The Calculus of Cloud Computing

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The Calculus of Cloud Computing

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Abstract. Cloud computing has attracted increasing attention in academia and industries. However, its fundamentals are still controversial, for example, what is cloud computing? What is the mathematical foundation of cloud computing? How can we use mathematical methods and thinking to treat cloud computing? This paper will address these three issues. For the first issue, this paper proposes a unified framework for cloud computing as a science, technology, engineering, system, service and industry. For the second and third issues, we propose the calculus of cloud computing, which treats many aspects of cloud computing using mathematical methods and thinking. The proposed approaches in this paper will facilitate the research and development of cloud computing, intelligent analytics, and business intelligence as well as artificial intelligence.

Keywords: cloud computing, big data analytics, intelligent analytics, and business intelligence as well as artificial intelligence.

1 Introduction

Cloud computing has attracted increasing attention in academia and industry in the past decade (Varghese & Buyya, 2019). The core of cloud computing can be summarized by the following 3 service models, 4 deployment models and 5 characteristics (Wu & Buyya, 2015) (Wu, Buyya, & Ramamohana, 2016)

- 3 service models: IaaS, PaaS and SaaS
- 4 deployment models: Public, Private, Community and Hybrid Cloud
- 5 characteristics: On-demand, Bread network access, Resource pool, rapid elasticity, and measured service.

The service models can be considered as service orientation (Wu, Buyya, & Ramamohana, 2016); deployment models as customized delivery, and 5 characteristics as shared infrastructure of the cloud.

However, the following three issues have not been drawn significant attention in the scholarly peer-reviewed literature:

- What is cloud computing?
- What is the mathematical foundation of cloud computing?
- How can we apply mathematical methods and thinking to cloud computing?

This paper will address these three issues. For the first issue, this paper proposes a unified framework for cloud computing as a science, technology, engineering, system,
service and industry. For the second and third issues, we propose the calculus of cloud computing, which treats many aspects of cloud computing using mathematical methods and thinking. The proposed approaches in this paper will facilitate the research and development of cloud computing, intelligent analytics, and business intelligence as well as artificial intelligence.

The remainder of this paper is organised as follows. Section 2 reviews the existing definitions of cloud computing and provides a unified definition of cloud computing towards a discipline of science and technology. Section 3 presents a unified framework for cloud computing as a science, technology, engineering, system, service and industry. Section 4 proposes the calculus of cloud computing, which treats many aspects of cloud computing using mathematical methods and thought. The final sections discuss the related work and end this paper with some concluding remarks and future work.

2 Defining Cloud Computing

There are many definitions of cloud computing. For example,

There are many definitions on CC (Buyya, Broberg, & Goscinski, 2010).

1. Cloud computing is shared pools of configurable computer system resources and higher-level services that can be rapidly provisioned with minimal management effort, often over the Internet (Wikipedia, 2019).
2. The National Institute of Standards and Technology's (NIST) defines cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (NIST, 2018).

The first definition given by Wikipedia considers cloud computing as computer system resources and higher-level services so that cloud computing is not related to science, engineering and technology, nor management. The second given by the National Institute of Standards and Technology's (NIST) considers cloud computing as a model for accessing computing resources. A model is a part of science, engineering and technology, nor management. But a model is not science, engineering and technology, nor management. Therefore, the above definitions have related to science, engineering and technology, nor management. Can we state that the definition of cloud computing is too much market-oriented, industry-oriented, far from the academic flavor. This is the reason why we consider cloud computing for our universities and students as well as scholars in the next section.

3 A Unified Framework for Cloud Computing

This section presents a unified framework for cloud computing as a science, technology, engineering, system, service and industry.
3.1 Cloud Computing as a Science and Technology

Cloud Computing is a science
Cloud Computing is a technology

3.2 Cloud Computing as a System

Cloud Computing is a system

3.3 Cloud Computing as a Management

Management is the process of manager’s coordinating and overseeing the work activities of others so that their activities are completed [30]. The main management functions or activities of a manager consist of planning, organizing, leading and controlling [30, p. 133] [29, pp. 14-19]. Cloud computing as a management can be briefly represented as:

Cloud computing as a management = Management of cloud computing + Cloud computing for management

The following subsections will look at management of cloud computing and cloud computing for management to some detail.

3.4 Cloud Computing as a Service
This section proposes the calculus of cloud computing, which treats many aspects of cloud computing using mathematical methods and thinking.

4.1 How to understand resources in cloud computing?

When defining cloud computing, (Wikipedia, 2019) uses computer system resources, whereas NIST uses computing resources. (Erl, Mahmood, & Puttini, 2013) uses IT resources as resources of cloud computing. (Varghese & Buyya, 2019) uses resources for cloud computing. This means that the resources of cloud computing should be either computer system resources or computing resources or IT resources. Are computer system resources, computing resources and IT resources same? No, mathematically,

\[ \text{IT} \subseteq \text{ICT} \subseteq \text{computing}. \]

That is,

\[ \text{IT resources} \subseteq \text{ICT resources} \subseteq \text{computing resources}. \]

Computer system resources can be either IT resources or ICT resources. Therefore, it is a part of computing resources. The above mathematical analysis implies that the IT resources is very limited in semantics, whereas ICT is more general and computing resources are most general and can be used as resources of cloud computing (Varghese & Buyya, 2019).
The above analysis leads to a new question. What are the resources of cloud computing. At least we have known that the resources contain Computer system resources, IT resources, ICT resources, computing resources, storage resources (Varghese & Buyya, 2019), etc. It is necessary to develop a research on this topic.

**Question 1**: Can we consider all these resources in the cloud computing as big data. If yes, then we have

IT resources \( \subseteq \) ICT resources \( \subseteq \) computing resources \( \subseteq \) big data.

In such a way, big data is the strategic resources of cloud computing. Big data is the basic and raw materials for resources and services processing in cloud computing.

### 4.2 How to understand types of cloud?

Hybrid Cloud is a multi-cloud with a combination of public and private clouds or a combination of public and private IT infrastructure (Varghese & Buyya, 2019).

- Hybrid cloud = public cloud + private cloud
- Hybrid cloud = public cloud \( \lor \) private cloud \( \lor \) community cloud

### 4.3 How to understand cloud services

IaaS, PaaS and SaaS

These three services are at three levels. Therefore, the relationships among them can be represented as

IaaS \( \oplus \) PaaS \( < \) IaaS \( \oplus \) SaaS. Am I right? 20 02 19

### 4.4 Cloud Analytics = Big data Analytics + Cloud Computing

Wu, Buyya and Ramamohana (2016) represent Big data Analytics mathematically as

Big data Analytics = Machine learning + Cloud Computing (1)

Machine learning is a part of artificial intelligence (Sun & Huo, 2019), that is machine learning \( \subseteq \) artificial intelligence. Then we can have

Big data Analytics = artificial intelligence + Cloud Computing (2)

Based on (Sun & Wang, 2017),

Big Data analytics = Big data + Big data analysis + Big DW + Big DM + Big SM + Big ML + Big Visualization

Where DW is data warehousing, DM is data mining, SM is statistical modeling, ML is machine learning

Then we have

Cloud Analytics = Big data + Big data analysis + Big DW + Big DM + Big SM + Big ML + Big Visualization + Cloud Computing (3)

This implies that the above result is more inclusive than either (1) or (2).
5 Discussion and Implications

We have mentioned several scholarly researches on cloud computing. In what follows, we will focus on related work, discussion and implications on the Calculus of Cloud Computing.

Calculus is a branch of mathematics that “deals with rates of change”, based on the Oxford Advanced Learners’ Dictionary. The term calculus is also used for naming specific methods of calculation or notation as well as some theories, such as propositional calculus and process calculus (https://en.wikipedia.org/wiki/Calculus, accessed 20 Feb 19). This paper uses the latter annotation of calculus for this research. We have searched for "The Calculus of Cloud Computing" using Google Scholar during our developing this research for a few times. There are no similar publications to this topic now.

6 Conclusion

This paper proposes a unified framework for cloud computing as a science, technology, engineering, system, service and industry. It also presents the calculus of cloud computing, which treats many aspects of cloud computing using mathematical methods (including logic and set theory) and thinking. The proposed approaches in this paper will facilitate the research and development of cloud computing, intelligent analytics, and business intelligence as well as artificial intelligence.

In the future work, besides mentioned in the previous section, we will analyse the proposed framework of cloud computing with the cases of the real world. We will also explore the calculus of cloud computing and its applications in big data analytics, web services and artificial intelligence.

If you have interest in this research and like to cooperate with me change it to a publication, please do not hesitate to contact me.

7 References


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