Towards Cloud-Based Engineering Systems

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Department of Electrical Engineering, Faculty of Sciences and Technology,
Universidade Nova de Lisboa, 2829-516 Caparica, Portugal
jf.martins@fct.unl.pt, cam@uninova.pt, jg@uninova.pt, lugo@fct.unl.pt

Abstract. Cloud-based Engineering Systems offer new possibilities to leverage the emerging “network effect”, by relying on the access to large pools of computational resources that are available in the “cloud” to overcome the limitations of environments with scarce processing and information storage capability. The impact of this approach is already observed in most engineering domains. Motivating engineering doctoral students to look into the potential of this novel research area is essential for their education. With this aim, the doctoral conference DoCEIS'15 focused on technological innovation for Cloud-based Engineering Systems, challenging the contributors to analyze in which ways their technical and scientific work could contribute to or benefit from this paradigm. The results of this initiative are briefly analyzed in this chapter.

Keywords: Cloud-based Systems, Cloud Computing, Internet of Things

1 Introduction

With the increasing demand on engineering systems applications and the rapid development of Internet technologies, cloud-based engineering systems appear as a multi-paradigm for sharing information, software and hardware, within the Internet-based environment.

Cloud-based Engineering Systems provide a truly multi-dimensional approach for modern engineering. The application scope is not only restricted to *regular* cloud computing, where information and services sharing are considered on both Internet and Intranet (giving clients the power to decide what information or services to use), but it goes beyond the infrastructures, towards areas such as design, manufacturing, and supervision, where users are able to configure, select and use customized information, resources and services for product / systems achievement and operation. The location of physical resources and devices being accessed are typically not known to the end user. It also provides facilities for users to develop, deploy and manage their applications ‘on the cloud’, which entails virtualization of resources that maintain and manage themselves. This is achieved through the synergetic multidisciplinary integration of several service components: Infrastructure-as-a-Service, Storage-as-a-Service, Database-as-a-Service, Information-as-a-Service, Process-as-a-Service, Platform-as-a-Service, Hardware-as-a-Service, and Software-as-a-Service and Integration-as-a-Service.

As a result, a large variety of multidisciplinary research challenges appear, where the Electrical and Computer Engineering related disciplines play a relevant role. Ranging from basic hardware to advanced software solutions, through state-of-the-art manufacturing and operation systems, the impact of Cloud-based Engineering Systems is expected to be enormous in the upcoming years.

Considering that a substantial amount of technological innovation results from the research works of doctoral students, it is important to call their attention for the potential of the Cloud-based Engineering Systems and the role they can play in the innovation process. The DoCEIS'15 (6^{th} Advanced Doctoral Conference on Computing, Electrical and Industrial Systems) was thus organized with this mission and some of the results are summarized in this introductory chapter.

2 Related Concepts and Trends

The origins of the term *cloud computing*, or *cloud* to make it shorter, are difficult to identify. These terms reached some popularity after Google and Amazon began to use them around 2006 to refer to the way people can have access to computer resources over the Web, either software, computer power, or data files, in opposition to having them on their own desktops. However, as pointed out in [1], a first reference to cloud computing appeared as early as 1996, in a Compaq Computer Corporation internal document, where internet cloud would accommodate moving all business software to the Web.

As a matter of fact, cloud computing has become a common jargon used to describe different kinds of solutions, or even misused to describe already available (old) products. As typically happens with other jargons, cloud computing can mean different things to different people. For some, cloud computing is only an additional marketing term. Nevertheless, the attention the area has got also motivated further developments on a number of technological facets such as security mechanisms, resource sharing, virtualization of processing capabilities, distributed storage, etc., in order to make it a reliable approach to business applications.

According to NIST (National Institute of Standards and Technology) [2], cloud computing model is composed of five essential characteristics, three service models, and four deployment models. The five essential characteristics include on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service, while the three service models are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Three main deployment models are considered: private cloud, community cloud, and public cloud. A fourth deployment model, hybrid cloud, is characterized as a combination of two or more distinct deployment models. The essential characteristics of cloud computing typically mentioned in the literature include:

- ***On-demand self-service***: A consumer can access to computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with the service providers.

- ***Ubiquitous network access***: Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g. mobile phones, tablets, laptops).
- ***Location-independent resource pooling***: The customer generally has no control or knowledge over the exact location of the provided resources. The service provider assigns different physical and virtual resources dynamically according to consumer demand.
- ***Rapid elasticity***: Capabilities can be rapidly and elastically provisioned to quickly scale up and released to quickly scale down.
- ***Measured servicing***: Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service. This measurement is the basis for billing of the used resources.

Within the engineering areas, the cloud symbol has been used for ages to represent networks. More recently, the term has been used to describe innovative application relying on Web usage. Remarkably, as an example of how widely the concept has been adopted, two major players in the EDA (electronic design automation) community, as Cadence and Synopsis, already started migration of their EDA tools in the cloud. Synopsys claimed that their VCS tool (Functional Verification for SoC Design) is the first EDA product to become available on a public cloud, as a Software as a Service (SaaS) offering. Other than having a potential strong impact on getting access to a vast network of computational resources, adoption of could computing has a direct impact in terms of version update and maintenance of the application, because they are not needed to be installed on each user's computer.

In terms of research, many projects have been launched to explore the opportunities offered by cloud computing to the development of novel engineering systems. While several of them have been addressing the development of new platforms and base components for cloud computing (e.g. ASCETIC, BETaaS, Broker@Cloud, Cactos, CELAR, Cloud4SOA, CoherentPaaS, CloudScale, CloudSpaces, CumuloNimbo, HARNESS, HEADS, MIDAS, MODAClouds, MONDO, PaaSage, Panacea, REMICS, RISCOSS, SeaClouds, SUCRE, VISION Cloud), various others are addressing the development of cloud-based engineering systems (examples in Table 1).

As an example, Fig. 1 illustrates the GloNet project [3] concept which relies on cloud-computing to deliver integrated multi-stakeholder business services enhancing complex products such as solar energy plants and intelligent buildings. Through sharing resources over a cloud-based platform and using collaboration spaces on top of this platform, networks of small and medium size enterprises can collaborate to provide services in interaction with the customer and local suppliers close to the customer, possibly located in different geographical regions.

Also in engineering education, cloud computing has been contributing to change the picture, as more and more students rely for their learning activities on resources available from the cloud, as in [4], which also support collaborative work, even carried on from different locations.

Table 1. A few examples of cloud-based engineering projects

Project	Focus	URL
ARTIST	Software modernization approach based on Model Driven Engineering techniques to automate the reverse and forward engineering of legacy applications to and from platform independent models, based Cloud Computing and related business models.	www.artist-project.eu/
BigFoot	Platform-as-a-Service solution for processing and interacting with large volumes of data coming from ICT Security, Smart Grid and other application areas	www.bigfootproject.eu/
ClodFlow	Enabling the remote use of computational services distributed on the cloud, seamlessly integrating these within established engineering design workflows and standards.	www.eu-cloudflow.eu/
CloudSME	Scalable platform for small or larger scale simulations, and enable the wider take-up of simulation technologies in manufacturing and engineering SMEs.	www.cloudsme.org/
ClouT	Leveraging cloud computing as an enabler that bridges the Internet of Things with the Internet of People via the Internet of Services, in support of smart cities	http://clout-project.eu/
GloNet	Design, develop, and deploy an agile virtual enterprise environment for collaborative networks of SMEs involved in highly customized and service-enhanced products through a cloud-based platform	www.glonet-fines.eu/
MSEE	Establishing foundations for service-oriented virtual factories and enterprises, including service Clouds.	www.msee-ip.eu

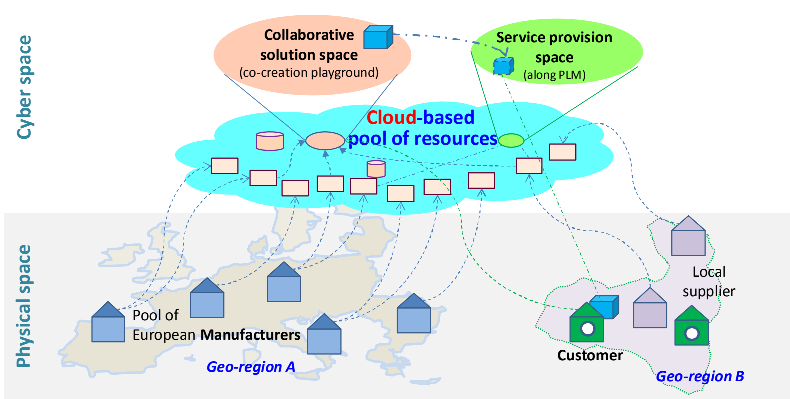

Fig. 1 – GloNet cloud-based engineering approach to service-enhance products

Also a number of other related terms have emerged to represent partially overlapping perspectives or focused application contexts. Some examples are:

Cloud-Based Industrial Cyber-Physical Systems - it is expected that cyber-physical systems (CPS) will benefit from emerging cloud computing technologies, including resource-flexibility and scalability [5]. This has the potential to improve the functionality of cyber-physical systems, as well as enabling a much wider usage of CPS's data and services.

Service-oriented Architecture (SOA) - Cloud computing adopts concepts from Service-oriented Architecture, where the user may decompose a problem into services that can be integrated to provide a solution.

Grid computing - Cloud computing can be considered as a kind of grid computing, where a cluster of networked, loosely coupled computers can cooperate in order to perform large computational intensive tasks.

Internet of Things (IoT): Understood as "*a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*" [6]. In this context, a "thing" can be understood as a real/physical or digital/virtual entity that exists and moves in space and time and is capable of being identified [7].

Big data / data science: The expansion of sensing capabilities, sensor networks, smart devices, and other sources, generating huge amounts of data, requires large and elastic storage capabilities, thus a clear candidate for cloud computing.

3 Example Contributions

Cloud-based Engineering Systems (CES) involve a set of challenges that are particularly relevant for Electrical and Computer Engineering (ECE) researchers and professionals. Most professionals (and students) focus on a specialization sub-field, rarely mastering a comprehensive view of the whole field. However, addressing each individual problem normally requires the capability to address problems from a multi-disciplinary perspective. Since CES require a "strong dialogue" among the various sub-fields of electrical and computer engineering (and other areas), it represents a particularly interesting subject to bring them together.

Under this assumption, a challenge was presented to DoCEIS'15 conference participants, which are doctoral students from various countries and different sub-fields, as summarized in the following alternative questions:

– *In which aspects your research is directly related with* ***Cloud-based Engineering Solutions****?*

Or, in alternative,

– *In which aspects your area of work could benefit from* ***Cloud-based Engineering Systems****?*

As a result, all contributors made an effort to analyze the relationship between their specific research work and the CES. Among the accepted papers there is a quite balanced distribution between those that can benefit from CES adoption and those that contribute to the development of support technologies and models for CES. A summary is given in Fig. 2, which also includes the percentage of contributions in each specific sub-field.

Smart grids, Energy Management (42%)	▪ Home and building energy management systems, including power consumption monitoring ▪ Efficient supply systems for sustainable cloud data centers ▪ Trading strategies in the electricity market and cloud-based decision support ecosystems ▪ User oriented smart services for low voltage networks ▪ Renewables energy smart and optimized management ▪ Super-capacitors and superconducting current limiters ▪ Magnetic energy storage systems
Cloud Computing for Advanced Services, robotics and manufacturing (30%)	▪ Event behavioral modeling applied in the creation of cloud-based services ▪ Geo-referenced dynamic event handling ▪ Data interoperability ▪ Service robots ▪ Collaboration platforms on the cloud ▪ Collaborative business ecosystems applied to cloud platforms ▪ Multi-agent, re-configurability approaches applied to manufacturing ▪ Context classifier in robotics domain ▪ Reconfigurable service-oriented event-driven systems ▪ Cloud-based manufacturing ▪ Fault injection to access cloud software dependability ▪ Supply chain risk management
Sensors, Actuators, Electronics, Telecommunications Embedded Systems and Advanced signal processing techniques (17%)	▪ Design of distributed embedded systems (e.g. controllers) using cloud services and Petri nets cloud based simulators ▪ Energy harvesting, DC-DC converter and power monitoring for extended autonomy in wireless sensor devices that connect to cloud platforms ▪ Piezoelectric devices for energy harvesting to be used in systems located in remote places ▪ Light memory devices ▪ Distributed RSS based localization in cloud based wireless sensor networks ▪ Distributed embedded systems ▪ Wireless sensor networks (WSN) ▪ Advanced signal-processing techniques (wavelets, graph-transformational swarms, etc.)
Healthcare, Elderly care and Human Interaction (11%)	▪ 3D visualization point cloud data using hand gesture recognition ▪ Pathological speech and voice identification using cloud reference databases ▪ 3D Human scanning solutions for medical measurements ▪ Brain-inspired health monitoring systems ▪ Health monitoring supported on real-time cloud services ▪ Medical high resolution image processing

Fig. 2 – DoCEIS'15: Relationship to (and Benefits from) Cloud-based Engineering Systems.

Amongst the areas that can either benefit from a CES or with a direct relationship with CES, energy management is the most represented in terms of submissions to the conference. This is certainly a result of the current challenges faced by society regarding the development of sustainable energy solutions. The materialization of smart grids strongly relies on ICT and sensing / measuring capabilities in order to shift the emphasis from the traditional "predict and supply" model to a more flexible and responsive "demand-based" model [8]. The integration of grid and cloud will be one of the key trends in CES development, in order to optimize cloud-based services, grid services and e-infrastructures. The full realization of this idea requires highly distributed cyber-physical functionalities, but also the involvement of the customers in close (collaborative) interaction with providers, a process that should go far beyond the traditional client-supplier relationship. The concept of cloud-based engineering systems can help reaching a shared vision of long-term sustainability and facilitate more effective use of resources.

Manufacturing is another area indicated as major potential beneficiary. "*Cloud Manufacturing (CM) is a customer-centric manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources to form temporary, reconfigurable production lines which enhance efficiency, reduce product lifecycle costs, and allow for optimal resource loading in response to variable-demand customer generated tasking*" [9]. In reality, cloud manufacturing is a misleading or meaningless term; it should better be referred to as cloud-based manufacturing. Achieving truly agile manufacturing systems, able to dynamically adjust to market dynamics, requires novel approaches that take the shop-floor as a collaborative ecosystem of (progressively more) intelligent and autonomous machines / resources. On the other hand, there is a need for stronger synergies among the various engineering areas involved in product design, manufacturing system design, manufacturing system deployment, manufacturing system operation, etc., which can also benefit from the conceptual insights of cloud-based systems.

In terms of conceptual and technological contributions to the development of CES, DoCEIS'15 includes a vast number of elements, ranging from the hardware level (electronic devices, sensors, telecommunication devices and systems), to software (interfacing and computing methods and models, advanced signal processing techniques, etc.), including specific approaches for embedded systems design.

Last but not less important, other important areas indicated as major potential beneficiaries are healthcare and elderly care, and human interaction. Application examples such as, 3D hand gesture recognition, 3D human scanning solutions, health monitoring systems, high-resolution medical imaging processing and pathological speech and voice identification benefit naturally from CES since huge amounts of data have to be acquired, stored and processed in real time.

Given the scope of DoCEIS, the mentioned contributions are naturally biased by an engineering perspective. The development of advanced cloud-based engineering systems would, however, require the involvement of other disciplines.

5 Concluding Remarks

The increasing development of Cloud-based Engineering Systems will surely have a strong impact in many sectors of society, where some impacts are already visible.

This development will be enlarged by flexible architectures, advanced compatibility mechanisms and new engineering methods. The increased Internet resources will stimulate market-oriented applications, while the integration of grids and cloud surely provide new services and e-infrastructures, opening excellent opportunities for the area of Electrical and Computer Engineering. Several current topics, ranging from the impact of emerging technologies on Cloud-based Engineering Systems to which services/enterprises/business are suitable to move to the cloud, are clearly reflected in the contributions to the DoCEIS'15 doctoral conference.

Acknowledgments. This work was supported in part by the GloNet project (FP7 program) funded by the European Commission, as well as partially financed by Portuguese Agency "FCT - Fundação para a Ciência e a Tecnologia" in the framework of project PEst-OE/EEI/UI0066/2011.

References

1. Regalado, A. (2011). "Who Coined 'Cloud Computing'?". Technology Review (MIT). http://www.technologyreview.com/news/425970/who-coined-cloud-computing/
2. Mell, P., Grance, T. (2011). The NIST Definition of Cloud Computing. NIST Special Publication 800-145. http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf
3. Camarinha-Matos, L. M., Ferrada, F., Oliveira, A.I. (2013). Interplay of Collaborative Networks in Product Servicing. In*: Collaborative Systems for Reindustrialization*, IFIP Series 408/2013, pp. 51-60.
4. Gomes, L., Costa, A. (2014). Cloud based development framework using IOPT Petri nets for embedded systems teaching; ISIE'2014 – 2014 IEEE International Symposium on Industrial Electronics; 1-4 June 2014, Istanbul, Turkey; pp 2202-2206; DOI: 10.1109/ISIE.2014.6864959
5. Colombo, A., Bangemann, Th., Karnouskos, S., Delsing, J., Stluka, P., Harrison, R., Jammes, F., Lastra, J.L. (Eds.) (2014). Industrial Cloud-Based Cyber-Physical Systems - The IMC-AESOP Approach, Springer, 245 p.
6. Sundmaeker, H.; Guillemin, P.; Friess, P.; Woelfflé, S. (Eds.) (2010). Vision and Challenges for Realising the Internet of Things. CERP-IoT, European Commission
7. Camarinha-Matos, L. M., Goes, J., Gomes, L., and Martins, J. (2013). Contributing to the Internet of Things. In: Technological Innovation for the Internet of Things, IFIP AICT Series 394/2013, Springer, pp. 3-12
8. Xi Fang; Misra, S.; Guoliang Xue; Dejun Yang, "Managing smart grid information in the cloud: opportunities, model, and applications," Network, IEEE , 26(4), pp.32-38, Jul-Aug 2012
9. Dazhong Wu, Matthew John Greer, David W. Rosen, Dirk Schaefer, Cloud manufacturing: Strategic vision and state-of-the-art, Journal of Manufacturing Systems, Volume 32, Issue 4, October 2013, Pages 564-579