European Research Activities in Cloud Computing

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Edited by

Dana Petcu and José Luis Vázquez-Poletti

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PREFACE

Cloud computing is currently undergoing a great deal of discussion. However, despite considerable efforts and investments in the industry of cloud computing, critical problems have yet to be solved and the research and development community involved in distributed computing is searching for viable solutions.

This book intends to present a snapshot of the on-going activities in research and development undertaken at the European level through collaborative work of multi-national teams in the frame of the FP7 programme of European Commission.

The material is split in four parts. Two are oriented towards the potential clients of cloud computing: on one side the service offer towards the potential clients of cloud computing, on another the methods of adopting the cloud computing paradigm. The other two parts address the cloud computing providers' problems: one deals with the cloud management while the second with the automation efforts.

The idea to group in a book the contributions of different European projects dealing with cloud computing problems has emerged on the occasion of organising the second Workshop on Software Services: cloud computing and Applications based on Software Services (2nd WoSS, June 6–9, 2011, in Timisoara, Romania, http://sprers.eu/events/2nd-woss).

In a period which is confused about what cloud computing can and cannot achieve, we hope that the content of the book will transform those clouds in the reader's sky into white, fluffy and friendly ones.

We warmly recommend this book to the students, researchers and developers working in the field of distributed computing.

—Dana Petcu and José Luis Vázquez-Poletti

INVITATION TO A JOURNEY IN THE ERA OF CLOUD COMPUTING

DANA PETCU

Before starting the adventure of solving the current cloud computing problems together with the authors, the reader is invited to a briefing on cloud computing and its status in European Research Area (ERA).

First Step is Also the First Problem: What is Cloud Computing?

A common understanding of the notion of cloud computing is still missing. This fact reflects a natural process in computer science, and especially in distributed computing. A similar example is that of grid computing, a term coined two decades ago and an acceptable definition of which has come about only in the middle of the last decade.

Taking into account the orientation of this book towards exposing the research and development activities in cloud computing in European collaborative projects, we are considering here the European Expert Group definition (from its report The Future of Cloud Computing. Opportunities for European Cloud Computing beyond 2010, January 2010):

> A cloud is an elastic execution environment of resources involving multiple stakeholders and providing a metered service at multiple granularities for a specified level of quality (of service).

This definition underlines two of the main characteristics of the cloud computing paradigm which differentiate it from other distributed computing paradigms: elasticity and metering.

The definition promoted by NIST (US National Institute of Standards and Technology) from January 2011 reveals another characteristic—on-demand provisioning:

> Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

The cloud computing paradigm shakes up the market of IT services by its pay-per-use concept for the leased resources and its promise to cut operational and capital costs. The resources, either infrastructure or software, are available over the network and their providers use a multi-tenant model and virtualisation techniques.

The deployment models of the cloud computing concept are currently classified as follows:

- Private Cloud, when the resources are owned or leased by a single organisation
- Community Cloud, when the resources are shared by several organisations between which agreements are established in topics like mission or security policies
- Public Cloud, when the resources are sold to a general public
- Hybrid Cloud, when a composition of several clouds of previous types is built for a service or application with the aim of providing a new business, enable data and application portability, or support elasticity when needed.

The resources in cloud computing are delivered as services. The "As a Service" (with the well known acronym aaS) paradigm refers to components across network which are available for reuse. A large variety of resources can be offered following this paradigm, leading to a general image of "anything" available "as a Service" (shortly XaaS). Hardware, software, platform, infrastructure, process, storage, database, identity, application, integration, network, monitoring, testing, high performance computing, communication, governance, security, backup, marketplace, and even human experience are nowadays offered "aaS." However, the most common service delivery models are the following three:

(1) **Software as a Service** (SaaS), also known as Application as a Service (AaaS), is the model in which an application is hosted as a service and customers access it using Internet protocols. It is the opposite of the Software as a Product model, currently used worldwide. Already, classical examples of SaaSs have emerged,

including office automation applications, accounting systems, online video conferencing, web analytics or web content management tools.

(2) **Platform as a Service** (PaaS), also known as Cloudware, offers the resources required to build new applications and services, without locally installing software. The current offer includes services for application design, development, testing, deployment, hosting for team collaboration, services for database integration, scalability, and versioning for state management.

(3) **Infrastructure as a Service** (IaaS), also known as Hardware as a Service (HaaS), allows the renting of CPU cycles, server space, network equipment, memory and storage space. The major benefit is the fact that the infrastructure can be dynamically scaled up and down depending on the users' needs.

Cloud computing technologies

While cloud computing is a new way of delivering resources, several old and new technologies and tools support the paradigm. The high interest in it, as well in its financial benefits has resulted in a large variety of technological offers. Any attempt for their classification will be absolute at the moment of its appearance, since the market is still highly dynamic.

With regards to this introductory material, we propose a simple classification based on several criteria of a refined delivery model, like hosted service or deployable services, distributed or single site offers.

Most well known in the cloud computing market are the hosted services, available to all delivery levels, SaaS, PaaS or IaaS, that are accessible as Public Cloud offers. On the other hand, for the developers of new services and applications, the deployable cloud-native or compliant services and tools are important assets. Since this book reports on the research activities of European computer scientists involved in the daily innovation of new technologies and tools for cloud computing, deployable services are a major topic.

Tables I.1 and I.2 below propose a taxonomy of the existing offers of cloud computing services, split at the highest level in offers for resources (Table I.1) and offers for services and application development (Table I.2). These tables provide just a snapshot of the available offers without trying to include all of them or to offer a straight split between categories (since several technological offer are spread over several categories). They intend only to help the reader of this book to identify the type of technologies that will be referred to in the following chapters.

Table I.1. A partial taxonomy of the resource offers available for cloud computing in the summer of 2011

	Offer type	System	Group	Representatives
Storage	Columnar databases	Hosted		Amazon Simple DB, BigTable
		Deplo-yable	Distri-buted	Cassandra, Hadoop HBase, Hypertable, Tiramole
			Single server	M BD, MonetDB, LucidDB, Akiban
	Key-value databases	Hosted		Amazon S3, RackSpace Cloud Files
		Deplo-yable	Distri-buted	Riak, Membase, kumofs, LightCloud, GridFS, Voldemort, Redis, Hibari, Kal, Ringo, Dynomite, SubCloud
			Single server	MemcacheDB, Tokyo Cabinet, Kyoto Cabinet, BerkleyDB, LevelDB, GT.M
	Document databases	Deplo-yable		MongoDB, CounchDB
	Distributed file-systems	Deplo-yable		Hadoop HDFS, Tahoe LAFS, Ceph, Sector, CloudStore, MooseFS, mofilefs, XtreemFS
	Distributed atomic databases			Zookeeper, Scalaris, Keyspace
	Distributed hash tables			Kademlia, Pastry, Tapestry, Chord
Compute	Map-Reduce	Hosted		Amazon Elastic Map Reduce
		Deplo-yable		Hadoop, Riak Map Reduce, Hive, Hadoop Pig, Cascading, CloudBase, Sawzall, Disco, Http Map Reduce, DyradLINQ, fairly
	Infrastruc-ture	Hosted		Amazon EC2, Amazon EBS, RackSpace Cloud Servers, GoGrid, Force.com, FlexiScale, Slicehost, ElasticHosts, CloudSigma, NewServers
		Deplo-yable		Eucalyptus, OpenNebula, OpenStack, Nimbus, XCAT, Cobbler, BoxGrinder, Tashi, VPN Cubed, Elastic Server, OpenQRM
Communicate	Message queues	Hosted		Amazon SQS, Amazon SNS, StormMQ, Linxter
		Deplo-yable	Clus-tered	RabbittMQ, ZeroMQ, HornetQ
			Single server	ActiveMQ, MorbidQ, Kestrel, MemcacheQ, Starling

Table I.2. A partial taxonomy of the developemnt offers available for cloud computing in the summer of 2011

Support	Type	Representatives
Platforms	Hosted	AppEngine, SmartPlatform, Heroku, Azure, GigaSpaces XAP, Stackato, CloudIQ, Cloud Burst, Jamcracker, Bungee Connect, LongJump, Enomaly ECP
	Deployable	AppScale, TyphoonAE, Cast, Project Caroline, SpawnGrid, Duostack, CloudFoundry, NodeJitsu, Nodester, DotCloud, CloudBees, OpenShift, Aneka, AppZero, vCloud, RightScale, JOALA Cloud Manager
APIs	Libraries and frameworks	DeltaCloud, DataNucleus, Spring Data, libcloud, CloudLoop, Dasein Cloud API, jclouds, Simple Cloud API, Restlet, Sun Cloud API, BOOM, SalsaHpc, Dryad, Orleans
	Standards	OCCI, CDMI
IDL		XPIDL, ETCH, WebIDL, Ice

Table I.3. Communication protocols

Support	Type	Representatives
Message queues	ASCII	STOMP
	Binary	AMQP, JMS
Serialization	Binary	Protocol buffers, Erlang external term format, MessagePack, Avro, BSON, XDR, ASN.1
	ASCII with binary support	UBF, S expressions, Bencode
	ASCII	JSON, XML, Netstrings, YAML, SDL
RPC	Binary	Sun RPC, BERT, Hessian, Thrift, AMF, RxPC
	ASCII	JSON RPC, XML RPC, SOAP
	Queues, deployable	Geaman, peafowl, beanstalkd

Tables I.1-3 indicates the communication protocols that are currently used in cloud computing.

What in Missing in the Cloud Computing World? Towards a Research Agenda

The main challenges for cloud computing identified in the Open Cloud Manifesto 2009 were data and application interoperability and portability, governance and management, metering and monitoring, as well as security. Note the projects that will be presented in this book emerged in the context of that year's concerns: the research proposals have responded to the call for projects elaborated under the umbrella of the moment-related needs of cloud computing that were specified above. Therefore, the reader will find in this book several ideas that take a concrete form in dealing with the complex conceptual and technical issues behind the main challenges of cloud computing.

The identification of new challenges is a constant topic both for researchers and practitioners. In this context, Armbrust et al. (2010) revised the top ten obstacles and opportunities for cloud computing. The primary obstacles identified are: data lock-in, confidentiality, auditability and transfer bottlenecks; quick scaling, performance unpredictability, scalable storage, management of large distributed systems, reputation sharing, software licensing and business continuity. Despite the concentrated efforts of the cloud technology developers, most of these problems still remain unsolved and are subjects of research agendas. In this context, the top ten opportunities mentioned by Armburst et al. are the following: use of multiple cloud providers, compatible software to enable hybrid clouds, special encryption and firewalls, higher bandwidth switches, improved support for virtualized resources (including debuggers), scalable store, build auto-scalers, snapshots acquiring techniques, reputation-guarding services, and pay-per-use licenses. In particular, the subject of using multiple clouds has revealed considerable interest, also reflected in this book.

Concerning the recommendations for the European Research Area in cloud computing, the European Expert Group in cloud computing stated in 2010:

> Europe's main opportunities to participate in the cloud movement consist in particular in aspects related to extending and completing the capabilities of current cloud systems, whereby the long-term goal consists in realizing meta-scalable cloud systems and services.

ERA of Cloud Computing

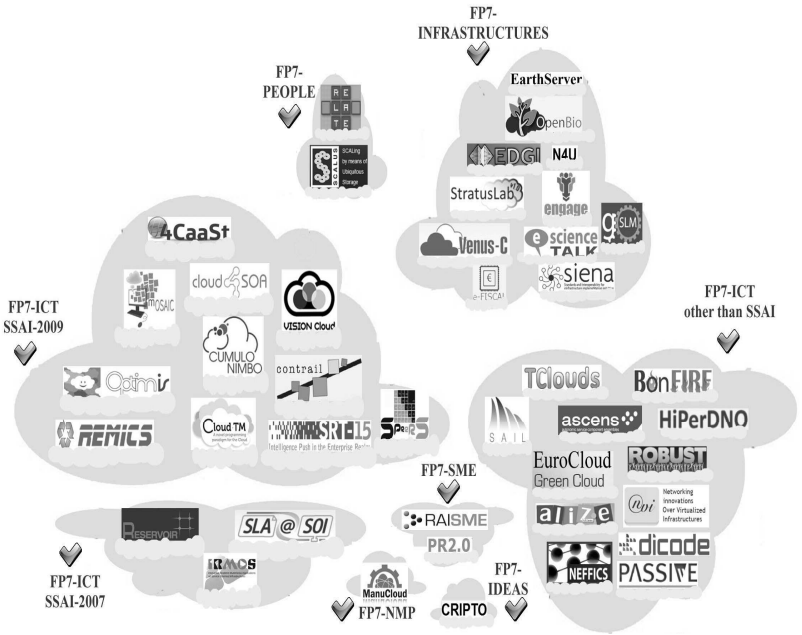
A new era in distributed computing was opened with the advent of cloud computing. Worldwide computer scientists, researchers, programmers, IT specialists, analysts, teachers, CEOs and even politicians are using the new paradigm in their daily activities or communications with the hope of contributing to some solutions of our daily societies' problems, through innovation or commercialization, or support of both.

The tremendous activities in cloud computing are recognised by experts designing the European Commission's programmes for research and development. Moreover, their analyses show that the era of cloud computing will be at least as long as that of the grid. Therefore, the Seventh Framework Programme (FP7) of the European Commission stimulates research, development and innovation in the cloud computing area through indication of the high expectations on: research and development activities in the context of the Cooperation programme in the Information and Communication Technologies (FP7-ICT), transfer of knowledge, and innovation or support activities in Ideas, People or Capacities programmes. Other European Commission's programmes, like Competitiveness and Innovation Framework Programme (CIP) or Cooperation in Science and Technology (COST) are also looking forward to applications related to cloud computing.

The landscape of current European Research Area (ERA) related to cloud computing is diverse, varying from new emerging concepts and technologies to simple usage in innovative applications. In what follows we will focus on the activities reported in the frame of FP7, organised in the context of projects of different sizes, from integrated projects (IP) and networks of excellences (NoE), to small targeted research projects (STREP) and support actions (SA). Fig. I.2 below presents in this context a snapshot of the clusters of the FP7 projects related to cloud computing. Note that this snapshot reflects the state of the art as of summer 2011 and it is developed with the occasion of preparing this chapter (not to reflect the opinion of the European Commission).

The biggest technological cluster (to which this book mainly refers, and marked as the biggest cloud in fig. I.1) is that developed under the SSAI Objective of FP7-ICT programme (Objective 1.2 from 2009: Service and Software Architectures, Infrastructures and Engineering), where at least ten projects are currently developing the concepts, technologies and tools of tomorrow's cloud computing. Their activities are relying upon the achievements of a previous SSAI cluster (Objective 1.2 from 2007: Internet of Services, Software and Virtualisation).

Fig. I.1. The clusters of FP7 projects related to cloud computing topics as of summer 2011



Other objectives of the FP7-ICT programmes are also currently supporting the cloud computing technologies through their enhancement or usage. Their activities are recognised in fig. I.1 as a particular group of twelve non-SSAI projects (i.e. FP7-ICT rather than SSAI).

An important contribution in terms of both technologies, applications and e-infrastructure support is provided by the consortium members of the projects supported by the Capacity programme, in particular the work-programme of FP7-Infrastructure. The specific group of projects is presented in fig. I.1 as the third biggest cluster (FP7-Infrastructures).

Several cloud computing related projects are encountered in other FP7 programmes, like Ideas or Peoples.

The promises and current contributions of these clusters of projects, researchers and practitioners are summarised in the tables I.4 to I.8 below. More details about eleven projects from the three biggest clusters presented in fig. I.1 can be found in this book.

Table I.4. The SSAI-2009 cluster of FP7 projects related to cloud computing topics

Acronym	Web page	Cloud-related topics
4CaaST	4caast.morfeo-project.org	The project aims to create a PaaS which supports the optimized and elastic hosting of Internet-scale multi-tier applications.
Cloud4SOA	www.cloud 4soa.eu	The project focuses on resolving the semantic interoperability issues of cloud infrastructures and on introducing a user-centric approach for cloud compliant applications. It combines three paradigms: cloud computing, Service Oriented Architectures (SOA) and lightweight semantics.
Cloud-TM	www.cloudtm. eu	The project aims at defining a programming paradigm and developing a self-optimizing distributed transactional memory middleware that spares programmers the burden of coding for distribution, persistence and fault-tolerance. The platform features autonomic resource provisioning and pervasive self-tuning schemes.
CONTRAIL	www.contrail-project.eu	The goal of the project is to 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.
Cumulo Nimbo	www.cumulo nimbo.eu	The project promise to deliver a PaaS that will provide consistency, availability, and simpler programming abstractions, such as transactions.
mOSAIC	www.mosaic-project.eu	The project builds an open source PaaS that negotiates cloud services as requested by their users. Moreover, it proposes a vendor-agnostic API for programming and deploying cloud-complaint applications

OPTIMIS	www.optimis-project.eu	The high-level objective is to enable an open and dependable cloud service ecosystem that delivers IT services that are adaptable, reliable, auditable and sustainable. This will allow organisations to automatically and seamlessly externalize services and applications to trustworthy and auditable cloud providers.
REMICS	www.remics.eu	The main objective is to specify, develop and evaluate a tool-supported model driven methodology for migrating legacy applications to interoperable service cloud platforms.
SPRERS	www.sprers.eu	The project supports dissemination of FP7-ICT project achievements related to software services, including organisation of trainings, workshops and this book.
SRT-15	www.srt-15.eu	The project intends to bridge the gap between cloud infrastructures and enterprise services by building a distributed service platform. It relies on four key enabling technologies: content-based routing, complex event processing, dependability and data privacy
VISION Cloud	www.vision cloud.eu	The goal of this project is to introduce 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.

Table I.5. Former SSAI-2007 cluster of FP7 projects related to cloud computing topics

Acronym	Web page	Cloud-related topics
RESERVOIR	www.reservoir-fp7.eu	By merging virtualisation, grid and business technologies, it allowed the migration of resources across geographies and administrative domains, maximising resource exploitation, and minimising costs.
IRMOS	www.irmosproject.eu	Designed, developed and validated cloud solutions allowing the adoption of interactive real-time applications, and especially multimedia applications, enabling their rich set of attributes (from time-constrained operation to dynamic service control and adaptation) and their efficient integration into cloud infrastructures.
SLA@SOI	sla-at-soi.eu	It has provided a framework for enhancing the provisioning of services with: predictability and dependability; transparent SLA management; automation of the process of negotiating SLAs and provisioning, delivery and monitoring of services

Table I.6. The cluster of FP7-ICT non-SSAI projects related to Cloud computing topics

Acronym	Web page	Cloud-related topics
Ascens	www.ascens-ist.eu	The project focuses on service-component ensembles, hierarchical ensembles built from service components, and knowledge units connected via a dynamic infrastructure. To realise ensembles of service components a set of case studies from robotics, cloud computing and e-Vehicles are used.
Aliz-e	www.aliz-e.org	The project develops the theory and practice behind embodied cognitive robots capable of maintaining believable any-depth affective interactions with a young user. The integration of cognitive components is based on cloud computing for embedded systems.
BonFIRE	www.bonfire-project.eu	The project designs, builds and operates a multi-site cloud facility to support applications, services and systems research targeting the Internet of Services community within the Future Internet.
Dicode	www.dicode-project.eu	The project facilitates and augments collaboration and decision making in data-intensive and cognitively-complex settings. It exploits and builds on several concepts like cloud computing, MapReduce, Hadoop, Mahout, and column databases, to search, analyze and aggregate data existing in diverse, extremely large, and rapidly evolving sources
EuroCloud	www.eurocloud server.com	The project focuses on improvement in system density and energy efficiency for data center applications to a scale supporting hundreds cores in a single server. Mobile cloud services are used in validation scenarios, while in general the targeted market is that of the companies able later on to construct efficient, environmentally clean and compact data centers for the deployment of green cloud services.

HiPerDNO	dea.brunel.ac.uk/ hiperdno/	The aim of the project is to develop a new generation of distribution network management systems that exploit near to real-time HPC solutions with inherent security and intelligent communications for smart distribution network operation and management. Cloud and grid computing are used to enable scalable data mining, feature extraction, and near to real-time state estimation.
NEFFICS	neffics.eu	The project builds an innovation-driven ecology for networked enterprises, on top of an established cloud-based, software-as-a-service business operation platform, combined with an advanced innovation management software platform.
NOVI	www.fp7-novi.eu	The project concentrates on efficient approaches to compose virtualised e-infrastructures towards a holistic Future Internet cloud service. Resources belonging to various levels are managed by separate providers. The project search methods, information systems and algorithms enable users with composite isolated slices, baskets of resources and services provided by federated infrastructures.
PASSIVE	ict-passive.eu	The project proposes an improved model of security for virtualised systems to ensure that separation of concerns can be achieved in large scale deployments, threats from co-hosted operating systems are detected and dealt with, and public trust in application providers is maintained in a dynamic hosting environment. It proposes a policy-based security architecture allowing the easy specification of security provisions; fully virtualised resource access, with fine-grained control over device access; and a dynamic system for authentication.

ROBUST	www.robust-project.eu	The project deals with large-scale data management and analysis tasks for understanding and managing complex user behaviours and ecosystems in online business communities. A highly scalable cloud and stream-based data management infrastructure serves to handle the real time analysis of large volumes of data.
SAIL	www.sail-project.eu	The project researches and develops novel networking technologies. It improves application support via an information-centric paradigm and develops mechanisms and protocols to realise the benefits of a Network of Information. It enables the co-existence of legacy and new networks via virtualisation of resources and self-management, fully integrating networking with cloud computing to produce cloud Networking.
TClouds	www.tclouds-project.eu	The project targets cloud computing security and minimisation of the widespread concerns about the security of personal data by putting its focus on privacy protection in cross-border infrastructures and on ensuring resilience against failures and attacks. TClouds develops a cloud infrastructure that can deliver computing and storage that achieves a high level of security, privacy, resilience, and yet is cost-efficient, simple and scalable.

Table I.7. The FP7-Infrastructures' cluster of projects related to Cloud computing topics

Acronym	Web page	Cloud-related topics
EarthServer	www.earthserver.eu	The project aims at open access and ad-hoc analytics on Earth science data, based on the geo service standards Web Coverage Service and Web Coverage Processing Service. It develops open-source client and server technologies scalable to Exabyte volumes, based on distributed processing, supercomputing, and cloud virtualisation.
EDGI	edgi-project.eu	The project aims to deploy desktop grid and cloud services for European Grid Initiative's user communities that require extremely large multi-national e-infrastructure. Software components of ARC, gLite, Unicore, BOINC, OpenNebula, Eucalyptus etc. are integrated into SG-DG-Cloud platforms for service provision. The project also provides a workflow-oriented science gateway to enable user communities to access the infrastructure more easily.
Engage	www.engage-project.eu	The main goal of the project is the deployment and use of an advanced service infrastructure, incorporating distributed and diverse public sector information resources as well as data curation, semantic annotation and visualisation tools. The project explores synergies with e-Infrastructure projects and service providers to leverage on existing grid and cloud services for curating, storing, processing and exploiting large amounts of public sector information.
EuBrazil OpenBio	www.eubrazilopenbio.eu	The project deploys an e-Infrastructure of open access resources (data, tools, services), to make significant strides towards supporting the needs and requirements of the biodiversity scientific community. This data e-Infrastructure results from the federation and integration of individual existing data, cloud, and grid EU and Brazilian infrastructures and resources across the biodiversity and taxonomy domain, namely Catalogue of Life, OpenModeller, D4Science-II and Venus-C.
e-ScienceTalk	www.e-sciencetalk.org	The project aims to bring the success stories of Europe's e-infrastructure to a wider audience. It coordinates the dissemination outputs of European e-Infrastructure projects, ensuring their results and influence are reported in print and online.

e-Fiscal	www.efiscal.eu	The scope of the e-FISCAL proposal is to analyse the e-infrastructure costs, facilitated by national entities (NGIs and HPC centres), compare them with equivalent commercial leased or on-demand offerings and provide an evaluation report.
gSLM	www.gslm.eu	The project aims to improve service level management (SLM) in the grid. It generates new approaches for SLM and offers best practices from e-infrastructure service provision in systems that span multiple administrative domains. The outputs are relevant for managing the QoS aspects of the “inter-cloud” solutions.
N4U	Not available	The project will provide an e-Science environment to deliver a virtual laboratory offering neuroscientists access to a wide range of datasets and algorithm pipelines, access to computational resources, services, and support. It will integrate and augment the service provision with computational resources from grid, cloud and HPC.
Siena	www.siena initiative.eu	SIENA defines a future e-Infrastructures roadmap focusing on interoperability and standards. The roadmap presents scenarios, identifies trends, investigates the innovation and impact sparked by cloud and grid computing, and delivers insight into how standards and the policy framework is shaping future developments and deployments.
Stratus Lab	stratuslab.eu	The StratusLab Toolkit integrates cloud and virtualisation technologies and services within grid sites and enriches existing computing infrastructures with IaaS provisioning paradigms.
Venus-C	www.venus-c.eu	VENUS-C proposes an open and generic API at platform level for scientific applications, striving towards interoperable services. Its platform will be based on Windows Azure, Eucalyptus, OpenNebula, EMOTIVE.

Table I.8. Other programmes' clusters of projects related to Cloud computing topics

Progr.	Acronym	Web page	Cloud-related topics
FP7-Ideas	Cripto	lib.bioinfo.pl/projects/view/29666	The project investigates topics in cryptography from a theoretical and practical perspective. The application domains investigated are cloud computing, electronic voting, protocols for trusted computing and privacy preserving methodologies.
FP7-NMP	Manu Cloud	www.manucloud-project.eu	The project develops and evaluates an IT infrastructure which supports on-demand manufacturing scenarios. It provides users with the ability to utilise the manufacturing capabilities of configurable, virtualised production networks, based on cloud-enabled, federated factories, supported by a set of SaaS applications.
FP7-People	RELATE	www.relate-itn.eu	The initial training network provides opportunities for young researchers to study the latest technologies, platforms and tools in engineering and provisioning of service-based cloud applications.
	SCALUS	www.scalus.eu	The initial training network aims at elevating education, research, and development inside areas of cluster, grid, and cloud storage.
FP7-SME	RAISME	www.raisme.eu	The project builds an open source platform for SME applications. It enables high-tech organisations with niche skills to rapidly build and scale innovative ICT applications. This is achieved through the use of mashup technology and cloud computing.
	PR2.0	Not available	The project promises an affordable, cost-effective centralised web tool for management of marketing campaigns using popular social media tools. It allows companies to monitor user-generated content about their business or brands, to manage their online reputation, and to be alerted to possible public relations crises. A cloud computing model ensure that the tool is accessible to SMEs

Cloud Computing in ERA—Whereto?

The FP7-ICT's Work-programme for 2011–2012 recognises that: "cloud computing is transforming the software and the service industry and can have a profound impact on business ICT strategies in all sectors." Therefore, one of its objectives (ICT-2011.1.2) specifically targets cloud computing technologies, while other objectives are supporting the spread of trust (ICT-2011.1.4) or applications (ICT-2011.5.5). In this context, the main topics of the next project proposals responding to the European Commission call for research and development activities will focus on:

- Hybrid clouds, in particular on topics like interoperability, portability, data protection and its distribution control, service composition across heterogeneous environments
- Intelligent techniques like automatic management of resources, agile elastic scalability, support for context-aware applications
- Improvement of current services and technologies such as those for infrastructure virtualisation, mobile applications, energy efficiency, network support for cloud computing, or open source implementations.

The CIP's ICT-PSP programme for 2011–2012 is also supporting the technological transfer of the results obtained in the frame of research activities towards general society, for example by sustaining the proposals for innovating and making government services more effective and fully interoperable. The emphasis is placed on cloud computing in public services allowing for efficiency gains, service aggregation, sharing and reuse.

On the other hand, long-term research activities in cloud computing are foreseen and recommended by several European organisations of experts, like ENISA (European Network and Information Security Agency) or e-IRG (e-Infrastructure Reflection Group). ENISA has already recommended (in its report cloud computing—Benefits, risks and recommendations for information security, 2009) focusing on building trust in clouds (with a special emphasis on data confidentiality and higher assurance in clouds), data protection in large scale cross-organisational systems (in special monitoring, traceability, forensics and evidence gathering, international regulations of data protection), or large scale computer system engineering (resource isolation mechanisms, interoperability between clouds, improved resilience).