pionier.net.pl/en/]) uses 12,5+PB of tape storage media, 2PB of disks as well as dozens of servers and SAN/LAN/WAN switches, across 10 sites in Poland and provides 20+GB/s of the data storage/access throughput. NDS model is also exploited to provide cloud-based storage for biomedical data in pMedicine project. PSNC is also active in data management-related working groups including TERENA TF-Storage (PSNC employee chairs the group) and e-IRG DMTF (Data Management Task Force). PSNC has also know-how on building cloud computing infrastructures and services on top of them, including the Campus Computing Service which enables the on-demand running of the scientific applications within the IaaS cloud based on ~1000 physical servers located in 21 computing centres and universities. PSNC has also a significant experience in developing, deploying and supporting the scientific workflow systems (Kepler, KIWI), related to its participation in DORII, NEXPRESS, EUFORIA, EGI_INSPIRE projects.

In RECIPE, PSNC will co-lead the WP3 (together with NIIFI) and will be involved in WP2 and WP4 as well as WP6. In the confines of these work packages PSNC will take part in definition of the Inter-cloud Architecture and the design and implementation of the Cloud Carrier Software Stack. PSNC will put main efforts into technical work related to federation and integration of IaaS clouds as well as development of the mechanisms for migration and exchange of virtual data storage entities, as well as data storage and handling techniques in the federated/ integrated IaaS clouds. PSNC will also take part in preparing the methodology and tools for evaluating the cloud offerings as well as in building the platform for modelling scientific workflows, basing on the experiences in related initiatives and projects. PSNC will also participate in the demonstration activities, in the confines of which it will among others provide the physical and virtual resources and infrastructure basing on PSNC's storage and computing clouds.

Key personnel

Dr. Norbert Meyer is head of the Supercomputing Department in PSNC. His research interests include distributed resource management, Grids, data management, graphical user interfaces and computing systems and network security. He was the coordinator of DORII, RINGrid, the NDS project and the Popular Archive Service of PLATON. His infrastructure- and service-related experience includes PRACE, EGEE and EGI projects. He is also interested in cloud computing and storage architectures and paradigms. He is a member of e-IRG and other international groups related to infrastructures and services development and distributed systems, HPC and Grids. Currently he is participating in EUDAT project focused on the long-term data preservation and curation.

Maciej Brzeźniak leads the data and storage management group in Supercomputing Department of PSNC. His interests include data management and storage technologies distributed architectures, storage systems performance, long-term data preservation as well as storage and server virtualisation, cloud computing and storage architectures and services. He co-led development of the NDS system. Currently, he co-leads the deployment of Popular Archive Service in Poland and is active in EUDAT project. He also chairs the TF-Storage group of TERENA and participates in e-IRG's DMTF.

Marcin Płóciennik leads the group of user interfaces and application deployment in PSNC. His research interests concern distributed computing systems, web services, instrumentation and sensor networks, workflow systems and graphical user interfaces technologies. He participated in several projects concerning HPC technology, e.g. DORII (deputy project coordinator), Euforia, CrossGrid, EGEE, BalticGrid, int.eu.grid, EGI_Inspire. He leads the Open Grid Forum Remote Instrumentation Services in Grid Environment Research Group and Access to Remote Instrumentation in Distributed Environment – Working Group.

2.2.4 SURFnet

SURFnet (http://www.surfnet.nl/) ensures that researchers, instructors, and students can work together simply and effectively with the aid of ICT. It therefore promotes, develops, and operates a trusted, connecting ICT infrastructure that facilitates optimum use of the possibilities offered by ICT. SURFnet is thus the driving force behind ICT-based innovation in higher education and research in the Netherlands. SURFnet's mission and vision are: a) to improve higher education and research by promoting, developing, and operating a trusted, connecting ICT infrastructure that facilitates optimum use of the possibilities offered by ICT; b) collaboration, researching and learning together, and sharing knowledge, data and tools all help determine the quality of higher education and research in the Netherlands. In this respect, SURFnet not only looks at the traditional Network infrastructure, but also wants to help institutions to make optimal use of the network infrastructure by creating the necessary ingredients for a collaboration environment between users . IaaS is one of those ingredients. IaaS (Infrastructure as a Service) is a way for institutions to make use of an integrated IT infrastructure without the need of having all necessary hardware on-site. IaaS services like computing and storage solutions are commercially available, but the services offered at this time do not meet the requirements of the institutions in terms of reliability, security, greenness and performance. SURFnet therefore believes that there may be a need for "cloud" services that are facilitated by SURFnet.

In the long run open standards for cloud computing are the way to go and this will facilitate failover and migration between (commercial/edu) clouds which is considered as very important by SURFnet. A researcher could for instance by default use a local country cloud (that's probably the safest cloud), but dependent on security/legal/costs/etc decide to move his VM in a later phase to a commercial cloud.

Key Personnel

Paul Dekkers works as technical product manager for SURFnet and is involved in the innovation and operation of various services. One of them is the "SURFnet private cloud", used by SURFnet services. Because of this platform, and services like SURFmailfilter and work in SURFcert, Mr. Dekkers has extensive knowledge of scalable and secure architectures. Another field of expertise is mobility: Paul is involved in international eduroam, and participating in research for ubiquitous mobility.

Rogier Spoor is working for the SURFnet department of Middleware Services which is responsible for development, innovation and operations of all middleware services of SURFnet, ranging from the eduroam, PKI and AAI/federation infrastructure to (private) cloud, DNS(SEC) and spamfiltering services and has a a strong participation in the various national and international innovation programs SURFnet is working on.

2.2.5 GRNET

The Greek Research and Technology Network (GRNET) S.A. (http://www.grnet.gr) was founded in 1998 under the auspices of the Ministry of Development – General Secretariat of Research and Development in order to provide high quality Internet services to the Greek research and academic community. GRNET S.A. represents Greece in the GEANT pan-European network, which offers high speed and high quality services to the European research and academic community. Apart from its role as the Greek NREN, GRNET is the leading distributed computing infrastructure provider in Greece having the responsibility to operate the Greek National Grid infrastructure (GRNET is the Greek NGI within the EGI European Grid infrastructure). GRNET is also active in the area of HPC computing being responsible for the deployment of the national HPC infrastructure, and is a member of PRACE. GRNET also leads the South-East European eInfrastructure activities through which strong joint vision and strategy is carried out together with 14 countries/NRENs in the region.

GRNET has wide experience in the deployment and operation of public and private cloud infrastructures as a partner in the StratusLab project. GRNET is leading the operations activity providing a significant number of physical resources to the project. GRNET aims to capitalize on the experience and competence that it has gained in the past from the provision of cloud services and the development efforts that it has put on the Okeanos (http://okeanos.grnet.gr) and Pithos (https://pithos.grnet.gr/) platforms.

GRNET aims to bring the Okeanos platform to the RECIPE project rendering it as one of the core enabling software components for the technical activities of the project, facilitating the provision of cloud services, and contributing with the development of project-specific services and APIs. Okeanos exposes an OpenStack API and when released will offer a complete set of cloud infrastructure services (compute, local storage and network). The main interest of GRNET in the project is to be in the set of core NRENs who form the pan-European federated cloud platform. Moreover, GRNET is interested on working in all the issues related to cloud federation, including technical, policy, and business and workflow-related issues. GRNET will be the leader of WP6 on "Demonstrations, exploitation and sustainability".

Key Personnel

Evangelos Floros holds a B.Sc. and a M.Sc. in Informatics from the University of Athens, Greece. He has extensive experience in High Performance Computing, distributed systems and grid computing technologies, having participated in a large number of related European Projects. In EGEE series of projects he acted as a deputy activity for of the User Community Expansion and Support activity. From this position he has chaired for three consecutive years the EGEE User Forum Program Committee. Currently he is involved in StratusLab project where he leads the cloud operations activity supervising the public cloud services provided by the project. He is also leading the HellasHPC initiative in Greece with the purpose to install and deploy a national supercomputing facility that will join PRACE organization Tier-1 European HPC infrastructure.

Dr. Panos Louridas joined GRNET in 2005 where he has been working on e-Infrastructure projects and planning. He has coordinated HellasGrid, the Greek Grid Initiative. He is now responsible for the complete suite of cloud services under development in GRNET, comprising IaaS, PaaS, SaaS platforms with the ability to provide thousands of virtual machines to thousands of users. He is currently active in the European Grid Initiative and the EGI-InSPIRE project, as well as in a number of other efforts involving cloud computing and high performance computing. Dr. Louridas has a PhD and an MSc from the University of Manchester, and a Diploma in Computer Science from the University of Athens, Greece. Before joining GRNET he worked in the banking sector. He is an active developer and has contributed code in various projects, commercial and academic. He is a member of the ACM, the IEEE, USENIX, and the AAAS.

2.2.6 Vrijheid

Vrijheid.net (http://www.vrijheid.net) was founded in 2008 to empower people, companies and governments with information solutions and consultancy. Recognizing that people often work for their computers instead of the other way around, Vrijheid.net offers consultancy to guide your organization to the next level of accountability and efficiency. It also offers knowledge and experience to transform companies work by help turning their traditional IT into cloud information solutions. These solutions distinguish themselves by being innovative, fast and fully accountable. They tend to focus on storage and cloud-independent.

As a cloud industry start-up SME, Vrijheid.net will bring significant cloud software engineering and development efforts to RECIPE. Most of the open source software development efforts will b placed in WP3 concerning the cloud brokering architecture. Vrijheid.net will also contribute to the project demonstrations under WP6.

Key Personnel

Maarten Koopmans, MSc Computational physics, has worked for various companies and institutions in various industries, from highly commercial to non-profit (governmental). All his work is always freely availaible under the most liberal (Apache) open source license and is exclusively based on OSS components and open standards. He has held various engineering and project management positions at ING, SURFnet and ICTU. After starting his company Vrijheid.net in 2008 he has specialized in cloud computing, with a strong focus on transparency and accountability. In 2010 he has acted as the work package lead for the pilots of the NDGF project "NEON" on behalf of UNINETT Sigma. The NEON project itself with all its metrics and its advice has resulted in a publication and various presentations - the fact that non-HPC jobs can be migrated cost effectively to the public cloud has been confirmed by peer reviews and has established

Maarten's skill level and reputation in the cloud computing and storage space. Based on the end report of NEON a publication at ACM was accepted: “Practical cloud evaluation from a Nordic eScience user perspective”, of which Mr. Koopmans was second author. With over 15 years of experience in computing, ICT architecture, project and program management he covers a wide area of expertise, ranging from high-end implementations to project management.

2.2.7 Flexiant

Flexiant (http://www.flexiant.com/) is the company behind Extility, the world’s most advanced Infrastructure as a Service (IaaS) Cloud Computing Software. We provide cloud infrastructure software and services for hosting providers, data centre owners, telecommunications operators and enterprises. Unique amongst its peers, Flexiant has a heritage in the service provider industry stretching back to 1997. Originally developed by hosting provider XCalibre Communications, our technology was designed specifically with the needs of the service provider in mind as the basis for Europe’s first cloud platform, FlexiScale, which we still run to this day. In 2009, following the sale of XCalibre’s web hosting business, the Extility technology and the team behind it became Flexiant Limited, entirely focused on further development of the Extility platform and enabling other companies to build their own cloud services. Our flagship product, Extility, was launched in March 2010, and is the culmination of many years of development of a service provider focussed IaaS cloud platform. Our public cloud platform, FlexiScale, showcases our Extility technology, illustrating how it enables end users to purchase computing services on a flexible, scalable, automated computing and hosting infrastructure. Customers can flex their requirements up and down on demand and only pay for the service that they actually use. As more and more service providers move towards a cloud model, and as Enterprise IT departments increasingly move towards a service provider model, Flexiant’s Extility technology is ideally placed to deliver the solution needed.

Flexiant, a dynamically growing cloud industry SME, will be the leader of WP5 on “Usability evaluation, platform and application interface” in RECIPE as well as the coordinator of the project dissemination activity in WP1.

Key personnel

Tabassum Sharif, Director of Operations. Mr. Sharif completed his B Eng in Electronic and Electrical Engineering at the School of Electrical and Electronic Engineering with the Corp of Royal Electrical and Mechanical Engineers. He has spent almost 8 years within the military specialising in Telecommunications and various other communication projects. He has previously worked with organisations within the Financial Services industry, Insurance industry and Prepayment Industry before coming to the ISP industry where he is currently employed as the Director of Operations for Flexiant. He brings a wealth of experience in translating theoretical ideologies and best practices into real world environments.

Craig Sheridan, FP7 Co-ordinator. BSc(Hons) in Network Computing, he has worked for Flexiant since inception in various roles including FP7 co-coordinator and systems administrator and has been a Support Team Leader and Systems Administrator for XCalibre Communications for the previous 5 years and has various IT related certifications. He has a wide range of Cloud technology expertise. Previous to this he worked for 8 years for Motorola as a Radio Frequencies Analyser.

2.2.8 UvA

The System and Network Engineering (SNE) Research group at the University of Amsterdam (http://www.science.uva.nl/research/sne/) researches on high-performance network and Cloud technologies that include architectural and service provisioning frameworks, cross-domain interaction between Cloud and network resource providers, optical and hybrid networking, resource descriptions using semantic web and programmable networks for the Future Internet and converged network+IT infrastructures. In collaboration with SURFnet and SARA, UvA has capabilities to access high-speed optical test bed installations in the optical photonic backbone of SURFnet in the Netherlands and internationally in the Global Lambda Integrated Facility (GLIF). The group is building tools and proof of concept applications that facilitate optimised performance of the Cloud infrastructure and Cloud based applications. Security of the required

mechanisms, infrastructure, middleware, applications and the privacy of data in distributed processing environments is an essential aspect of the research. UvA is a founding member and key contributor to CineGrid, GLIF and OGF.

The UvA relevant expertise and know-how includes general cloud architecture and cloud security infrastructure research and development, standardisation in the framework of the OGF ISOD-RG, the general infrastructure services and network topology description models and languages based on Semantic Web RDF framework (currently being contributed to OGF NML-WG). Expertise in the security area includes the development of the Generic AAA architecture and AAA Authorisation framework (described in RFC2904-2906); GAAA Toolkit development and implementation of the specialised profiles in a number of projects such as GEYSERS, PHOSPHORUS, NextGrid, DataGrid; development of the gLite Authorisation Framework and XACML interoperability profile for EGEE-OSG-Globus cooperation; recent development of the Dynamic Access Control Infrastructure (DACI) for Cloud based virtualised infrastructure services provisioned on demand. UvA will contribute to the RECIPE project with the development of the Cloud interoperability framework, including supporting information model and inter-cloud/inter-layer interfaces definition, as part of WP3. Other contribution will include development of the federated security architecture and infrastructure for inter-cloud and cloud-campus integration. UvA will be the leader of WP2 on “Architecture survey, analysis, and feedback”.

Key Personnel

Dr. Yuri Demchenko obtained his Ph.D in Instrumentation and Measurement from Kiev Polytechnic Institute in 1988. He is active in the area of computer communication, networking and security since 1995. In 1998 Yuri became a Project officer at TERENA where he supervised, planned and supported a number of task forces and projects in the area of Network Security; Authentication and Authorisation Infrastructure, Grid Middleware. In 2003 Dr. Demchenko joined the Systems and Network Engineering group at University of Amsterdam where he has been involved in the research on generic AAA Authorisation architecture for multi-domain network resource provisioning, Grid Security middleware and Authorization, and currently general Cloud and Cloud Security architecture, within a number of national and international funded projects such as GEYSERS, Phosphorus, EGEE, NextGrid, Collaboratory.nl. Currently he is involved in two European projects GEANT3 and GEYSERS where he takes part in the development of the GEMBus Composable Services middleware and Authentication and Authorisation Infrastructure (AAI) for on-demand Infrastructure Services provisioning. Dr. Demchenko is actively contributing to OGF, in particular to Infrastructure and Security areas.

Dr. Mihai Lucian Cristea received his B.Sc. degree in Automation and Computer Science Engineering in 1999 and M.Sc. degree in Artificial Intelligence in Process Control in 2000 from the "Dunarea de Jos" University of Galati, Romania. During his Ph.D. research between 2002 and 2006 at Leiden University, The Netherlands, he contributed to the Streamline network traffic processing framework at multi-gigabits speeds. At University of Amsterdam, Dr. Cristea was involved in the research of Token Based Networking that allows lightpaths selection at multi-gigabit speeds on behalf of the applications. Since 2009, he is involved in the research of programmable networks for binding applications to networks, especially when applied to the inter-cloud problems. He was involved in the following EU funded projects SCAMPI, LOBSTER, Phosphorus, and GEYSERS projects, and recently created and run a Cloud technologies test bed at SNE/UvA.

Prof. Cees de Laat, Dr. ir., is associate professor and leader of the System and Network Engineering Science group at the University of Amsterdam. Research in his group includes optical/switched networking for Internet transport of massive amounts of data in TeraScale eScience applications, Semantic web to describe networks and associated resources, distributed cross organization Authorization architectures and Systems Security & privacy of information in distributed environments. With SURFnet he develops and implements projects in the SURFnet7 Research on Networks. He collaborates in the NSF - OptIPuter project. He serves in the Open Grid Forum as IETF Liaison and is acting co-chair of the Grid High Performance Networking Research Group (GHPN-RG) and is chair of GridForum.nl and board member of ISOC.nl. He is co-founder and organizer of several of the past meetings of the Global Lambda Integrated Facility (GLIF) and founding member of CineGrid.org.

2.2.9 FORTH

The Foundation for Research and Technology - Hellas (FORTH) (http://www.forth.gr), established in 1983, is the largest Greek State R&D Centre. FORTH hosts seven major Research Institutes. The Institute of Computer Science (ICS) has established an internationally acknowledged excellence in conducting basic and applied research, developing applications and products, and providing services. FORTH-ICS, besides its pioneering contributions in the sector of Information and Telecommunications Technologies in Greece, cooperates, in the context of European and international collaborative R&D programs, with universities, research centres and other organisations at national and international level, thus contributing to the exchange of scientific ideas and the creation and transfer of new technologies. In the area of storage systems, FORTH-ICS has extensive experience and activities, within CARV (Computer Architecture and VLSI Systems). CARV has an 18-year experience in interconnection network architectures and communication protocols for high-performance compute and storage systems. Recently, CARV has built a 10-GBit/s communication subsystem and storage area network prototype, including the hardware platform and the full software stack, which is currently being used for further research in the area. In 2008 FORTH-ICS (and CARV) has filed for a patent in the area of storage subsystems. CARV has participated in numerous projects in this area (EU: SIVSS, Unisix, SARC, HiPEAC, SCALUS, STREAM. IOLANES, CumuloNimbo, Encore, TEXT, TransForm, DeSyRe, FASTER; National: MASC, ATHLOS).

In RECIPE, FORTH will be the leader of WP4 on “Business layer, scientific workflow and process integration” as well as contribute to the usability evaluation, platform and application interface developments, demonstrations, exploitation, and sustainability.

Key Personnel

Dr. Kostas Magoutis has over fifteen years of academic and industrial experience on scalable computer systems and services. He is currently a Researcher with the Institute of Computer Science, FORTH, Greece and affiliated faculty with the Computer Science Department, University of Crete, Greece. Prior to joining FORTH (2009), Dr. Magoutis held the position of Research Staff Member with the Department of Services Technologies at the IBM T. J. Watson Research Center, in Hawthorne, NY since 2003, and taught at Columbia University. At IBM T. J. Watson, Dr. Magoutis’ research in distributed systems management technologies had an impact on both IBM products (winning an IBM Outstanding Technical Group Award for contributions to the IBM Tivoli Storage Productivity Center) and in engineering successful IBM services. Dr. Magoutis leads the SCALEWORKS FP7 MC-IEF project (2009-2011) and participates in the STREAM (2008-2011) and CumuloNimbo (2010-2013) FP7 STREP projects. His research has received several IBM Invention Awards and two best-paper awards in prestigious USENIX conferences (Annual Technical Conference 2002, BSD Conference 2002). Dr. Magoutis holds a Ph.D. degree in Computer Science from Harvard University and is a recipient of J. William Fulbright, Alexander S. Onassis, and EU Marie Curie Fellowships.

Prof. Angelos Bilas is currently a Professor of Computer Science at FORTH-ICS and the University of Crete, Greece, where he has also held an Associate Professor position between 2002-2011. Prof. Bilas received his diploma in Computer Engineering from the University of Patras in 1993, and the M.S and Ph.D. degrees in Computer Science from Princeton University, NJ in 1995 and 1998 respectively. His current interests include architectures and systems software support for efficient storage systems, low-latency high-bandwidth communication protocols, and runtime-system support for multi-core processors. His work has been published in prestigious conferences in computer architecture and systems. Prof. Bilas is the recipient of a Marie Curie Excellent Teams Award (2005-2009), has served in the Editorial Board of IEEE Computer Architecture Letters (CAL), and currently serves in the Editorial Board of the Journal of Parallel and Distributed Computing (JPDC).

Other members of FORTH-ICS that will be involved in this work are **Prof. Manolis Katevenis** (technology trends) and **Dr. Manolis Marazakis** (I/O communication protocols).

2.3 Consortium as a whole

In order to achieve the RECIPE project objectives – discussed in Section 1 – the project consortium consists of representatives of both the R&E sector and the commercial cloud industry from all over Europe (Fig.8).

The project participants believe that the composition of the consortium is appropriate to be able to:

- leverage on the existing research network (NREN) infrastructures and mechanisms,
- do the early adaptation of the Inter-cloud Architecture and Cloud Carrier Service Stack proposals within the NRENs' domain,
- make the demonstrations and service pilots for typical HE users in the R&E community,
- and finally push the developments towards SMEs and cloud industry (including practical standards and best practices taken up by cloud SMEs first) for exploitation and sustainability.

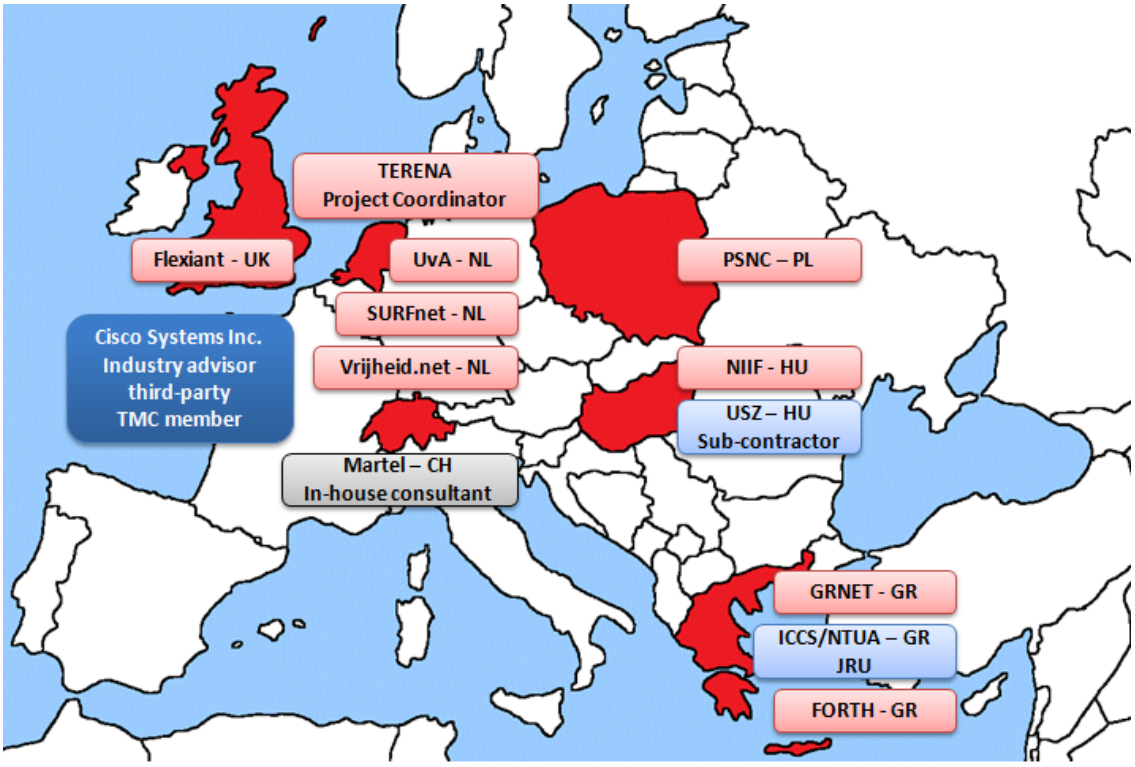


Fig. 8 Project consortium participants and third-parties

The RECIPE project consortium is coordinated by TERENA that is the non-profit European association of research networks, and the project administration is provided by Martel as an in-house consultant of TERENA.

The project consortium has four Research Network (NREN) participants as follows:

- NIIF – Hungary (Public, Non-profit)
- PSNC – Poland (Public, Non-profit)
- SURFnet – Netherlands (SME)
- GRNET – Greece (State-owned organization under the supervision of the Ministry of Development)

NRENs are serving the national research and education communities and they have been collaborating at the pan-European level (under the Trans-European Research and Education Networking Association, TERENA) for more than 25 years. NRENs have well-established business and sustainability models. Although, they financial models are slightly different, they all cover operational costs in the combination of national government funding, the contribution of their member organizations, and also from scientific projects in a sustainable manner.

NRENs have the sufficient technical knowledge and competence to get infrastructure and technologies (i.e. data network, storage, authentication, authorization and accounting) to support their IaaS cloud services. The national identity federations and global con-federation (see FP7 project GÉANT activity on eduGAIN [conf]) run by NRENs ensure the necessary security, privacy and improve trust. The European NREN community thus can bring the long-term sustainability commitments and can also bring the traditional European values (e.g., data protection, European jurisdiction) and policies into the project. They have the potential to work out common, shared European policies, and pre-standards, as well as to roll out technical prototypes and real-life service pilots. NRENs' infrastructure is typically flexible and open to implement features/functions requested by users (i.e. scientific user applications). NRENs' data network is already integrated with the campus network infrastructures as much as possible (e.g., some NRENs can deliver end-to-end lightpath services, bypassing the unnecessary middle-boxes, all the way down to the desktop). NRENs have the ability to influence user's best practices/approaches, and the practice in educating the users and disseminating knowledge, ideas, products, and services.

RECIPE project consortium has two cloud industry SMEs participants and an industry vendor as advisory third-party to the consortium as follows:

- Flexiant – United Kingdom (Commercial, SME)
- Vrijheid.net – Netherlands (Commercial, SME)
    - Cisco Systems Inc. (Commercial third-party, equipment vendor)

Commercial cloud industry partners bring the professional technology background and the deep understanding on the business-centric cloud operation and service provisioning into the project. Due to the high flexibility and scalability of their infrastructure the necessary economy of scale (that is so important for the cost-sensitive R&E sector) can be ensured by them. The quick adaptation to the rapidly changing business models and new business opportunities justify their existence and they transfer this knowledge into the project for the benefit of the HE users.

RECIPE project consortium also has one research institute and one university participants in addition it has two other universities as JRU of GRNET and sub-contractor of NIIF.

- FORTH – Greece (Research institute, Non-profit participant)
- University of Amsterdam – Netherlands (Public, Non-profit participant)
    - University of Szeged – Hungary (Public, Non-profit, Sub-contractor)
    - University of Athens – Greece (Public, Non-profit, JRU)

Universities know all about their campus infrastructure and the requirements of their IT department as well as the HE users' and user applications' needs. Obviously, one of the fastest growing cost centres at any organization whether it is a university or business is the growth of IT. There is no question that IT provides incredible value to both advancing research and education and, in the future, the demand for more IT services are only going to grow. But with growing pressure on universities to reduce costs there is going to be a very close look at the IT department and demand for greater rationalization. IT alone represents anywhere from 25-40% of the electrical energy consumption at most institutions. Many universities now manage 1- 5 MW data centres, which is the power consumption of a small town or factory. IT departments are also required to physically manage thousands of servers, Internet access points, wireless infrastructure and a host of other services [bsa]. IT operations nowadays do not fit with the primary mandate of a typical university and they have to find the way how to deal with the growing demands and new challenges. Just like the integration of the campus network infrastructure with the NREN (and through commercial peering with global internet providers), universities are now looking for an integrated campus-cloud infrastructure model that meets their specific requirements and policies as well as opens up a new architectural dimension. Campuses need seamless access to industry cloud offerings within the same workflow as they deal with private cloud offerings (i.e. business processes can flow seamlessly from campuses to NREN and beyond to commercials).

The most important attribute of the RECIPE project consortium at large is that the participants share a quite common technical vision on Resource Clouds for R&E, thanks to their long-term collaboration. The four NREN participants are member of TERENA (the project coordinator) and have been collaborating together at the Pan-European level for many years. Universities are the members of their NRENs and being served by

the national research networks operated by the corresponding NRENs. Universities themselves are also participating in the TERENA activities in a voluntary basis. The cloud industry SMEs participating in the project have been collaborating with the NREN community for a long time. Apparently, Cisco Systems Inc. is an associate member of TERENA.

In addition to the RECIPE project consortium participants the following three organisations are involved in the project as different legal form of third-parties.

2.3.1 Joint Research Unit of GRNET

Institute of Communication and Computer Systems (ICCS) (http://www.iccs.gr/eng/) will contribute to RECIPE project as a JRU of GRNET. ICCS will work in WP2 to investigate SFA (Slice Federation Architecture) as a candidate for federation mechanism in RECIPE. The federation of different cloud platforms at the network layer requires the interconnection of the isolated networks. This can be performed by a media specific switch. ICCS will investigate the integration of an OpenFlow switch that can couple different Ethernet and GRE tunnels at the campus side in a scalable way without implementing multiple bridges at the hypervisor level of the cloud. ICCS will also contribute to WP3 on the implementation of the necessary wrapper API for the integration of GRNET cloud with the SFA modules. Overall, ICCS will closely support GRNET's development and demonstration efforts in WP3 and WP6.

ICCS is a non profit Academic Research Entity associated with the School of Electrical & Computer Engineering of the National Technical University of Athens (NTUA). ICCS is governed by a five member Board of Directors, coordinated by the Director of the Institute elected by the Faculty of NTUA. ICCS is actively involved in R&D programs sponsored by Greek and European Research Initiatives. Its research interests and areas of expertise are on management, planning, and design of broadband networks that are based on evolving Future Internet technologies. ICCS supports undergraduate and graduate teaching & research of NTUA school of Electrical engineer in Distributed Network/System modelling, evaluation and planning in areas such as: Future Internet architectures, legacy & novel management schemas for high-speed optical communications, wireless networks, ad-hoc & sensor networks, network security, distributed storage & processing systems (computational grids – cloud computing), techno-economic analysis & planning in deregulated telecommunications markets.

Key Personnel

Dr.Vasilis Maglaris is a Professor of Electrical & Computer Engineering at the National Technical University of Athens (NTUA) since 1989 and Director of the NETMODE Laboratory. He received his Diploma in Mechanical & Electrical Engineering from NTUA in 1974 and the Ph.D. degree from Columbia University, New York in 1979. He subsequently held various industrial and academic positions in the USA (1979-1989) and in Greece (1989-now). His interests are on Internet technologies and distributed computing systems. He is currently chairing the governance committee of GÉANT, the Pan-European next generation interconnection of more than 34 National Research & Education Networks in the extended European Research Area.

Dr Dimitris Kalogeras is affiliated with the Institute of Communications & Computer Systems (ICCS). Within ICCS, he is a Senior Researcher at the Network Management & Optimal Design Laboratory (NETMODE), School of Electrical & Computer Engineering. He obtained his Engineering Diploma (1990) and the Doctorate degree (1996), both in Electrical & Computer Engineering from NTUA. His research spans several aspects of advanced network technologies and protocols. He is consulting on planning the new generations of GRNET (the Greek National Research & Education Network) during the last three phases of its network evolution including its latest hybrid optical design and the NTUA Campus Local Area Network. Dr. Kalogeras was involved in several European Research & Technological Development projects, e.g. on IPv6 (6Net) and on Network Security (GEANT2 / GN2 – JRA2). He served in several European Commission technical panels and, for two terms, he was with the Technical Committee of the Trans-European Research & Education Networking (TERENA). He has participated in the evolution of Pan-

European Academic research network since TEN-34 following up within TEN-155, GN, GN2 and currently with GN3.

Dr. Leonidas Lymberopoulos is a Senior Researcher at the NETMODE Laboratory, School of Electrical & Computer Engineering. His research is in the area of distributed networks and Internet protocols &technologies, policy-based network management and future Internetcontrol & management protocols &architectures. He graduated from the School of Electrical and Computer Engineering, NTUA (2000). He received his Ph.D. from the Department of Computing, Imperial College London (2000-2004) and worked for two years at UCL as Research Fellow (2004-2006) prior to joining NTUA (2006). He has participated in a number of research and development projects (FP6 STREP Argugrid at NTUA, RUNES IP FP6 at UCL, EPSRC PolyNet, Cisco Polyander, NTUA Evaluation Project). He is currently the associate technical coordinator of the NOVI FP7 STREP project and participates to the activities of the FIREStation Support Action.

Dr. Ioannis Konstantinou is a senior researcher at the CSLAB. He has received his Diploma in ECE from NTUA in 2004, his M.Sc. in Techno-Economic Systems from NTUA in 2007 and his PhD from NTUA in 2011. His research interests lie in the field of distributed data management systems utilizing cloud computing and peer-to-peer technologies. Since 2005 he has participated in numerous EU – funded (FP6-FP7) and GR – funded such as Arcomem, StratusLab, Gredia, Gridnews, Greed, E-vacations, eService4U, etc. He is responsible for the design, development and deployment of large-scale distributed data management platform prototypes based in peer to peer, grid and cloud technologies.

2.3.2 Sub-contractor of NIIF

The Software Engineering Department of University of Szeged (USZ-SED) (http://www.inf.u-szeged.hu/sed/) has in depth knowledge and expertise in the field of JEE based scalable application development. One task of the USZ-SED in RECIPE will be to integrate the cluster layer of the JEE stack with the necessary APIs provided by the broker of the cloud. Another field where USZ-SED is going to be involved is the integration of the cloud broker with the management infrastructure of the network provider. This integration is going to be done with the help of the results achieved in the GN2 and GN3 projects. The third field where USZ-SED is going to be involved is in the WP5 where as a usability evaluation and platform and application interface requirement source USZ-SED is going to provide the Telenor EDH telemedical solution and implement the necessary APIs provided by the broker of the cloud. USZ-SED was chosen by NIIF as a sub-contractor mainly because of their in-depth experiences with specific cloud platforms (PaaS) and applications (SaaS) developed by them. Since RECIPE focuses on IaaS clouds and uses PaaS/SaaS for demonstration purposes only, sub-contracting was an appropriate form for USZ-SED to be involved in RECIPE.

The Software Engineering Department (SED) operates within the Institute of Informatics at one of the leading universities in Hungary, the University of Szeged. SED conduct researches in the field of software quality, embedded systems, computer networks and open source, scalable software technologies. It has long been in close cooperation with substantial international and national industrial partners in several joint R&D projects. The scientific achievements of the researchers working at SED are well justified by the great number of publications in prestigious scientific journals and conference proceedings. SED has long experience in monitoring and developing software systems, static and dynamic source code analysis for quality assurance and open source technologies. SED has been conducting R&D projects since 1998 in cooperation with one of the largest companies producing large amounts of open source software, the Nokia Corporation. SED operates an Open Source Laboratory, whose main objective is to popularize this development paradigm. There is an intensive collaboration with industrial partners in the field of telemedicine and clinical decisions. Telemedical products already available on the market, and the patents related to the telemedicine are all the results of the intensive collaboration of the researcher and developer team at the USZ-SED and different industrial partners (Telenor, Telenor Objects, General Electric Healthcare, Nokia, etc.)

Key Personnel:

Dr. Vilmos Bilicki holds MSc (1999) from electrical engineering and PhD (2010) from Information Science and Technology. He joined to the department of Software Engineering of the University of Szeged (USZ) in 2001 as a research assistant, where he studied distributed storages and compression of the SIP protocol. He was the technological leader of several domestic and foreign industrial research and development projects (more than 20 projects among them different FP6 and FP7 projects). He is a founding member and also a Cisco Certified Academy Instructor of the Cisco Academy at the USZ. He is teaching CCNA and CCNP oriented optional courses for more than 5 years. In 2008 and 2009 he was a member of the program committee of the International Conference on Networking and Services. He is a founding member of the Intelligent Medical Systems section of the Hungarian Scientific Association for Infocommunications. He is an active researcher as well, having authored 36 publications with 20 independent citations. He is also an owner of an European patent in the field of telemedicine.

2.3.3 Industry advisor of RECIPE

Cisco Systems Inc. (http://www.cisco.com) will be a third-party to RECIPE with no budget. Cisco believes that research into Resource Clouds as proposed by RECIPE project is a very interesting approach for an Infrastructure as a Service (IaaS) architecture. This investigation and all resulting recommendations will enhance our understanding of sharing cloud resources. Cisco Systems sells infrastructure products that are used in cloud offerings. As such Cisco sees investigations into this expanding area as being beneficial to the community and Cisco are already involved in many other IaaS projects. Cisco will sit on the Technical Management Committee (TMC) of RECIPE and will share their public information and assist in moving this project forward. (See Cisco's support letter in Annex I.)

Cisco Systems, Inc. is the worldwide leader in networking for the Internet. Today, networks are an essential part of business, education, government, and home communications. Cisco hardware, software, and service offerings are used to create the Internet solutions that make these networks possible, giving individuals, companies, and countries easy access to information anywhere, at any time. In addition, Cisco has pioneered the use of the Internet in its own business practice and offers consulting services based on its experience to help other organizations around the world. Cisco was founded in 1984 by a small group of computer scientists from Stanford University.

Key Personnel

Klaas Wierenga is a senior consulting engineer in the office of the CTO at Cisco. His 15-plus years of experience include the planning, analysis, and design of numerous solutions for enterprises, municipalities, hospitals, and universities in the fields of mobility, security, and identity worldwide. Mr. Wierenga is the original creator of the worldwide eduroam service for federated network access in academia and co-creator of the federated identity solution that forms the basis of the Dutch government's e-Identity portfolio. He is the author of numerous publications and has presented many times on wireless networking, security, and identity topics. Mr. Wierenga is active within 3GPP, in the group responsible for the security architecture of future mobile networks. He serves as chairman of the Abfab Working Group in the IETF, which deals with federated access for non-web applications, as well as of the Task Force on Mobility and Network Middleware of TERENA, the European Association for Research and Education Networks. He holds a master's degree in computer science from the University of Groningen (The Netherlands).

2.4 Resources to be committed

The RECIPE project participants represent all the main stakeholders of the R&E community. The partners have been collaborating together for many years e.g., in task forces established under the auspices of the TERENA Technical Programme. For instance, Task Force Storage (http://www.terena.org/tf-storage/) provides a forum for exchanging and promoting ideas, experience and knowledge, as well as fostering collaborations among NRENs, academic and research institutions on the topic of data storage, data management and cloud storage. However, even our joint efforts and resources are not sufficient to achieve the overall objectives of RECIPE, which is why we are asking for EU funding.

2.4.1 Human resources

RECIPE is proposed to be a 24 month-long project. The total person-month committed to the project is 403 PM (16.79 FTE). We named 32 people from 13 organisations (9 consortium partners and 4 other participants) in the description of work who will put efforts into the project. The overall RECIPE project budget figures are as follows:

- **Total budget: 3,568,776.00 euro**
- **EC contribution requested: 2,531,072.00 euro (70.92% of the total cost)**

The budget distribution by major cost components is as follows:

- Personnel cost (with overhead): 3,341,876.00 euro (93.64% of the total cost)
- Travel cost (excluding overhead): 111,200.00 euro (3.11% of the total cost)
- Sub-contracting cost with USZ (without VAT and overhead): 54,000.00 euro

The total budget and its distribution by activity type shown in Fig.9 are as follows:

- Management activity (including overhead)
  - Project management: 267,300.00 euro (7.49% of the total cost)
  - Dissemination coordination: 20,800.00 euro (0.58% of the total cost)
  - Travel: 172,900.00 euro (4.84% of the total cost)
- Research activity (including overhead): 2,652,096.00 euro (74.31% of the total cost)
- Demonstration activity (including overhead): 455,680.00 euro (12.77% of the total cost)

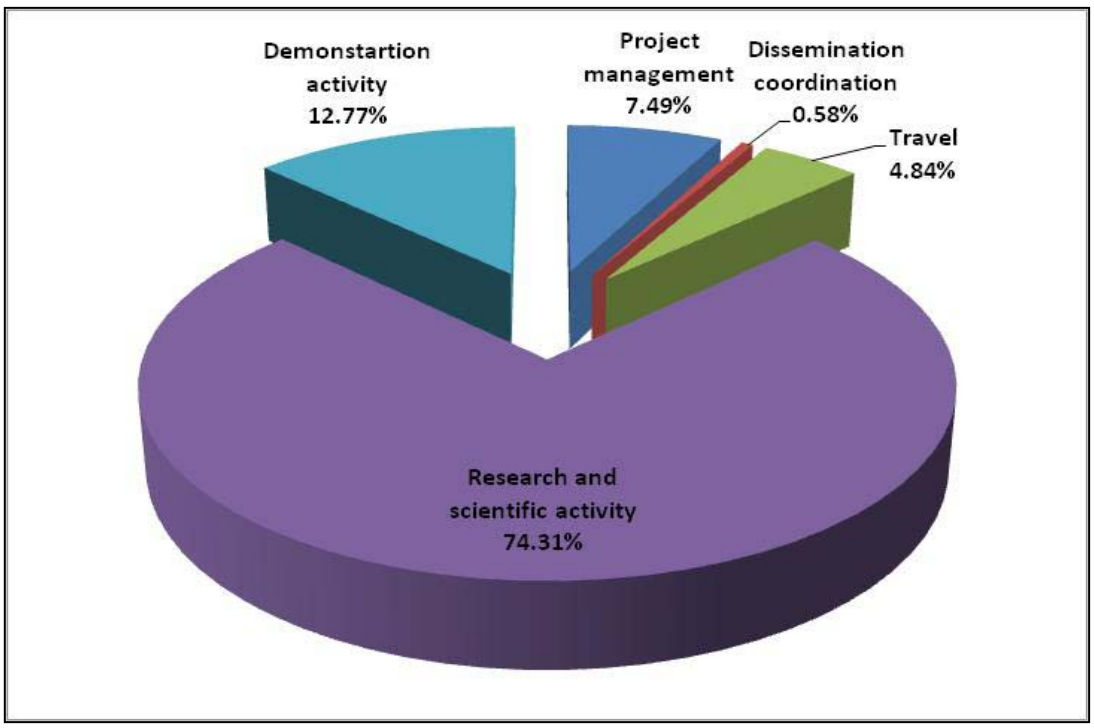


Fig. 9 Budget distribution by activity type

The well-balanced person-month distribution by partner and he thoughtfully designed person-month distribution by work package are shown in Fig. 10.

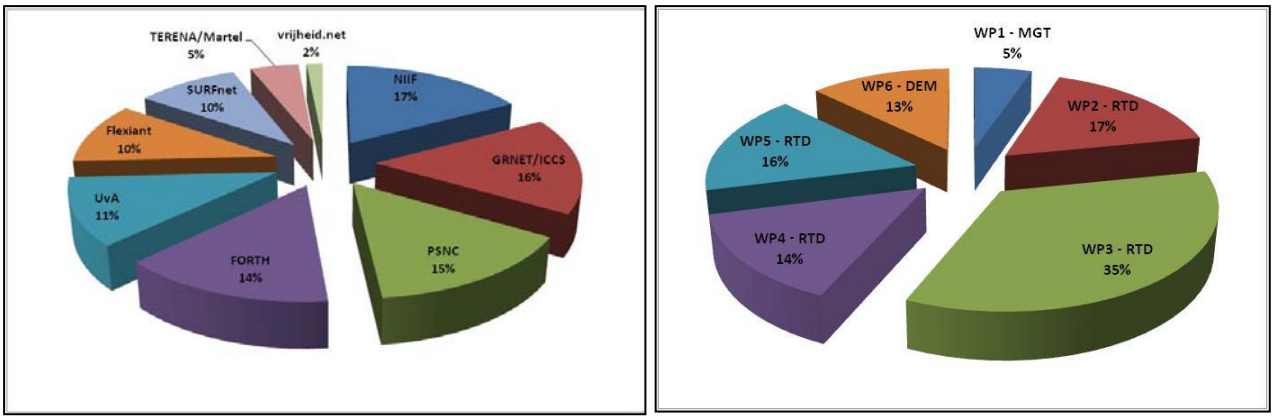


Fig 10. Person-month distribution by partner and by work package

Fig. 11 shows the total budget per partner (form A3.2)

Proposal Submission Forms

EUROPEAN COMMISSION

7th Framework Programme on Research, Technological Development and Demonstration

A3.2: Budget

			Estimated budget (whole duration of the project)									
Participant Nr	Organisation Short Name	Organisation country	RTD	Demonstration	Training	Coordination	Support	Management	Other	Total	Total receipts	Requested EU contributions
1	TERENA	NL	0	0	0	0	0	290400	0	290400	0	281300
2	NIIF	HU	332400	48000	0	0	0	27520	0	407920	0	292300
3	PSNC	PL	406080	45120	0	0	0	26560	0	477760	0	343720
4	SURFnet	NL	337680	120600	0	0	0	12600	0	470880	0	320560
5	GRNET	EL	340560	170280	0	0	0	25560	0	536400	0	269620
6	Vrijheid	NL	80000	16000	0	0	0	11200	0	107200	0	75000
7	Flexiant	UK	312000	8000	0	0	0	33600	0	353600	0	265000
8	UvA	NL	390976	47680	0	0	0	16960	0	455616	0	327672
9	FORTH	EL	452400	0	0	0	0	16600	0	469000	0	355900
		Total	2652096	455680	0	0	0	461000	0	3568776	0	2531072

Fig. 11 Total budget (A3.2)

2.4.2 Infrastructure resources

Partners in RECIPE will bring their computing and network resources as well as test bed setups from previous EU and national projects in order to support any development and testing in the project's time frame. These resources will be committed as an in-kind contribution from partners, and therefore they will not be charged to the project.

The following list resources will be committed by partners:

- Flexiant will provide the following resources for the project needs:
  - VMs for all project participants for project purposes on the Flexiscale virtual platform.
  - A communal project test bed will be provided with higher scalability and capacities of up to 100 VMs.
  - A bookable use of a Flexiant demonstration platform in Flexiant's data centre
  - The Extility software stack will be made available to partners in the form of a downloadable ISO image to virtualise hardware at their own premises if required.

- PSNC will commit resources that include servers (dozen or more), hypervisors and cloud stacks (KVM, Open Stack), RAID-backed storage (10TBs or more), workstations and software licenses.
    - PSNC will be able to provide both permanent and/or ad hoc resources in the amounts required for the project to progress.
- NIIFI will provide resources of the operational community IaaS Cloud infrastructure built on OpenNebula, KVM, and libvirt that is currently laid over 50 physical servers geographically distributed among the major Hungarian data networking regional centres, and also includes 1PByte of storage backup facility. Certain percentage along with modern data network connections will be offered as a test bed, as an incubation infrastructure for the project.
- GRNET will allocate the necessary percentage of the production infrastructure currently running Okeanos platform for the IaaS reference deployment and demonstration requirements of the project. These resources are currently hosted in the cloud-computing data centre managed by GRNET. Therefore, all necessary operational expenses (hardware maintenance, electricity and data centre administration) will be covered by GRNET's own manpower.
- UvA will contribute with their test bed on Cloud and Optical Networking technologies developed in a number of national and EU project. The test bed provides both Cloud IaaS and PaaS platform and can be used to deploy and test RECIPE software and tools in combined IaaS/PaaS environment. The test-bed provides a cloud-machine (48cores, 128GB-RAM, 600GB storage) for on-demand computation and storage resources. These resources are provided with the aid of OpenNebula installed on the cloud-machine and LICL software installed on a second machine. UvA test bed is well connected via SURFnet to GÉANT network and other research and education networks in Europe and worldwide.

The planned setup of the RECIPE test bed interconnecting the aforementioned cloud resources is depicted in Fig. 12.

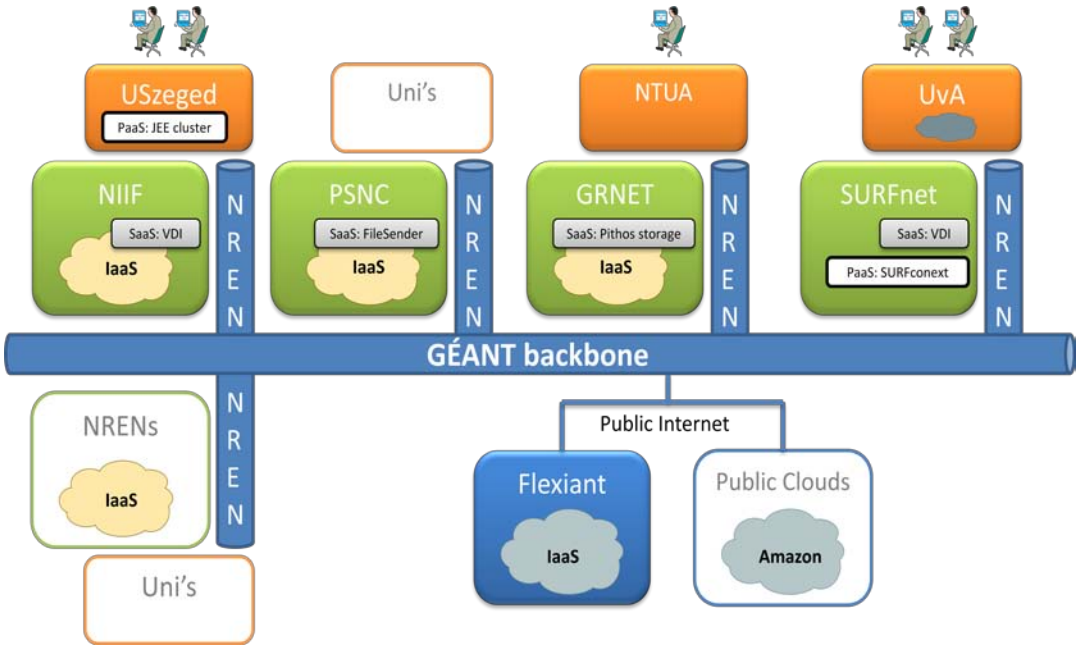


Fig. 12 Inter-cloud experimental test bed setup contributed by the project participants to RECIPE

3 Impact

3.1 Expected impacts listed in the work programme

3.1.1 Major impact

The section describes how the RECIPE project will contribute towards the expected impacts listed in the work programme. The first and foremost impact listed by EC says:
"Emergence of European interoperable clouds contributing to an internal market of services in the EU whilst providing very significant business opportunities to SME's; improved trust in cloud-based applications and storage for citizens and business."

This complex sentence is analysed in four parts:

1. Emergence of European interoperable clouds…

RECIPE addresses cloud interoperability by designing, prototyping, piloting and documenting (in the form of recipes) the solutions for IaaS clouds interoperability.

- RECIPE delivers the technical means to the Cloud Customers and Users for using the Cloud Providers' resources in a reliable, secure, scalable and sustainable way, i.e. the Cloud Carrier Software Stacks (CCSS) that brings cloud resources to campuses hiding the technical, business and policy-related complexities from the Cloud Customer;
- RECIPE implements cloud resource brokering model, which is the well-known paradigm in IT (see e.g. Grids), however needs the innovative implementation for IaaS clouds, including solution for loosely integrating IaaS private clouds owned by NRENs and public clouds managed by companies, that enables user application/ platform to easily (e.g. transparently to Cloud User) roam between providers mitigating the vendor and/or provider lock-in risk;
- RECIPE provides a novel tight-integrating solution of IaaS resources which is innovative in the sense that assures the mobility of the cloud entities to the extent not met in current solutions, including VMs' images and disk slices, multi-domain virtual networks and cloud data storage repositories interchangeable among distinct private IaaS clouds to the scale not possible nowadays; this enables the infrastructure owners to provide high-profile, integrated services for users facilitating the reliable, geographically distributed and organisationally diverse but logically coupled IaaS clouds of computation and data storage resources;
    - RECIPE assures user's data mobility provided by cloud storage solutions backed by federated/integrated virtual data storage entities and protected by appropriate security mechanisms;
    - RECIPE provides in-depth security model spanning all relevant cloud stack layers assuring that the security settings and policies are appropriately respected while the virtual entities are exchanged among resource clouds and mutually accessed across the brokered/ federated IaaS infrastructures; this enables the real data mobility, even for applications that required data security and privacy which is an innovative feature of the proposed model.

From the Cloud Customer point of view the solutions provided by RECIPE mitigate the risks of vendor and cloud provider lock-ins, which are currently among most important concerns related to cloud usage.

- RECIPE provides the innovative technical means for migrating the application easily, safely and reliably among resource providers as it proposes the open source CCSS-based on open and standard resource management and access interfaces;
- The project equips the Cloud Customers with the innovative tools and methodology for calculating/comparing costs of in-house running of the services vs. outsourcing them to external cloud resources infrastructure as well as solution for on-line comparison of operations.
- RECIPE assures not only the freedom of the users to choose from IaaS resources market offers but also gives the users the chance to make an optimal vendor selection decision based on data collected, audited and provided by the trusted, vendor-neutral Cloud Carriers that are the European NRENs in our case (but can be other trusted organisations or associations in general).

2. …contributing to an internal market of services in the EU…

- RECIPE provides the technology and ontology for offering the cloud resources to multiple users (campuses and other large groups of users/associations) in standardized/harmonized way, governed by the transparent /clear rules and policies.
- RECIPE model allows the IaaS providers to target the clearly-defined needs of users and their applications and understand the trust mechanisms. The brokering function aids to evaluate the offerings against their needs, by providing automatic or semi-automatic portfolio comparison tools and methodologies;
- RECIPE speeds-up the development of an open market of services in the EU by improving the user's awareness, know-how, and trust in cloud resources offerings. RECIPE creates the real opportunity to offer services to the European market while, being compliant with the European law, solves issues that happen when public institutions try to use cloud services located in the US, India, or Chine.

3. …providing very significant business opportunities to SME's…

From a Resource Provider point of view, the project provides new, significant business opportunities to SME's

- SMEs can enter IaaS cloud market easier than before by adhering to open source, well-documented, practically proven and demonstrated cloud offering models (on the business/policy level) and interfacing to CCSS (on the technical level);
- Small and elastic SMEs can quickly and effectively respond to particular user /application requirements (e.g., security-related) which are well-described and expressed in the well understood language of CCSS model, its architecture and interfaces;
- The IaaS cloud resource owners can easily approach the potential clients (universities in our case) by adopting to the Cloud Carrier model and adhering to CCSS architecture and its interfaces;
- RECIPE provides not only the technical solution but also the knowledge transfer, 'recipes', demonstration and advertisement of the cloud resource offerings to potential Cloud Customers;
- The focus of RECIPE is to open the doors to the campuses for the IaaS cloud owners, by putting NRENs, the service providers already trusted by universities, in the role of the Cloud Carriers; however this approach can also be reused in other cases such as associations of digital libraries against set of cloud storage providers etc.
- CCSS proposed by RECIPE is based on publicly-known, well-documented and tested interfaces thus protecting the integration investments/efforts made by resource owners to adhere to the proposed cloud offering model.

4. …improved trust in cloud-based applications and storage for citizens and business.

- RECIPE improves the trust in the security of data and services in clouds and addresses the data privacy, governance and control concerns by:
    - developing and proposing in-depth security model assuring that access rights are respected across different IaaS clouds while virtual resources/entities are mutually accessed by brokered IaaS clouds and/or are migrated/ exchanged among tightly integrated IaaS clusters;
    - proposing the new AAI mechanisms acting on all relevant levels of cloud stack that enables the in-depth, fine-grain data access control as well as provides auditability, accountability and non-repudiation of data access, usage and modification;
    - applying appropriate security-related mechanisms on legal, national ad organisational borders (e.g. by keeping the encryption keys to data within a given country while storing encrypted data blocks elsewhere); usage and legal aspects of these mechanisms are documented and described in form of 'recipes';
- RECIPE paves the way for the increased trust into cloud offerings as:
    - it provides the methodology and tools (CCSS) for implementing the Cloud Carrier role; NRENs, playing the role of Cloud Carries, are typically maintain trusted services and offer trusted resources to universities and campuses;

  - in RECIPE, NRENs not only provide services but also act as trusted service and infrastructure auditor and evaluator of the value, security, trustworthiness level and legal compliance of IaaS providers;
  - the project feeds the users with the knowledge, know-how and best practices by producing the 'recipes' that help user to make an educated choices on cloud offerings in terms of costs, scalability, reliability, as well as data safety and confidentiality requirements;
- RECIPE deals with typical user's concerns while depositing the data and running applications in the clouds including questions like: Where is my data?; Who can access it?; Whose (what country, organisation, company) law/policy/rule applies to my data access/control; etc. by proposing and implementing security mechanisms to be used at legal, national, infrastructure and organisational borders (e.g. applying the encryption on the trust borders).

3.1.2 Further impacts

The further impacts and the associated RECIPE project's responses are summarised in the table blow.

Expected impacts of the call	**Our project's response**
Availability of platforms for easy and controlled development and deployment of value-added services through innovative service front-ends.	RECIPE directly influence the availability of platforms for easy and controlled deployment of value-added services: • The creation of documented best practices (supported by pilots and demos), encourages the users, services providers, data centres and NRENs to invent and develop new applications that are able to benefit from elastic IaaS back-ends able to scale application and platform resources beyond the user's system or single (private) or community cloud; • RECIPE provides the means of supporting workflows typical to higher education and scientific application use so that bridges the gap between scientific cloud user community and cloud resource providers. • RECIPE provides new, federated and scalable back-ends (both brokered and integrated resource clouds) for application and platform architects. • RECIPE provides the means and methodologies for controlling, auditing and evaluating the cloud resource offers (best practice and providers audits done by Cloud Carriers).
Lower barriers for service providers and users to develop, select, combine and use value-added services through significant advances in cloud computing technologies and standardised and open interfaces.	RECIPE will demonstrate how different cloud federation members can interconnect via well-established standard (or at least quasi-standard) interfaces. RECIPE will also propose a shared European IaaS cloud policy that regulates the participation conditions, mutual resource accounting, security concerns, as well as acceptable consumer policies. In particular the project addresses (aims at lowering) the major barriers that typically prevent users from applying cloud paradigms: • It defines and harmonizes (i.e. pave the way for standardization) service interfaces on different levels including high-level end-user services (CCSS) and low-level infrastructure APIs (e.g. for data and VMs management). Importantly, security mechanisms are leveraged among the various service providers. • It collects and disseminates the know-how ('recipes'), thus boosting the adoption of cloud-backed services by individuals and small institutions with limited IT expertise.
Efficient implementation of mainstream software applications on massively parallel architectures.	RECIPE addresses this objective indirectly, as it offers an integrated cloud architecture to be demonstrated on NREN cloud resources (in computing and data centres) to partition resources into smaller virtual run-time environments in order to ensure the secure and separated

	execution of sensitive scientific jobs.
Easier evolution of legacy software over time, thanks to innovative methods and tools managing the complete lifecycle of software from requirements to run-time.	RECIPE heavily builds upon the legacy software components and services worked out in previous IaaS cloud initiatives and EC projects.
Fast innovation cycles in service industry, e.g. through the use of Open Source development model.	We expect that RECIPE will play a key role for accelerating innovation as the landscape today in cloud platforms is, and will continue to be heterogeneous with a high level of complexity associated with semantics, APIs, usage rules, business models, etc. Such complexity is the main reason for long innovation cycles and high barriers-to-entry for new players (that again has an impact on innovation cycle). RECIPE plans to reduce its complexity by designing a resilient, secure, and trusted reference Inter-cloud Architecture (IA), proposing a consistent, harmonised, and interoperable CCSS, as well as demonstrating the benefits of the inter-cloud carrier model with some pre-selected key e-science platforms and applications.
A strengthened industry in Europe for software-based services offering a large choice of services satisfying key societal and economical needs, with reinforced capabilities to engineer and produce software solutions and on-line services.	RECIPE will strengthen R&E services by simplifying access to cloud infrastructures. In addition, the proposed architecture will reflect the key European values such as data protection, environment protection, overall cost savings through federation, and establishing public-private-partnerships with public IaaS cloud providers. In fact RECIPE does not aim to build a single technology that will dominate a market segment, but rather will make simplified access to the existing and future cloud technologies for R&E, which is an important component of European society and economic growth.
Improve governance and control, especially in a landscape where there is little or no control of licensing terms and SLAs	RECIPE will indirectly support this objective by increasing clarity in the offered SLAs and licensing terms for federated cloud platforms. This is particularly important at this early stage of cloud adoption, as there is a high degree of obscurity in all related issues and terms. In addition RECIPE will directly relate this clarity to the reference architecture it will design so that users and applications will be able to see how SLAs and terms are actually enforced by the underlying platform, reducing user concerns and eliminating adoption barriers.
Strengthen our understanding of privacy & legal issues for data in the cloud	RECIPE aims at building a trusted reference architecture. The main goal is not to provide new techniques for privacy but rather to clarify requirements and features so that both users and providers are able to efficiently interact and agree on the desired level of privacy, e.g. via well specified SLAs. Thus, RECIPE will significantly contribute to methodologies for much needed clarity in privacy specification, especially in the more complex federated environments.
Strengthen security and dependability of cloud platforms	Working out a shared, in-depth security framework is one of the key project objectives. Furthermore RECIPE will also impact this objective for “data in the cloud” by designing a secure and available reference architecture for federating storage clouds. Specifications will be given that allow providers and users to understand platform semantics in federated environments. RECIPEs outcome will help bringing clarity in dependability issues for federated cloud platforms.
Improving interoperability, reducing lock-in risks, and improving portability of data and metadata	The reference IA provides a means for considering federation of heterogeneous resources upfront when designing and/or porting applications, which inherently reduces the risk for vendor and technology lock-ins.

3.2 Dissemination and/or exploitation of project results, and management of IPR

3.2.1 Dissemination of project results

In principle, RECIPE project's dissemination is about providing useful information about the project results, and raising awareness about the existence of those results. The dissemination plan contains the following main components:

- **Project website**: The RECIPE project website will be designed, hosted and maintained by TERENA, the project coordinator. TERENA will make a proposal for the project logo and the overall look and feel of the website. All the templates used by electronic and printed communication materials including official documents (i.e. deliverables, reports) presentations, posters, leaflets, etc. will be provided by TERENA.
- **Official news items, leaflets and public relation activities:** TERENA will also take care of the official news items appearing on the website and being fed into the official news channel of the NREN community maintained by TERENA. The very first news item will be a straightforward, 'start-up' leaflet explaining the project objectives, activities and administrative facts.
- **Management and coordination of the overall project dissemination activity:** Flexiant will co-ordinate and manage the dissemination activity, carry out the detailed dissemination plan (under WP1), as well as maintain all the project information at one place. Flexiant will take care of the project information to be documented and kept up to date (e.g., the database of key project personnel/contacts), collate all the information ready for use in deliverables and newsletters, as well as keep the key project messages consistent.
- **Production of printed materials and shipment:** NIIF will print out/produce the necessary printed materials and take care of their shipments to places (e.g., venue of the demonstrations).
- **Communication to EC project office:** Martel (the in-house consultant of TERENA) will take care of the official documents to be sent to EC. It includes the deliverables (format, language and consistency check) and the quarterly and final reports.

Bearing the aforementioned roles and responsibilities in mind, Flexiant will be the central store of all the project information. Martel will get the official documents from the central store to be submitted to EC, TERENA will pick up the key project messages from the central store to write the news items and update the website, NIIF will get the PR materials from the central store to print them out and ship to demo/conference locations. The technical content for the communication and dissemination materials and official deliverables must be provided by all the participants under the corresponding technical work packages (WP2-5). In general, about 3-5% of the technical work packages' efforts will be dedicated to dissemination that adds up to 10-15 PM in total during the whole project duration. WP1 only includes the management and coordination efforts of the project dissemination. RECIPE plans to distribute via its website the open source tools produced and keep them updated. The results will be automatically transferred into the NRENs environment by the project participants and eventually adopted in their production environments.

Universities, NRENs, and industry stakeholders involved each have their particular channels of dissemination and exploitation, ranging from conferences (e.g. TERENA Networking Conference), standardization bodies (e.g. IETF, ITU-T, ETSI, TMforum/IPsphere), papers and articles, courseware, licenses and products. Articles will be produced in scientific literature, in order to publicise the results, as they become available. Through participation in various conferences (e.g. the yearly Supercomputing event and the TERENA Network Conference as well as the country-specific NREN annual conferences) the availability of the RECIPE prototypes and the latest results, will be made available to the user community at large extent.

3.2.2 Exploitation of the project results

Exploiting results to RECIPE means looking beyond generating publicity to actually encouraging stakeholders to use or further develop project results. As the project targets to establish a trusted pan-European IaaS cloud service based on shared disciplines it is important to set up a business model that applies after the end of the projects.

The following items are considered here:

- All the technical achievements of the project would be made public, the documents are shared, and the practical knowledge is synthesized into a coherent knowledge base (wiki).
- The development of all software components is driven out to the open source.
- The trusted cloud service would be based on the European network of NRENs, a small set of reliable providers. Providing semi-market services NRENs have already established an operation and business model for the data network. The same sustainability disciplines can be applied here.
- Due to the permanent structure of NRENs, the direct advantages as well as the key concerns will be made evident to the member organizations. Thus there would be a permanent and massive user community counting to several thousands of organizations behind the service.
- Using TCO calculations the direct benefits of the IaaS cloud services would be made evident to consumers. Smaller organizations who cannot afford own physical IT would experience a lower price barrier. Larger organizations would benefit from hardware consolidation yields, i.e. significant reduction in electricity bills.
- Spin-off SMEs might also take the knowledge and implement similar services for market-driven communities.

In order to exploit the results to the fullest extent, and to have the maximum impact, the general agreement of the project is to develop architectures, tools and technologies that are open to anyone to deploy in their networks (whether or not they are a partner in the RECIPE consortium). For this reason, the tools that will be developed will follow the key principles of open source. Nevertheless, it is accepted that a single partner (or partners jointly) might develop proprietary software in parallel that is designed to be ultimately commercialised, either in conjunction with an existing or as a new product. This/these partner(s) will conserve the right to apply for the intellectual property related to that product. In this case, the principles outlined in Section 3.2.3 will apply.

3.2.3 Management of Intellectual Property and Patent Requests

The FP7 Rules for Participation require that any Intellectual Property generated by a project (referred to in the contract as "foreground") should be adequately protected and exploited. Protection and exploitation of IPR are often issues that have important implications for the projects, in particular when industrial participants are involved. The standard EU Grant Agreement sets out the general rules regarding IPR, their use and dissemination. The Grant Agreement distinguishes between access rights to IPR which is generated previously and/or independently of the project ("background") and access rights to IPR generated during the execution of the project (“foreground”). It further distinguishes between those access rights that are necessary in order for the work on the project to be carried out, and those access rights needed for subsequent exploitation of the “foreground” generated by the project. As far as the protection and exploitation of the knowledge generated by FP7 projects is concerned, all beneficiaries (contractors) have an obligation to protect such “foreground” if it is capable of industrial or commercial exploitation. Any publications of “foreground” should not compromise the IPR protection policies of the participants.

The RECIPE project’s handling of IPR will be completely in-line with Annex II of the Model Contract and the “Guide to Intellectual Property Rules for FP7 projects”. Further related details (e.g. publishing, confidentiality, joint ownership) will also be provided in the Consortium Agreement. An *Intellectual Property Committee (IPC)* will be appointed by the GA. The IPC will be in charge of assisting WP Leaders, upon request, in identifying knowledge that could be the subject matter of protection, use or dissemination on the basis of publications and activity reports issued by WP Leaders. As part of its tasks, the IPC will also review the results of the research that could be conveyed to standardisation groups. The IPC will assist the GA in the implementation of measures in connection with dissemination and protection of knowledge.

An *IPR Manager* will be appointed at the beginning of the project among partners, and will lead the Intellectual Property Committee (IPC). The IPC will ensure that the issues related to Intellectual Property Rights are properly assessed and in accordance with fundamental ethical rules and principles recognised at European level.

4 Ethical issues

This proposal is concerned with technology for rating applications that will improve the cost-effectiveness and capabilities of numerous activities at a personal, professional, and societal level. As such, there are no ethical issues.

	YES	PAGE
Informed Consent		
• Does the proposal involve children?		
• Does the proposal involve patients or persons not able to give consent?		
• Does the proposal involve adult healthy volunteers?		
• Does the proposal involve Human Genetic Material?		
• Does the proposal involve Human biological samples?		
• Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?		
• Does the proposal involve Human Foetal Tissue / Cells?		
• Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
• Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Does the proposal involve tracking the location or observation of people?		
Research on Animals		
• Does the proposal involve research on animals?		
• Are those animals transgenic small laboratory animals?		
• Are those animals transgenic farm animals?		
• Are those animals cloned farm animals?		
• Are those animals non-human primates?		
Research Involving Developing Countries		
• Use of local resources (genetic, animal, plant etc)		
• Impact on local community		
Dual Use		
• Research having direct military application		
• Research having the potential for terrorist abuse		
ICT Implants		
• Does the proposal involve clinical trials of ICT implants?		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	YES	

5 Consideration of gender aspects

The partners are aware of the fact that few women are currently working in the areas relevant to this project. Partners have already taken steps to redress this imbalance by strongly encouraging female scientists and engineers to pursue design careers. In addition, all participating institutes support gender equality. The consortium will strive to further employ female scientists and engineers in the project by raising partner awareness using regular communication about gender equality.

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Annex I – Support letter of Cisco Systems Inc.

22 December 2011

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Trans-European Research and Education Networking Association
TERENA Secretariat
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Subject: Letter of support from Cisco Systems for the RECIPE proposal

Dear RECIPE Project coordinator,

On behalf of Cisco Systems, I am writing in support of the "Research & Education and Cloud Industry Partnership in Europe (RECIPE)" project proposal. Cisco believes that research into Resource Clouds as proposed by TERENA is a very interesting approach for an infrastructure as a service (IaaS) architecture. This investigation and all resulting recommendations will enhance our understanding of sharing cloud resources.

Cisco Systems sells infrastructure products that are used in cloud offerings. As such we see investigations into this expanding area as being beneficial to the community and we are already involved in many other IaaS projects. If we are allowed to participate as a third party to this project and sit on the Technical Management Committee (TMC), we will gladly share our public information and assist in moving this project forward.

Therefore, I give my full support to the RECIPE proposal on behalf of Cisco Systems, since I am confident that the RECIPE project will be able to deliver interesting and timely recommendations in this area.

Yours sincerely,