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Software Engineering Issues from the Cloud Application Perspective

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Any IT application needs a model of computation, a model of storage, and a model of communication. This job is undoubtedly taken care of by Software engineering. This keynote paper: presents a 21st century vision of computing along with the challenges posed towards software engineering and the position of software engineers in cloud computing. Cloud computing is one contemporary technology in which the research community has recently embarked. Cloud Computing, being descendant of several other computing areas like distributed and grid computing, inherits their advancements and limitations as well. Towards the end goal of this paper we focus on the dissection of the clouds in different layers and a look at what is expected from software engineers with regards to issues/challenges of these layers.

Keywords: Model of Computation/ storage/ communication, Distributed Computing, Grid Computing.

1. Introduction

The Cloud's computing utilities enable a lively start up to compete with the capacity of established competitors' captive data centers. Cloud programming models promise to democratize the web [11], enabling end user application development that supports enterprise and even Internet scale applications. "The cloud means that you are generally getting your IT services from the public Internet as opposed to the more private networks you are used to,"

Industrial leaders such as Microsoft [21], Google [19], and IBM are engaged in the paradigm. There are industrial conferences such as Cloud Computing Conference & Expo. Many techniques for cloud computing have been mature [8][9]. Companies have begun to ship cloud computing machines [8][14]. News reveals that Microsoft has filed a patent on pay-by-use for its software [20].

Companies are increasingly adopting this new paradigm where they do not wish to commit resources for engineering computing infra-structure. Instead, they acquire these resources as and when they need it as services. Indeed there is increasing focus on so-called Software-as-a-Service. However the observance states that one of the key technical issues behind SaaS lies in it being a shared and centrally hosted software service since SaaS vendors support different customer needs from the common application and infrastructure through appropriate sharing and customizations (termed multi-tenancy in SaaS parlance). So, Cloud computing offers new possibilities for software engineering researchers to study multilateral software development.

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2. Forces Driving Cloud Computing

In this section, we study the factors pushing the growth rate of Cloud Computing so that we may also compare these with the risks involved in.

2.1. Expanded Sources of Innovation

Enterprises are spending millions of amount to deliver smarter business outcomes with agility and speed. They are focusing on interoperability and innovations. The headcounts are going up and still up in this direction and with the latest networked infrastructure available, the pace of innovations along with their elegant results is the show-stopper. Standards are also evolving along with the emerging nature of the market.

2.2. Rising Energy Cost & Green Compliance

The world is getting smarter in the race of energy savings and low power consumption. Here is the chance that Cloud Computing may be helpful in saving of energy via automatic workload distribution among already installed servers or machines run and managed by other companies.

2.3. Datacenter Pressures

Existing data centers, if already fully occupied, may not tolerate the extra pressure of workload whereas Cloud computing model delivers a massively scalable and flexible platform for hosting existing and emerging data-intensive workloads since the needed resources may be added on ad-hoc basis.

2.4. Increased Network Capacity and Availability

The days are gone when we were longing to speed up the computer's operational promptness and to connect two or more computers with the similar or even higher data rates. In the era of 21st century where even every desktop is equipped with NICs of Gigabyte transfer capacities, we are not concerned with that how we can still accelerates the transfer rates further rather we are focusing on, how we can exploit this present technology's competence to its maximum extent. Cloud Computing model encourages and optimizes emerging Internet scale workloads such as search, video, audio, 3D Internet, machine learning, mobile computing etc.

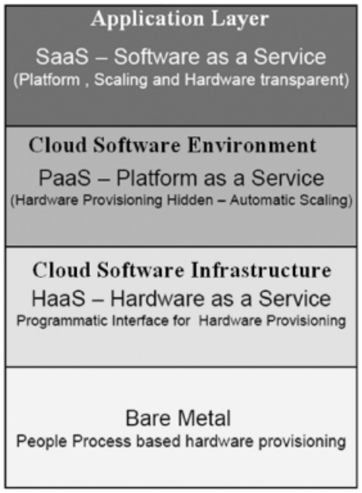

Fig. Layered Model of Cloud Computing

2.5. Partnerships and Collaborations

Undoubtedly, Cloud Computing is the result of collaboration of Big-and-Big or Big-and-Small enterprises which are joining the hands together in order to achieve maximum efficiency at minimum cost [2]. Cloud Computing provides a collaboration platform for knowledge sharing.

2.6. Data-Intensive Applications

Applications involving huge data transfer between machines and that too quite frequently are always in need of more and more resources with the timeline. Besides rapid provisioning of IT resources, massive scaling, Cloud computing also accelerates creation of new services via swift prototyping capabilities.

2.7. Shared Services Across Lines of Business

Cloud computing grip is large enough which engrosses and delivers the services right from software needs (SaaS) to hardware needs (IaaS) of any client. Clouds today provide the Industry specific services, cross industry services, virtualized and scalable infrastructure which may be shared remotely anywhere by different divisions of a enterprise (client).

3. Layered Structure of Cloud Computing

Following the highlighted advantages of Cloud Computing, we proceed to study the layered model of Cloud Computing environment as a whole and describe the services provided and each layer and the dependencies between them. In the later section we will focus on the challenges or issues related with Software Engineering in context with this layered model.

3.1. Application Layer

The cloud application layer is the most visible layer to the end-users of the cloud. Normally, the users access the services provided by this layer through web-portals, and are sometimes required to pay fees to use them. This in turn lessens the restrictions on the hardware requirements needed at the users' end, and allows them to obtain superb performance to some of their CPU-intensive and memory-intensive workloads without necessitating huge capital investments in their local machines.

Since a cloud application is deployed at the provider's computing infrastructure (rather than at the users' desktop machines), the developers of the application are able to roll smaller patches to the system and add new features without disturbing the users with requests to install major updates or service packs. This layer is normally referred to as Software as a Service (SaaS). Salesforce's Customer Relationships Management (CRM) system [9] and Google Apps [19] are two examples of SaaS.

Despite of many cost-effective and other benefits of this model, several deployment issues hinder its wide adoption. Specifically, the security and availability of the cloud applications are two of the major issues in this model, and they are currently avoided by the use of lenient service level agreements (SLA). Additionally, the integration of legacy applications and the migration of the users' data to the cloud is another matter that is also slowing the adoption of SaaS. Cloud applications' providers need to address end-users' concerns about security and safety of storing confidential data on the cloud, users authentication and authorization, up-time and performance, as well as data backup and disaster recovery and provide reliable SLAs for their cloud applications.

3.2. Cloud Software Environment Layer

The second layer is the cloud software environment layer. The users of this layer are cloud applications' developers, implementing their applications for and deploying them on the cloud. The providers of the cloud software environments supply the developers with a programming-language-level environment with a set of well-defined APIs to facilitate the interaction between the environments and the cloud applications. The service provided by cloud systems in this layer is commonly referred to as Platform as a Service (PaaS). One example of systems in this category is Google's App Engine [19], which provides a python runtime environment and APIs for applications to interact with Google's cloud runtime environment. Furthermore, developers have the ability to integrate other services to their applications on-demand. This in turn makes the cloud application development a less complicated task, accelerates the deployment time and minimizes the logic faults in the application.

3.3. Cloud Software Infrastructure Layer

The cloud software infrastructure layer [1] provides fundamental resources to other higher-level layers. Cloud services offered in this layer are computational services, data storage services and network services.

3.3.1. Computational Services

Amazon's Elastic Compute Cloud (EC2) [7][8], and Enomalism elastic computing infrastructure [13] are arguably the two most popular examples of commercial systems available in this cloud category. In this space, there are also several academic open-source cloud projects [14], [15].

3.3.2. Data Storage Services

The second infrastructure resource is data storage, which allows users to store their data at remote disks and access them anytime from any place. This service is commonly known as Data-Storage as a Service (DaaS), and it facilitates cloud applications to scale beyond their limited servers. Example of commercial DaaS-systems is Amazon's S3 [12] [17].

3.3.3. Network Services

As the need for a guaranteed quality of service (QoS) for network communication, cloud systems are obliged to provide some communication capability that is service-oriented, configurable, schedulable, predictable, and reliable. Towards this goal, the concept of Communication as a Service (CaaS) emerged to support such requirements, as well as network security, dynamic provisioning of virtual overlays for traffic isolation or dedicated bandwidth, guaranteed message delay, communication encryption, and network monitoring. One recent example of systems that belong to CaaS is Microsoft Connected Service Framework (CSF) [24].

3.4. Bare Metal

The bottom layer is the actual physical hardware and switches that form the backbone of the cloud. In this regard, users of this layer of the cloud are normally big enterprises with huge IT requirements in need of subleasing Hardware as a Service (HaaS). For that, the HaaS provider operates, manages and upgrades the hardware on behalf of its consumers, for the life-time of the sublease. This model is advantageous to the enterprise users, since they do not need to invest in building and managing data centers. One of 6 the early examples HaaS is Morgan Stanley's sublease contract with IBM in 2004 [18]. HaaS providers have to address a number of technical challenges in operating and managing their services. Efficiency, ease and speed of provisioning such large scale systems, for example is a major challenge. Other examples of challenges that arise at this cloud layer include data center management, scheduling, and power-consumption optimizations.

4. A CALL FOR SOFTWARE ENGINEERING

In the light of above features, it may be deduced that several obstacles are present on the success path of Cloud Computing such as security [10], privacy [15], regulatory and legal issues [3]. Besides these, the negotiation of QoS between users and providers to establish SLAs(Service Level Agreements); mechanisms and algorithms for allocation of VM resources to meet SLAs; and manage risks associated with the violation of SLAs. Furthermore, interaction protocols needs to be extended to support interoperability between different Cloud service providers. We do see that in Cloud Computing environment [16], the development of software is multilateral unlike the application software development. The difference between these two approaches presents some of the noticeable challenges to software engineering, which may be described as follows:

i. Software Composition: In application software development, software engineers develop the coherent set of modules whereas Cloud Computing, being a multidisciplinary software development, is actually a composition of interoperable third-party components or services therefore the challenge for software engineers is the selection of service.

ii. Query Oriented versus API Oriented Programming: Map Reduce [5][6], Streaming and Complex Event Processing require developers to adopt a more functional query-oriented style of processing to derive information. Rather than a large surface area of OO APIs [13] these systems use an extension of SQL like operations where clients pass in application specific functions which are executed against associated data sources. While most developers are familiar with basic SQL, many lack experience doing complex join queries or function composition such as map reduces. Hence education and practice in formulating and expressing query programs is critical for future cloud developers.

iii. Availability of Source Code: In application software development full source of the code is available and in multilateral software development there is no source code available because of third-party components. Therefore the challenge for software engineers is the complete comprehension of the system.

iv. Loosely Coupled Service Design: While simple in principle, it is still a challenge to design services so that applications can be loosely coupled. When the computing resources in a cloud cannot satisfy a computing requirement, the cloud is merged with another cloud to seek additional resources to meet the demand. The extent of cloud integration may, however, vary. For instance, if the integration merely seeks sharing of certain resources, a simple way is to link up these clouds. Clouds in such a bridged cloud cluster can be loosely coupled. Nevertheless, after cloud integration, the computing resources may need to be redistributed among clouds. These clouds then become tightly coupled. Thus, adding such a bridge will result in chain reactions [14] within a cloud cluster, which is then transformed into a set of tightly coupled clouds. As such, a cloud cluster is hardly separable and may only increase the complexity of cloud management, which is of course undesirable.

v. Execution Model: The application software developed generally is executed on single machine whereas the multilateral software developed for Cloud Computing is often distributed between multiple machines. Therefore the challenge for software engineers is the traceability of state of executing entity and debugging.

vi. Testing Criterion: Cloud interactions can be considered similar to the interactions in SOA [2]. We have also seen in SOA that such data exchanges between services may result in integration problem. So we have to have some successful testing criteria for Cloud Applications like the one proposed for SOA [1].

5. Concluding Remarks

The emergence of Cloud Computing has been noticed by one and all in the Information and Communication Technology (ICT) industry [4]. Cloud Computing promises substantial benefits for small, medium and large organizations. Realizing those benefits will require a focus on new application development challenges as well as the use of new programming models and practices.

So the area, where the software engineering may mark its presence is by generating a theory for multilateral software development. Although on the way, the cloud provider's perspective is still under-explored but still software engineers have to come out with a thick enough roadmap to manage the increased complexity. We also need to develop analysis and optimization methodologies for the individual SaaS components which are then fed to the higher-level modeling and simulation framework to evaluate the functionality of the clouds.

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