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CLOUD COMPUTING: STATE-OF-THE-ART AND RESEARCH CHALLENGES AND SECURITY

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Abstract: Cloud computing has recently emerged as a new paradigm for hosting and delivering services over the Internet. Cloud computing is attractive to business owners as it eliminates the requirement for users to plan ahead for provisioning, and allows enterprises to start from the small and increase resources only when there is a rise in service demand. However, despite the fact that cloud computing offers huge opportunities to the IT industry, the development of cloud computing technology is currently at its infancy, with many issues still to be addressed. In this paper, we present a survey of cloud computing, highlighting its key concepts, architectural principles, and state-of-the-art implementation as well as research challenges. The aim of this paper is to provide a better understanding of the design challenges of cloud computing and identify important research directions in this increasingly important area

Keywords: Cloud computing, Data centers, Virtualization, security.

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INTRODUCTION

Cloud computing delivers infrastructure, platform, and software as services, which are made available as subscription-based services in a pay-as-you-go model to consumers. These services in industry are respectively referred to as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). The importance of these services is highlighted in a recent report from Berkeley as: "Cloud computing, the long-held dream of computing as a utility, has the potential to transform a large part of the IT industry, making software even more attractive as a service. This paper proposes a new research direction in the field of Cloud Computing: how to support users in selecting trustworthy Cloud providers using trust and reputation concepts. We identified a set with the most important parameters required to support the consumers in selecting Cloud providers based on a broad survey of the current state-of-the-art literatures. Role of service provider is divided into two: the *infrastructure providers* who manage cloud platforms and lease resources according to a usage-based pricing model, and *service providers*, who rent resources from one or many infrastructure providers to serve the end users.

• Five characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.

• Four deployment models: private clouds, community clouds, public clouds, and hybrid clouds.

• Three service models: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). The emergence of cloud computing has made a tremendous impact on the Information Technology (IT) industry over the past few years, where large companies such as Google, Amazon and Microsoft strive to provide more powerful, reliable and cost-efficient cloud platforms, and business enterprises seek to reshape their business models to gain benefit from this new paradigm. Indeed, cloud computing provides several compelling features that make it attractive to business owners, as shown below. *No up-front investment*: Cloud computing uses a pay-asyou-go pricing model. A service provider does not need to

Invest in the infrastructure to start gaining benefit from cloud computing. It simply rents resources from the cloud according to its own needs and pay for the usage.

Lowering operating cost: Resources in a cloud environment can be rapidly allocated and de-allocated on demand. Hence, a service provider no longer needs to provision capacities according to the peak load. This provides huge savings since resources can be released to save on operating costs when service demand is low.

Highly scalable: Infrastructure providers pool large amount of resources from data centers and make them easily accessible. A service provider can easily expand its service to large scales in order to handle rapid increase in service demands (e.g., flash-crowd effect). This model is sometimes called surge computing.

Reducing business risks and maintenance expenses: By outsourcing the service infrastructure to the clouds, a service provider shifts its business risks (such as hardware failures) to infrastructure providers, who often have better expertise and are better equipped for managing these risks. In addition, a service provider can cut down the hardware maintenance and the staff training costs. However, although cloud computing has shown considerable opportunities to the IT industry, it also brings many unique challenges that need to be carefully addressed. In this paper, we present a survey of cloud computing, highlighting its key concepts, architectural principles, state-of-the-art implementations as well as research challenges. Our aim is to provide a better understanding of the design challenges of cloud computing and identify important research directions in this fascinating topic.

The remainder of this paper is organized as follows. In Sect. we provide an overview of cloud computing and compare it with other related technologies. In Sect. we describe the architecture of cloud computing and present its design principles. The key features and characteristics of cloud computing are detailed in Sect.

2. OVERVIEW

This section presents a general overview of cloud computing, including its definition and a comparison with related concepts.

2.1 Definitions

The main idea behind cloud computing is not a new one. John McCarthy in the 1960s already envisioned that computing facilities will be provided to the general public like a utility. The term “cloud” has also been used in various contexts such as describing large ATM networks in the 1990s. However, it was after Google’s CEO Eric Schmidt used the word to describe the business model of providing services across the Internet in 2006, that the term really started to gain popularity. Since then, the term cloud computing has been used mainly as a marketing term in a variety of contexts to represent many different ideas. Certainly, the lack of a standard definition of cloud computing has generated not only market hypes, but also a fair amount of skepticism and confusion. For this reason, recently there has been work on standardizing the definition of cloud computing.

2.2 Research Challenges

The research done so far has provided some glimpses of the ways in which enterprise might change but an issue that has not been discussed in the literature to any significant extent is how to plan and design the actual organizational changes that will be required as IT provision changes as applications are migrated to the cloud, and as cloud services replace current desktop services. We know from 50 years of experience that the benefits of new technologies can only be realized when enterprises change their structure and processes to take advantage of technological innovation and, for sure, we can only realize the benefits of cloud computing if such changes take place. There was a major organizational change when PCs became cheap enough to buy on individual departmental budgets and power shifted away from the IT department. Cloud computing is likely to result in a similar change but on a more significant scale, because power not only shifts away from the IT department, but also shifts outside the organization to companies such as Amazon. This raises a number of questions:

• What will be the changing role for the central IT department within organizations? Will their role change from "provider to certifier, consultant and arbitrator" as Yanosky suggests, or will the complexity of IT systems and the lack of customized support from cloud providers and online support forums mean that organizations will still need central IT to provide and support most of their systems?

• How would compliance departments react to the migration of applications and data to cloud service providers? They might not have the same level of access to a cloud as they currently do to their internal systems, so how would they have to change their working practices?

• What are the political implications for organizations that lose control over some aspects of their services? Will it mean that moving to a cloud based system will be resisted by support personnel and system administrators who might either be worried about losing their jobs, or about no longer having complete control over a system? Would system administrators be happy to give up some of their control over systems and rely on cloud service providers for the support of end users?

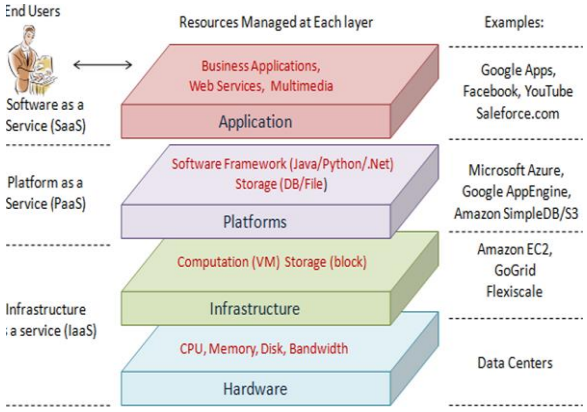
• Would end users care about this? And would they change their working practices when central IT no longer has complete control over a system?

3. Cloud computing architecture

This section describes the architectural, business and various operation models of cloud computing.

3.1 A layered model of cloud computing

Generally speaking, the architecture of a cloud computing environment can be divided into 4 layers: the hardware Data center layer, the infrastructure layer, the platform layer and the application layer, as shown in Fig. 1. We describe each of them in detail:



The hardware layer: This layer is responsible for managing the physical resources of the cloud, including physical servers, routers, switches, power and cooling systems. In practice, the hardware layer is typically implemented in data centers. A data center usually contains thousands of servers that are organized in racks and interconnected through switches, routers or other fabrics. Typical issues at hardware layer include hardware configuration, faulttolerance, traffic management, power and cooling resource management.

The infrastructure layer: Also known as the virtualization layer, the infrastructure layer creates a pool of storage and computing resources by partitioning the physical resources using virtualization technologies such as Xen.

KVM and VMware. The infrastructure layer is an essential component of cloud computing, since many key features, such as dynamic resource assignment, are only made available through virtualization technologies.

The platform layer: Built on top of the infrastructure layer, the platform layer consists of operating systems and application frameworks. The purpose of the platform layer is to minimize the burden of deploying applications directly into VM containers. For example, Google App Engine operates at the platform layer to provide API support for implementing storage, database and business logic of typical web applications.

The application layer: At the highest level of the hierarchy, the application layer consists of the actual cloud applications.

Different from traditional applications, cloud applications can leverage the automatic-scaling feature to achieve better performance, availability and lower operating cost. Compared to traditional service hosting environments such as dedicated server farms, the architecture of cloud computing is more modular. Each layer is loosely coupled with the layers above and below, allowing each layer to evolve separately. This is similar to the design of the OSI model for network protocols. The architectural modularity allows cloud computing to support a wide range of application requirements while reducing management and maintenance overhead.

4 State-of-the-art

In this section, we present the state-of-the-art implementations of cloud computing. We first describe the key technologies currently used for cloud computing. Then, we survey the popular cloud computing products

4.2 Data security

Data security is another important research topic in cloud computing. Since service providers typically do not have access to the physical security system of data centers, they must rely on the infrastructure provider to achieve full data security. Even for a virtual private cloud, the service provider can only specify the security setting remotely, without knowing whether it is fully implemented. The infrastructure provider, in this context, must achieve the following objectives: (1) *confidentiality*, for secure data access and transfer, and (2) *auditability*, for attesting whether security setting of applications has been tampered or not. Confidentiality is usually achieved using cryptographic protocols, whereas audit ability can be achieved using remote attestation techniques. Remote attestation typically requires a trusted platform module (TPM) to generate non-forgeable system summary (i.e. system state encrypted using TPM's private key) as the proof of system security. However, in a virtualized environment like the clouds, VMs can dynamically migrate from one location to another, hence directly using remote attestation is not sufficient. In this case, it is critical to build trust mechanisms at every architectural layer of the cloud. Firstly, the hardware layer must be trusted using hardware TPM. Secondly, the virtualization platform must be trusted using secure virtual machine monitors.

VM migration should only be allowed if both source and destination servers are trusted. Recent work has been devoted to designing efficient protocols for trust establishment and management.

5. CONCLUSION

The message here in our paper should not be taken as a negative comment on the use of cloud computing for enterprise, but that Cloud computing has recently emerged as a compelling paradigm for managing and delivering services over the Internet. The rise of cloud computing is rapidly changing the landscape of information technology, and ultimately turning the long-held promise of utility computing into a reality. However, despite the significant benefits offered by cloud computing, the current technologies are not matured enough to realize its full potential. Many key challenges in this domain, including automatic resource provisioning, power management and security management, are only starting to receive attention from the research community. Therefore, we believe there is still tremendous opportunity for researchers to make groundbreaking contributions in this field, and bring significant impact to their development in the industry.

In this paper, we have surveyed the state-of-the-art of cloud computing, covering its essential concepts, architectural designs, prominent characteristics, key technologies as well as research directions. As the development of cloud computing technology is still at an early stage, we hope our work will provide a better understanding of the design challenges of cloud computing, and pave the way for further research in this area.

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