Virtual Desktop Infrastructure (VDI) Technology: FI4VDI project

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Abstract. This paper presents an analysis of the FI4VDI project, whose innovative model is the development of service delivery using cloud computing in order to create an infrastructure suite aims at large companies and SMEs alike, educational institutions, universities and/or research centres that would contribute to competitiveness and provide an efficient solution to reducing the carbon footprint derived from the use of information technology.

The penetration of Cloud Computing in sectors as public administration and industry is resulting slow, consequently it is missing the competitive advantages that this technology can provide for both ICT-provider companies and end users thereof. For encouraging the use of cloud computing, from the R+D Centers and services involved in this project, the experience and knowledge of this technology could be transferred and the use of virtual desktops to the clusters of ICT companies, thus including in this way a differentiating service in their portfolios products and also contributing to the development of the economy and the society.

The aim of the FI4VDI project is: to develop a federated infrastructure network for the creation of virtual desktop services. Firstly, by evaluating the position and perception of public and private organisations in the southwest Europe as regards the desirability of the virtualising IT operating environments, and secondly, by promoting the spread of cloud computing pretending achieve savings, efficiency, simplicity and productivity improvement. In pursuing the project resources are used to generate highly innovative services through a PAAS (Platform as a Service) and SaaS (Software as a Service) to enable the generation of virtualization services jobs for users of public and private sector inside southwest Europe. The development of this infrastructure is to ensure that users data protection and compliance with the rules relating to safety information and established SLAs. The launch of this service will result in an improvement through technological innovation and cost savings in targeted sectors thereof.

The provision of cloud computing services by supercomputing centres has a positive effect on the ecological footprint; dependence on physical ICT infrastructures is reduced when these are replaced by virtual ones, and this in turn produces a marked reduction in energy consumption in these institutions.

With a federated cloud computing model, desktops can be connected to dedicated servers with high rates of effective utilisation, greatly increasing energy efficiency and reducing the carbon footprint associated with the service.
The goal of the project is to develop a federated infrastructure network for the creation and management of energy efficient ICT services.
Organizations involved in the project FI4VDI
Organisations that participated actively as infrastructure providers included

- The Supercomputing Centre Castille and Leon
  Castille and Leon Region ES41 (Spain)
- The Computing and Advanced Technologies Centre Extremadura
  Extremadura Region ES43 (Spain)
- The University of Lerida Faculty of Arts Computer Centre Ponent
  Catalonia Region ES51 (Spain)
- The University of Montpellier 2 Sciences et Techniques
  Languedoc-Roussillon Region FR81 (France)

Organisations that participated actively as business associations included

- The Innovative Business Association for Network Security and
  Information Systems (Spain)
- Aveiro Association of Companies for an Innovation Network
  Central Region PT16 (Portugal)
- The Science and Technology Park Agri-Food Consortium Lerida
  Catalonia Region ES51 (Spain)

Keywords: VDI, Federated Infrastructure, Distributed Data Centre, Energy Efficiency, Carbon Footprint.

1 FI4VDI-SUDOE Project Objectives

The aim of the FI4VDI project is to develop a federated infrastructure network for the generation of virtual desktop services, and to promote sustainable development by leveraging the benefits deriving from transnational cooperation.
In brief, the project proposed the creation of a private cloud infrastructure using the resources available in various supercomputing centres located in different SUDOE regions, trying to ensure the protection of users' data and compliance with regulations pertaining to information security and the service-level agreements established. Implementation of this service would entail improved competitiveness and cost savings in the sectors targeted, where energy savings and efficiency are a distinguishing feature.
With a federated cloud computing model, desktops can be connected to dedicated servers with high rates of effective utilisation, greatly increasing energy efficiency and reducing the carbon footprint associated with the service. [1]
The problem addressed by the project was the need to determine the position and perception of public and private entities located in the SUDOE Space as regards the desirability of virtualisation of IT operating environments, and to promote the spread of cloud computing as a means to achieve savings, efficiency and simplicity

with the primary objective of ensuring improved productivity.
The territorial cooperation program of the European Space Southwest (SUDOE), Fig. 1., supports regional development through transnational co-financing projects through the FEDER (Fondo Europeo de Desarrollo Regional). Involved Spanish, French, Portuguese and British regions (Gibraltar) government agencies, can contribute to the growth and sustainable development of the area South-West Europe by developing transnational cooperation projects in different issues.

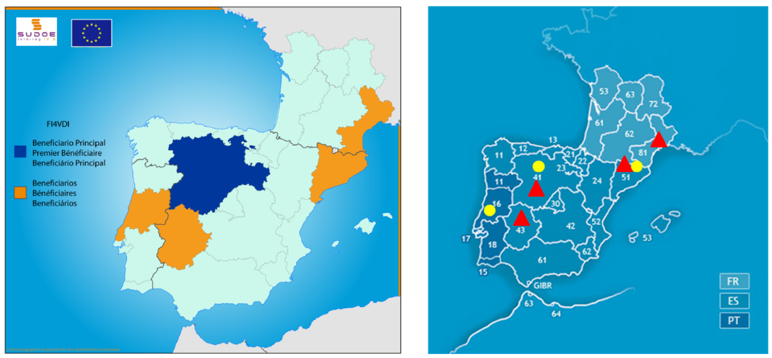

Fig. 1. Scope of the FI4VDI project in the SUDOE Space `www.sudoe.eu`. Setting of the FI4VDI project: profile of the partners participating in the project.

The origin of the project: The provision of cloud computing services by supercomputing centres has a positive effect on ecological footprints; dependence on physical ICT infrastructures is reduced when these are replaced by virtual ones, and this in turn produces a marked reduction in energy consumption in these institutions.
Project strategy and structure:

- Task group 0. Preparation
- Task group 1. Project coordination and management
- Task group 2. Technical infrastructure development
- Task group 3. Adapting applications to the cloud environment
- Task group 4. Integration. Prototypes
- Task group 5. Project monitoring and evaluation
- Task group 6. Publicity and information. Market capitalisation

2 Virtual Desktop Infrastructure-VDI as a technology proposal [2] [3]

The term desktop virtualization was introduced in the 1990s to describe the process of separation between the desktop, which encompasses the data and programmes that users employ for their work, and the physical machine. A "virtual" desktop is stored remotely on a central server rather than on the hard disk of an individual personal computer. This means that when users work on their desktop from their laptop or PC, all their programmes, applications, processes and data are stored and run centrally, allowing users to access their desktops from any device that can connect remotely to the central server, such as laptops, PCs, smartphones, or thin clients.

Through desktop virtualisation, the entire environment of an information system or the environment itself is encapsulated and delivered to a remote device. This device can be based on a completely different hardware architecture from the one used by the projected desktop environment. It can also be based on a completely different operating system.

Desktop virtualisation consists of the use of virtual machines to enable multiple network users to maintain their individual desktops on a single server or host computer. The central computer may be located in a residence, in the company or in a data centre. Users may be geographically dispersed and connected to the central computer via a local area network (LAN), wide area network (WAN) or via the Internet.

Desktop virtualisation offers advantages over the traditional model, in which each computer functions as a complete and independent unit with its own operating system, peripherals and applications. Energy costs are reduced because resources can be shared and allocated to users according to their needs, and the integrity of user information is enhanced because the data centre stores and safeguards all data and backups. Furthermore, software conflicts are minimised by reducing the total number of programmes stored on computers, and although the resources are distributed, all users can personalise and customise their desktops to meet their specific needs. Thus, desktop virtualisation provides greater flexibility than the client/server paradigm.

The limitations of desktop virtualisation include the possibility of security risks if the network is not well managed, the loss of user autonomy and data privacy, the challenges involved in creating and maintaining drivers for printers and other peripherals, difficulties in managing complex multimedia applications and problems in maintaining the addresses of virtual machine users consistent with those held by the data centre.

Benefits of VDI technology

Like any other technology, desktop virtualisation provides a number of key benefits that render this technology the first choice for a large number of users:

- Enhanced security and reduced desktop support costs [4]
- Reduced general hardware costs [5]
- Ensured business continuity [6]
- An eco-friendly alternative [7]
- Improved data security
- Instant implementation of new desktops and use of applications
- Virtually zero downtime in the case of hardware failure
- Significant reduction in the cost of new deployments
- The PC replacement cycle is extended from 2-3 years to 5-6 years or more

– Existing desktops include multiple monitors, bidirectional audio/video, video streaming, USB port supports, etc.
– Company employees can access their virtual desktops from any PC, including a PC in the employee's home
– Resources tailored to desktop needs
– Multiple desktops on demand
– Free provision of desktop computers (controlled by the policies of each corporation)

3 Description of the technical task groups of FI4VDI PROJECT

3.1 Infrastructure development

A **Technical design:**
A federated infrastructure is an aggregate of multiple resources, including virtualization resources, likely with heterogeneous architectures and geographically distributed members; the main goal is to make these characteristics transparent to the end-user. The end-user should be able to use and manage the whole resources using a single user/password set.
The design of the federation infrastructure includes a central node, known as "Federator Node" and any number of federated nodes, known as "Federated Zone" each. The "Federator Node" acts as Master of the federation infrastructure. This Master is located somewhere over any public or private cloud. [10]
The functions of the "Federator Node" are:
– Store and manage the root database for users and authentication
– Serve as single access point for users. Web interfaces and CLI are available
– Manage the deployment of virtual machines over the "Federated Zones"
There is not virtualization infrastructure (hypervisors or storage) in the "Federator Node".
"Federated Zones" are controlled by the "Federator Node". This one receives and processes the users requests for creating and deleting virtual machines. Orders are sent to single or multiple "Federated Zones". Every "Federated Zone" has a synchronous read-only copy of the users database. Hypervisors and storage are locally available in "Federated Zones". There is a local "Deployment Manager" receiving orders from "Federator Node" too.
End-Users perform deployment requests at "Federator Node". According to the permissions schema (ACL), virtual machines can be launched to single or multiple "Federated Zones". In order to avoid SPOFs (Single Point of Failure), the "Federated Node" is built over High Availability infrastructure, in a mix of physical and virtual servers.
Every launched Virtual Machine is independent from any other one. This is a purpose for multiple VMs in the same or different "Federated Zones". User credentials (User/Password) must be valid all over the federation infrastructure. And this will be valid even if new "Federated Zones" are added in the future.

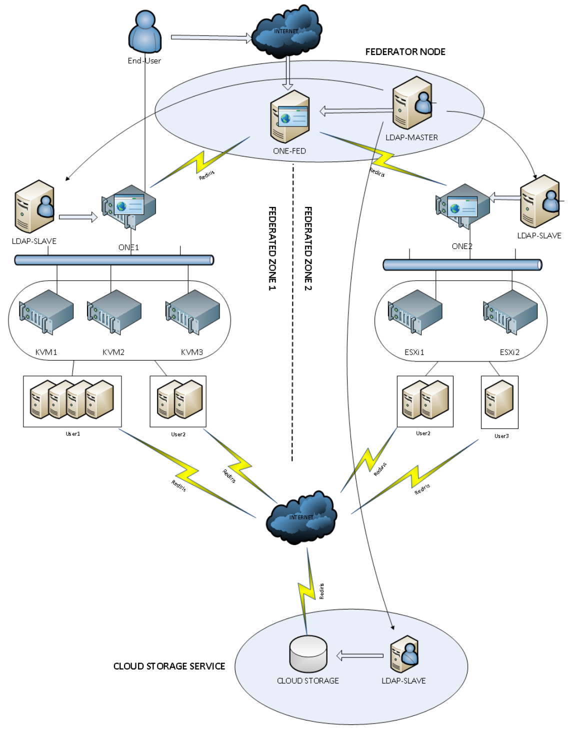

Fig. 2. Lower layer technical design. Main Items Source. FCSCL, 2014.

"Federated Zones" has XEN, KVM and VMWare hypervisors. Users can choose between then. A pool of heterogeneous hypervisors simplifies the job when clients want to migrate their virtual machines from other clouds to this one. In most cases their virtual machines will be compatible with any of the hypervisors without converting them.

The software that handles the whole federation infrastructure is "OpenNebula" (ONE) [8]. ONE is a deployment manager for Virtual Machines. It is licensed as Free Software (Apache License v2). Version 4.6 and following ones integrate a federated working mode. This mode fully matches the proposed technical scheme.

There is an ONE instance in Master Mode (ONE-FED) in "Federator Node". Users database is managed by an OpenLDAP instance (LDAP-MASTER). This instance is stored in "Federator Node" too. ONE provides multiple user interfaces, including web (known as Sunstone), CLI, OCCI (Open Cloud Computing Interface) and EC2 (Elastic Compute Cloud).

Any "Federated Zone" is locally governed by an ONE instance in slave mode (ONE1, ONE2, ONE3). This ONE performs any deployment operation ordered by the MASTER ONE. In order to reduce network traffic a read-only synchronous copy of users database (LDAP-SLAVE) is stored for local consul-

tations. Communications efficiency is one of the main goals of the infrastructure.
ONE-FED much reach any "ONE SLAVE" anytime in order to manage de-

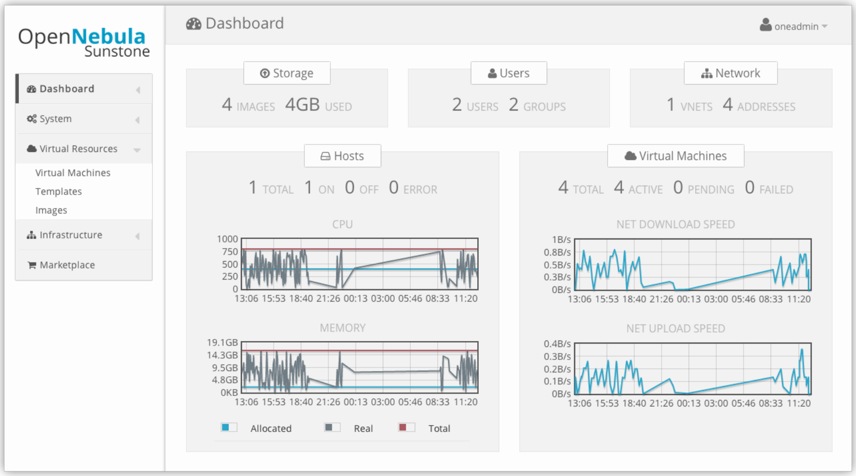

Fig. 3. Lower layer technical design. Main Items Source. FCSCL, 2014.

ployments and monitoring VMs. Because every "ONE SLAVE " is usually remotely located, with different security policies, the communications are supported by Lan-to-Lan IPSec VPNs. When possible, links are also supported over 802.1Q VLANs with R+D+i background networks (vg.- Spanish RedIRIS, French RENATER, European GEANT).
As value added service, a cloud storage stack is available for every end-user (CLOUD STORAGE). This one is built over the OwnCloud [9] software. OwnCloud is Free Software (AGPL3) and is located in "Federator Node", although it could be located anywhere over the Internet. The storage service is available from any VM in any "Federated Zone". It is available from any other place over Internet.
CLOUD STORAGE service uses the same LDAP users database in order to be completely integrated in the federation infrastructure.
One of the main purposes of this design is scalability. New "Federated Zones" can be fastly added in a few steps. The federation infrastructure is a "living entity" and can grow in order to accommodate to peak loads.
Nowadays, the federation infrastructure is composed of 3 "Federated Zones". The "Federated Node" and the "CLOUD STORAGE" are physically located in the same datacenter that one of the "Federated Zones", but logically isolated.
Each "Federated Zone" belongs and is provided by a different Project Partner.

B **Timeline Deployment**

3 phases have been defined in the project roadmap. To deploy the federated infrastructure many IT items (servers, storage systems, network devices, etc) are needed.

Phase 1 is known as restoration of value for IT systems. Project partners' datacenters were mostly equipped with HPC (High Performance Computing) IT systems. As most partners are 'Supercomputing Centers', HPC IT systems were the usual equipment. Nowadays, the logical evolution of 'Supercomputing Centers' has been from HPC to Cloud. Some HPC IT systems has been reused as Cloud IT systems. In these systems, many of the old computing servers are now hypervisors.

So, many of the necessary IT systems for the project were currently available. Specifically:

- COMPUTAEX Partner:
  - 4 HP Proliant BL460c-G6 servers
  - HP EVA8100 Fiber Channel NAS/SAN Storage
  - HP Storageworks EML 245e Tape Storage
  - RedIRIS 10Gb connectivity
- UdL Partner:
  - 1 HP Proliant DL380 G5 Server
  - RedIRIS 10Gb connectivity
- FCSCL Partner:
  - 3 HP Proliant DL580 servers
  - Dell Equallogic 6100 iSCSI SAN Storage
  - RedIRIS 1Gb connectivity (10Gb update in progress)
- UM2 Partner:
  - 2 IBM dx360 M3 servers
  - IBM DCS9900 Parallel Storage
  - RENATER 1Gb connectivity

Phase 2. Many of the necessary IT systems involved in the project has been obtained in Phase 1. But the pool of necessary IT systems is not complete. Because of this, many IT equipment has been acquired. During phase 2 we will invest in new infrastructure servers. Specifically:

- COMPUTAEX Partner:
  - 3PAR 7200 FC SAN Storage
  - 2 HP BL465 G8 Servers
- FCSCL Partner:
  - Dell Equallogic 6100 iSCSI SAN Storage

Phase 2 is finished with the technical work for setting the federation up and running.

The foundations for **Phase 3** falls over communications [11]. The federated infrastructure is extended with a new partner: CESGA (Centro de Supercomputacin de Galicia, www.cesga.es). The new partner is a Supercomputing Center too. Storage systems will be deployed at CESGA's datacenter and will be also connected with the network of the Federated Infrastructure.

The main goal, using storage and high capacity network, is to use the new

member for backup tasks and contingency plan. As a prototype, the obtained knowhow will allow to add new "Backup Zones" in a few single steps.
Backup Zones store copies of data and virtual machines running at Federated Zones. It is not a fully equipped Federated Zone as it hasn't a complete pool of hypervisors, but it can be used in this way if necessary.

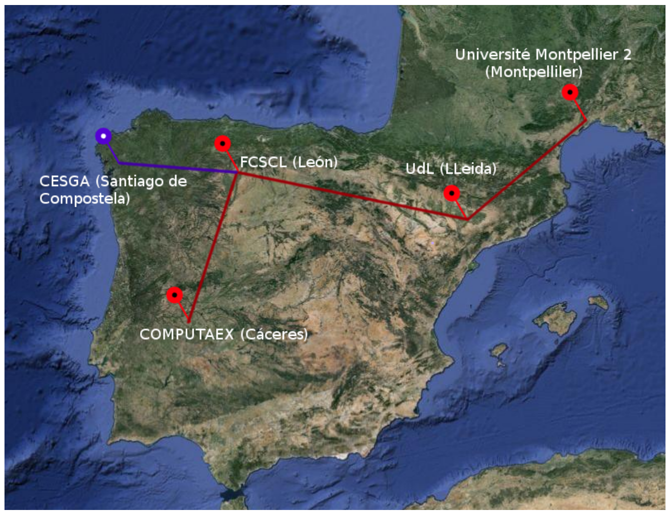

Fig. 4. Physical locations included in the Federated Infrastructure. Red for "Federated Zones" and purple for "Backup Zones" Source: FCSCL. Google Maps, 2014.

3.2 Prototypes and adaptation processes to the Cloud paradigm of applications

After designing a global interface access and monitoring for all the participating entities and potential end users, we proceed to implement 4 prototypes and Cloud adaptation processes, with applications in different scenarios, both public and private sector:

1. VDI University and Academic Management: eGovernment - Procedures for university management replicated with the same hw and sw resources. Mass deployment of virtual desktops on demand, persistent or non-persistent in the environment of a classroom working. Electronic Administration of Public Universities of Castilla y Leon.
2. VDI Health management: management model and formalization of knowledge (study of cases) Surgical Oncology : model and formalization of knowledge management (colorectal cancer study of cases - CCR).
3. VDI Public Administration: Municipalities Digital Network - a machine on demand application that handles certain specificities linked to the LOPD (Ley

Orgánica de Protección de Datos in spanish). Application in the cloud for managing the Data Protection Act for Provincial Councils and Deputations. Migration of the corporate systems of the Council of Leon, a Cloud Computing environment on FCSCL systems.
4. VDI Outsourcing. Outsourcing of resources and services. Automated Diagnostic System for Energy Efficiency

By the interconection of various Networks Communications Science and Technology of EU Member States-Regions SUDOE facilitates access to prototypes and applications and/or developments adapted to the Cloud paradigm developed by the project participants entities or any other end user of interest in other SUDOE territories.

4 Indicators of FI4VDI project

The indicators are a useful tool to determine the degree of progress of the project. These measuring instruments used to assess changes in relation to the initial situation and to detect difficulties or deviations from the work plan.
There are three categories:
Performance indicators - generally corresponds to the products resulting from the implementation of the project.

- R+D projects with added value from an environmental perspective
- Companies and SMEs that have been part of innovation partnerships funded
- Projects of telecommunications networks and for encouraging the application of ICTs
- Deployment Type: Private/Public/Hybrid/Community
- Participation in Conferences, Workshops and Working day diffusion

Outcome indicators - reports on the short-term effects on the target audience of the operation financed.

- New technologies developed
- Transnational cooperation in innovative networks created
- Tools (applications and services) for technological transfer between companies and technological centers and SMEs adopted in SUDOE countries/regions
- Companies and SMEs that have benefited from project results conducted
- SUDOE area with improved access to ICTs
- Publications resulting from the project

Impact indicators - This indicator will reflect the result of the action taken in the long term. This is to assess the impact beyond the direct and immediate effect on direct beneficiaries.

- New technologies transferred to enterprises, SMEs and/or managing entities
- Permanent networks of cooperation established
- Agents (institutions, enterprises, SMEs, etc.) connected to telecommunication networks created
- Rate of adoption of Cloud computing model
- Rate of knowledge of Cloud computing and virtualization technology

5 Results

Here FI4VDI Project expected results are described:

- Creation of a Platform as a Service (PaaS) for mass deployment of virtual desktops. Federation of the participant supercomputing centres infrastructures.
- Creation of an innovative cloud computing service aimed at users in the public and private sectors.
- Enhanced competitiveness and cost savings in the sectors targeted by the service created.
- Establishment of strategic recommendations: definition of reliable models for cloud computing (service levels, system capacity, system restoration, interoperability through shared service infrastructures, migration models), identification of service areas and evaluate and promotion of cloud computing as a tool for achieving cost savings and technological optimisation.
- Establishment of technological recommendations: identification of existing solutions and possibilities, assessment of the real capacity of suppliers, selection of an applications and systems map, initiation of a cloud computing strategy by adopting private clouds and infrastructure and platform services, establishment of system migration plans and identification of cloud computing as a model that fosters other technologies which are either emerging or in the process of expansion, such as energy sustainability in the area of IT or open source solutions.
- Establishment of management recommendations: definition of systems for assessing investment returns, analysis of organisational impact and identification of change management models, development of new contracting models and practices, standardisation and organisation of common services and definition of risk analysis models.

6 Conclusions

The spread of cloud computing in the Spanish public sector is still limited, and is more common among local authorities than among regional and state institutions. In general, the most common mode of deployment is private.
Savings, efficiency and simplicity are the reasons that have prompted public authority institutions to contract cloud computing services.
Those public institutions that decided to adopt cloud computing did so after carrying out a legal analysis focused primarily on data protection legislation.
According to the public authority bodies that have adopted cloud computing, the principle benefits of this model are the savings in costs and time it represents, whilst integrity of services and data was identified as the main difficulty.
The Spanish public sector perceived the cloud as a technological and, above all, operational advantage which has met their initial expectations regarding cloud computing.
Among the public authority bodies already using cloud computing, the future

prospects are very bright: they intended to continue working in the cloud, they would recommend this technology to other institutions and they expected to continue to obtain future benefits from using the cloud.
However, those public institutions that are not yet using the cloud were more wary: few intended to incorporate technological solutions, and only a minority of these would consider cloud computing.

Acknowledgments
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Fig. 5. Ref. SOE4/P3/E804-FI4VDI. Project FI4VDI-SUDOE corporate logo.

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