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Editorial for special section of grid computing journal on "Cloud Computing and Services Science"

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The rise of cloud computing popularity is undeniable. Although the notion of cloud computing is itself a bit 'clouded' and stories about cloud computing are to some extent hyped as a result of cloud marketing, studies indicate that clouds have some clear benefits and the usage of clouds is growing [3].

Cloud computing has several *characteristics* that explain its growth and popularity in the last decade. Maybe the most salient ones are self-service, pay-per-use, and elasticity [1].

With *self-service*, the cloud user can deploy and customize features of a cloud instance without human interaction with the provider. Cloud resources such as computing power, storage, and networks are thus provisioned on demand, and can also be changed by the user at later times according to evolving requirements. Thus, the customer can flexibly manage and balance the cost and quality of cloud services.

The *pay-per-use* model allows the cloud user to pay only for the time and intensity of use of cloud services. This model can be beneficial to the provider if it suffers from revenue leakage due to software piracy. It is certainly attractive to the less frequent user who cannot afford perpetual licensing.

The cloud computing system is able to adapt to workload changes by provisioning and de-provisioning resources. Through this *elasticity* characteristic the provider avoids over- and under-provisioning, and thus decreases costs and exploits profit potential, by making resources available that match at all times the current demand as closely as possible [5].

These characteristics have been founded on the result of a number of earlier and still ongoing *technological developments* [2], most notably virtualization, services computing, and grid computing.

Virtualization is a technology with which physical components and infrastructures can be turned into one or more flexible versions of themselves through adding a layer of abstraction between these resources and their users. Virtualization allows pooling of resources and creation of virtual versions that satisfy the user requirements.

*S*haring the resources of multiple networked computers from different owners for large-scale computing and data intensive tasks is called *grid computing*. Grids typically handle non-interactive workloads with geographically dispersed and disparate computing systems and resources. One of the major challenges is therefore to cope with heterogeneity and to provide a seamless environment to users. Middleware systems have been developed to realize the necessary abstraction and utility.

Based on the service-oriented architecture paradigm, and underpinned by web services standards, *services computing* enables publication, discovery, requesting and provisioning of self-contained units of functionality within an IT environment. These units of functionality are called IT services, which can be composed to form more complex IT services that satisfy more specific user requirements. Ultimately, IT services are used to support business services, achieving improved efficiency or innovation.

To summarize the relationship between and the relative advancements of these developments and cloud computing: grid computing provides the amount of resources needed by the user; virtualization provides an image of these resources that is convenient to the user; cloud computing adds a busi-

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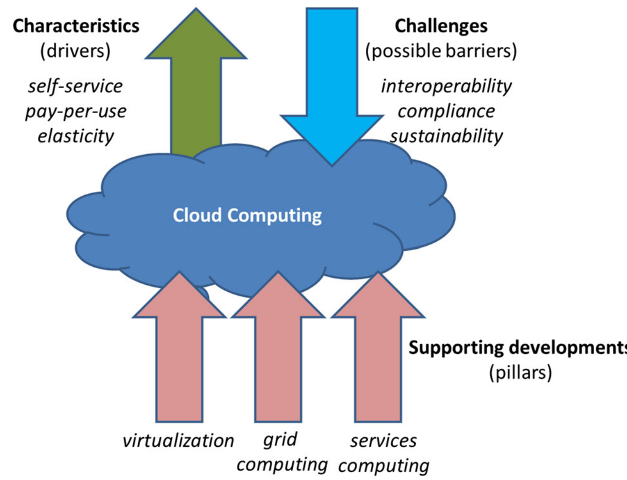
ness model for using services in which cost and quality can be balanced while under- and over-provisioning is minimized; and services computing allows the user to access the cloud, the provider to maintain and rapidly modify component systems at low cost, and to achieve interoperability among clouds.

Despite its attractive characteristics, cloud computing also has *challenges* which need to be addressed in order to support further growth and wider adoption [8]. Besides an overall architectural method that can help to systematically address the requirements of cloud computing [6], we identify three issues with technical as well as business related perspectives: interoperability, compliance, and sustainability.

- *Interoperability* Clouds typically offer provider-specific interfaces to their users. This leads to provider lock-in, which severely hinders a user to choose among alternative cloud offerings, combine cloud offerings from different providers, or switch to another cloud provider. For true cloud ecosystems, users should be able to interoperate with arbitrary clouds, and clouds should be able to interoperate with other clouds. Cloud interoperability must exist at several levels [4]. It comprises much more than just moving data to, from, or between clouds, but must also settle agreements on pricing, availability, security and many other issues, including business focused issues related to compliance.
- *Compliance* Security and privacy are important societal issues, with important implications for customers and providers of cloud environments. Security and privacy risks can be mitigated or prevented by a combination of (information) technical and procedural practices. However, because of the increasing popularity of cloud computing services, new laws and regulations have been introduced to enforce requirements with respect to data collection, storage and processing. Compliance to such regulations may require complicated and more costly measures, especially if regulations differ per geographical region.
- *Sustainability* Although cloud computing is usually seen as a way to save energy, because of the efficiency gain of sharing resources, being able to quantify such saving is entirely another thing. The energy footprint of our digital economy is large and continuously growing (currently about 10 % of the total electricity consumption; [7]), which underscores the importance of energy saving technologies. In this respect, cloud computing should be considered from two perspectives: the energy saving that results from a transition from traditional to cloud computing, and the impact of cloud computing to the growth of the digital economy (and hence of its energy footprint).

The figure below depicts the forces involved in cloud computing popularity and adoption. It shows that the mentioned technology developments act as pillars for supporting and advancing cloud computing, whereas the characteristics featured by cloud computing act as drivers. On the other hand, the identified challenges need to be addressed or otherwise these may turn into barriers that stop or slow down further uptake of cloud computing.



The papers in this Special Section are revised and extended versions of papers accepted and presented at the Second International Conference on Cloud Computing and Services Science (CLOSER 2012). Being part of the CLOSER Conference Series, CLOSER 2012 focused on innovations in the increasingly popular paradigm of cloud computing, using theory, methods and techniques from the cross-disciplinary field of services science [9].

Only two articles were finally accepted for this special section. They address very different areas and concerns of cloud computing, namely (i) energy consumption as an important environmental problem associated with cloud computing, and (ii) matchmaking as a means to let customers freely choose between optimized offers of competing cloud providers.

The first article, entitled "Carbon-aware distributed cloud: multi-level grouping genetic algorithm," by Farrahi Moghaddam, Farrahi Moghaddam, and Cheriet, introduces a methodology for attaining energy efficiency in modern distributed systems. It proposes the Multi-Level Grouping Genetic Algorithm (MLGGA), designed for complex optimization problems such as reducing greenhouse gas (GHG) emissions in a distributed cloud over a network of data centers. The algorithm is validated through simulation with real data, where the results are compared with other state-of-the-art approaches.

The second article, "Matching the business perspectives of providers and customers in future cloud markets," by Di Modica and Tomarchio, defines a semantic model that helps customers and providers of cloud resources to characterize their demands and offers, respectively. Tools that implement the model can perform the matchmaking between a customer and a provider, such that the customer's utilities and the provider's profits are optimized. This kind of matchmaking will be crucial in future cloud markets where customers are not constrained by lock-in costs, but can freely choose between competing providers with differentiated capabilities and QoS levels. The proposal has been validated with a software prototype in a case study.

These two articles are illustrative for the broad range of topics that pertain to cloud computing and services science. In terms of the characteristics and challenges mentioned above, article (i) leverages elasticity with consideration of energy efficiency, and contributes to the challenge of sustainability; and article (ii) leverages self-service with consideration of matchmaking and contributes to the challenge of interoperability. The compliance challenge is not covered in this Special Section, but the related security and privacy issues already received much attention elsewhere and architectural requirements for their treatment were also covered in this journal (Bhaskar Prasad, 2011).

Although limited in coverage, this special section shows some important new developments in cloud computing. Cloud computing is a very active research field. The results from these and many other developments that address current issues and challenges in this field will prepare the next evolutionary steps of this exciting paradigm. We believe that the presented work is informative and provides new ideas and inspiration for further work. We hope the readers agree.

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