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A Survey on Quality of Service in the Cloud to Enrich Cloud Reliability

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ABSTRACT: Quality of Service (QoS) plays a vital role in the reservation of resources within the service oriented distributed systems and has been widely investigated in the well-established paradigm of Grid Computing. The coming out of a new concept, Cloud Computing, continues the natural growth of Distributed Systems to cater for changes in application domains and system requirements. Virtualization of resources, a main technology underlying Cloud Computing, creates new challenges to be investigated within QoS and presents opportunities to apply the knowledge and lessons learnt from Grid Computing**.**

QoS has been an issue in many of the Distributed Computing paradigms, such as High Performance Computing and Grid Computing. The aim of this paper is to address QoS, especially in the context of the emerging paradigm Cloud Computing and propose relevant research questions. The objectives of this paper are to discuss the confusion surrounding the term Cloud, the current consensus of what Cloud Computing is and the inheritance by Grid Computing to this emerging paradigm. Emphasis is placed on the state of QoS provisioning in Grids and the technology to enable it in Cloud Computing. Finally, open research questions within QoS relevant to Cloud Computing are proposed and the direction of various future researches is envisioned.

KEYWORDS: Quality of Service, Virtualisation, Cloud Computing, Grid Computing, Resource Management.

I. INTRODUCTION

Quality of Service (QoS) is a vast topic in distributed systems and is quite often treated as the resource reservation control mechanisms in place to conform some level of performance and availability of a service. The scope of this paper is mainly concerned with the management and performance of re-sources such as processors, memory, storage and networks in Cloud Computing. QoS is not only limited to guarantee of performance and availability, added to that it can cover other aspects of service quality, such as security and dependability which are beyond the limit of this paper,. The problems surrounding resource reservation are non-trivial for all but the most basic best report guarantees and the problems behind resource capacity planning are non-deterministic polynomial-time hard to solve. QoS provides a level of assurance that the resource requirements of an application are strictly supported. QoS models are associated with End-Users and Providers (often Brokers), involve resource capacity planning via the use of schedulers and load balancers and utilize Service Level Agreements (SLA). SLAs provide a facility to agree upon QoS between an End-User and Provider and define End-User resource requirements and Provider guarantees, thus assuring an End-User that they are receiving the services for which they have paid. This paper will define the term Cloud, discuss the heritage of Grids in Cloud Computing, and define the paradigms. The paper will explore the history and current state of QoS within Grid Computing, relevant to the scope of this paper will discuss commercial Cloud adopters, describe Cloud Computing research projects and open source solutions and Virtualization technology in the context of QoS.

II. CLOUDS VS GRIDS

Before the relevance of QoS within Cloud Computing can be considered, concrete definitions are essential in being able to characterize current Cloud Systems. This will facilitate in reducing the scope of research questions by

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excluding more generalized definitions of Clouds made by computing experts.

Being able to categorize a cloud by its capabilities is key to formulating a concise definition. A general consensus is held that Clouds fall into at least one of three types of system, dependent on the actors involved and the services they provide. The definitions of these three types of system are:

1. Software as a Service (SaaS), defined as a provider that supplies remotely run software packages, via the Internet to consumers, on a utility based pricing model. A typical example application could be an online alternative to a word processor or spreadsheet.

2. Platform as a Service (PaaS), defined as a provider that offers an additional layer of abstraction above the virtualised infrastructure. This provides a software platform that traces of restrictions in the type of software that can be deployed in exchange for built-in scalability.

3. Infrastructure as a Service (IaaS), defined as a provider that provisions compute and storage resource capacity via virtualization allowing physical resources to be assigned and split dynamically.

These three categories of system are tiered from the bottom up, meaning that for a PaaS provider to function the use of an IaaS provider would be mandatory or alternatively the PaaS provider could deploy and utilize their own IaaS. Previous tiers are obscured from the End-User and services are provided transparently. This allows for increased flexibility, the possibility of an open market and reductions in cost. The evolution of Cloud computing has its roots in multiple Internet related distributed system technologies and computing paradigms such as Cluster Computing, P2P, Service Computing, Utility Computing and most importantly Grid Computing. QoS within Grids has been a major topic of interest and continues to be actively researched. This paper is reminiscent of the position that resource management and performance research was at in the early days of Grid Research, when the issues were just becoming understood.

- **Grid Computing has been defined as**

System that coordinates resources that are not subject to centralized control using standard, open, general purpose protocols and interfaces to deliver nontrivial qualities of service and was hailed as the next revolution in computer science after the creation of the Internet and shares many of the same goals as Cloud Computing. Thus the majority of the lessons already learnt within the research topics is highly relevant to Cloud computing. The motivation behind research into Grid Computing was initially the need to manage large scale resource intensive scientific applications across multiple administrative domains that require many more resources than that can be provided by a single computer. Cloud computing shares this motivation, but within a new context oriented towards business rather than academic resource management, for the stipulation of reliable services rather than batch oriented scientific applications. This difference in the application domain and requirements being pushed by industry does not mean that the scientific community cannot leverage Cloud Computing, far from it, as illustrated by Grid Batch.

There is much crossover between the two paradigms and many goals are shared. Cloud Computing will be enabled through the next generation of data center technology. The current generation of data centres are already leaning heavily towards the virtualisation of computer and storage resources, the technological foundation of a Cloud, enabling the consolidation of proprietary servers running legacy software. This is being achieved through the creation of virtual machines which run on large physical servers utilising the latest technology. This provides the benefits of being able to both reduce maintenance cost and minimise lost revenue due to downtime and also takes advantage of the improvements in computer efficiency facilitated by hardware vendors such as Intel and AMD.

Research has already been carried out on the commercial benefits of Utility Computing within the Grid Economy and thus it is easy to envisage why such an economic model is important in Clouds and is being exploited within Cloud Computing, which is heavily oriented towards business applications and where revenue is a primary concern.

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III. QUALITY OF SERVICE IN GRID

By exploring the current state of QoS in Grid Computing, the lessons already learnt can be exploited and potentially utilised in the Clouds. In the early 21st Century the dynamics of the Internet economy changed and the ratification of e-commerce as a new source of revenue growth within businesses increased. This led to the development of the Web Service, as businesses turned to service Oriented Architectures to simplify their interactions in the digital world, through the loose coupling of the service providers and consumers.

The introduction of Web Services affected the development of Grid Computing as emphasis was placed on Grids providing services to reduce the complexity and cost that had been previously associated with them. The Service-Oriented economy also provided the mechanism to create virtual organisations where computation resources could be shared securely. Service oriented Grids created new problems concerning the management and availability of shared resources across organisational boundaries. Grids relied for many years on the provisioning of resources on a best effort guiding principle of operation and as interest in commercial utilisation of Grids surmounted, more stringent guarantees on the management of resources via QoS were realised as a necessity for the widespread adoption of Grids to take place in industry.

The following two subsections of this paper will focus on the management of resources to guarantee performance and the technology in place to facilitate the reservation of resources, both of which are highly relevant to Cloud Computing.

- **Resource Management**

Without the management of resources Grids would be unable to function. Resource management encompasses the dynamic allocation of tasks to computational resource and requires the use of a scheduler (or broker) to guarantee performance. QoS is enabled in Grids by the efficient scheduling of tasks, this guarantees that the resource requirements of an application are strictly supported, but resources are not over provisioned and used in the most efficient manner possible. Sequences of tasks are represented as workflows, directed graphs comprised of precedent constrained nodes, which each represent the specific ordered invocation of a service on computational resources to process a given task. Several research projects have tackled the complexities of resource reservation and allocation in Grids such as the Phosphorus Project and utilise schedulers such as DSRT and PBS.

- **Service Level Agreement Standardisation**

As the importance of Service Level Agreements (SLAs) as facilitators for the widening commercial uptake of Grids has grown, substantial effort has been made in standardising their use. The Web Services Agreement Specification (WS-Agreement) is one such standardisation effort by the Open Grid Forum. WS-Agreement is a Web Services protocol for establishing an agreement between two parties, using an extensible XML language for specifying the content of an agreement, and agreement templates used to discover appropriate agreement parties. The specification consists of three parts.

- ✓ A schema for specifying an agreement.
- ✓ A schema for specifying an agreed template.
- ✓ A set of operations for managing an agreements life-cycle.

Although WS-Agreement can be effectively used to facilitate SLAs, the life-cycle model does not accommodate the dynamic nature of the Grid economy, providing facilities to negotiate and renegotiate an agreement. The current state of the art research in QoS within Grids is concentrating on this problem. Another cutting edge topic of research surrounding QoS in Grid Computing, is solving problems related to risk assessment and dependability of service providers and is being tackled by projects such as Assess Grid. Consortiums have researched heavily into QoS, but more specifically SLA's. Many of the objectives of the project are also relevant in the context of Cloud Computing, such as how to evaluate the reliability of Cloud service providers and how best to estimate the risks involved in accepting any given SLA but are not relevant to the scope of this paper.

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IV. CLOUDS TODAY

- **Commercial Cloud Adopters**

An overview of commercial cloud vendors, the technology they have in place and the state of their QoS provisioning is essential for the priorities of academic research to be in sink with the needs of businesses and for research into QoS to be of real world intrinsic value. In this paper four main commercial adopters of Cloud technology will be discussed, which are providing services and software products guiding the direction of research in Cloud Computing. Amazon the first company to supply Cloud infrastructure services via its Amazon Web Service products in early 2006, provides a PaaS architecture on a pay per use financial model. The architecture is marketed as two individual products the Amazon Elastic Compute Cloud (Amazon EC2) and the Amazon Simple Storage Service (Amazon S3) and a set of well-defined API's that are becoming widely adopted as standards in many open source Cloud architectures such as Enomalism, Eucalyptus, and OpenNebula.

Another contender positioning themselves as a provider of Cloud services is Google. Google provides SaaS via its Google Apps] software and a PaaS via its Google App Engine

IBM has released a literature on its vision of cloud computing and provides a PaaS based around the API's created by Amazon, know as IBM's Research Compute Cloud. IBM also supplies enterprise Cloud Computing solutions in the form of Cloud Service know as IBM Computing on Demand.

Microsoft the final commercial organization with an interest in Cloud Computing, is not providing Cloud services, but is instead developing the Azure Services Platform

- **Open Source Cloud Implementations**

Understanding the specific technical problems surrounding QoS is not possible in commercial Clouds as the services they provide are transparent, the End- User has no idea of the underlying implementation. Advanced understanding and knowledge of all aspects of Cloud Computing in detail is required to understand the limitations present in commercial QoS provisioning. This subsection discusses three popular distributions of open source Cloud architectures that can be used to shed light on how QoS would be best integrated into a Cloud and which architecture would be best suited as a test bed for use in QoS research. These packages fall into the IaaS or PaaS cloud system previously discussed. SaaS systems have been omitted from the scope of this paper as there are currently no out of the box open source solutions available, most likely due to a lack of PaaS API standards, but there are commercial entities such as Sales Force that provide SaaS packages that can run on Amazon Web Services.

- **Resource Virtualization**

Understanding Cloud architectures from the bottom up, starting with the technology that supports the provisioning of resources, both physical and virtual, in Cloud infrastructures is key to understanding the importance of QoS in Cloud Computing and how its implementation will differ from that of Grid Computing. The current state of the art technology in Cloud Computing centers on the virtualization of resources at the lowest level, a characteristic that distinguishes Clouds from Grids. The main technology enabling virtualization is the Hypervisor, a Virtual Machine Manager (VMM) that partitions a physical host server transparently via emulation or hardware-assisted virtualization. This provides a complete simulated hardware environment; known as a virtual machine, in which a guest operating system can execute in complete isolation. There are several benefits of utilizing virtual machines. Hardware can be consolidated when several servers are underutilized and provisioned as needed endowing an organization with reductions in the up-front cost of hardware purchases and virtual machines can be migrated from one physical location to another with ease as the need arises. Academics can also benefit from utilizing virtual machines. There is often a limitation imposed on Grid users to what software they can use to develop a computer based simulation experiment. There are no such limitations on the availability of software that can be installed in virtual machine images.

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V. Conclusion

In this paper the confusion surrounding the term Cloud, the current consensus of what Cloud Computing is and the relevance of QoS in Clouds have been discussed. The importance of Grid Computing heritage in the Clouds has been explained and the relevance of past QoS research in Grids discussed. The motivation behind, concepts, technology, projects and the state of QoS in Cloud Computing have been reviewed. A vision of some of the problems surrounding QoS in Cloud Computing is constructed through the proposition of open research questions.

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