Cloud Computing Technology: Promises and Concerns

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ABSTRACT
Recently, the concept of cloud computing has witnessed dramatic worldwide growth in the field of information technology (IT). Cloud computing has gained its popularity as a new computing paradigm from an ability to facilitate the provision and use of IT infrastructure, platforms, and applications of any kind in the form of services that are electronically available over the internet. As a result, cloud computing is heading rapidly towards mainstream usage and adoption for many customers, developers, enterprises, governmental institutions, and researchers. In this survey, we give an overview of cloud computing and their application domains, including the challenges that should be addressed in order to push the cloud technology further. Then, we present a systematic and comprehensive taxonomy of the cloud computing technology. Moreover, we review the most popular and successful open source cloud computing technologies and projects. Finally, we identify several open research issues that need to be investigated in the future. This paper intends to help new researchers entering the domain of cloud computing by providing a comprehensive survey on recent developments.

General Terms
Computer Networks, Distributed Systems, Cloud Computing.

Keywords
Cloud computing, cloud services, virtualization, elasticity, open source cloud technologies.

1. INTRODUCTION
Pick up any information technology (IT) magazine or open any IT radio or TV channel or visit any IT website or blog, "cloud computing" will definitely catch your eyes. As an emerging technology and business paradigm, cloud computing promises a different way to architect, configure, and remotely manage computing services [1]. In the traditional computing infrastructure, operating systems, applications and data are typically stored as well as managed on an individual client's personal computer (PC) [2]. On the contrary, cloud computing facilitates the provision and use of IT infrastructure, platforms, and applications of any kind as services that are electronically available over the internet [3, 4]. The later enables millions of users to use, as well as access to, cloud resources (hardware and software) simultaneously through a variety of devices, including PCs, laptops, smartphones, and PDAs.

Generally, cloud computing has been increasingly used for solving business, scientific and engineering problems rising in both industry and academic communities. From one hand, it offers scientific and engineering researchers a new way to deploy computation and data-intensive applications (e.g. scientific and engineering applications, data mining, computational financing, gaming, and social networking, etc.) without any infrastructure investments. On the other hand, cloud computing is a business model. It is based on the concept of dynamic provisioning, which is applied not only to services but also to compute capability, storage, networking, and IT infrastructure in general. From this perspective, cloud computing is helping enterprises, governments, public and private institutions, and research organizations shape more effective and demand-driven computing systems.

To summarize, the major objective behind the cloud computing is to allow users, enterprises, governments, public and private institutions, and young researchers to benefit from all of the provided features and technologies, without the need for deep knowledge about or expertise with each one of them. It also provides a flexible costing mechanism, which aims to cut costs and help customers focus on their core business instead of being impeded by IT obstacles.

2. WHAT IS CLOUD COMPUTING?
Over the last decade, the term "cloud computing" has been increasingly used in the business and academic communities. Indeed, lots of computer scientists and researchers have attempted to define exactly what "cloud computing" is. Among the numerous definitions, we choose the widely quoted as follows:

A definition of cloud computing was established by the U.S. National Institute of Standards and Technology (NIST) [5], states that: "cloud computing is 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." The definition demonstrates the essential characteristics of cloud computing environments, for instance, on-demand self-service, accessible through broad networks like internet, can be quickly as well as easily scaled up or down on demand, draw from unlimited pool of computing resources and involves some sort of metering capability to track usage.

Gartner [6] simply described cloud computing as "a style of computing where scalable and elastic IT capabilities are provided as a service to multiple external customers using internet technologies" [7]. Garter examines qualities of cloud clouding mostly from the point of view of industry. The emphasis in this definition is on the functional characteristics of the cloud environment, for example, whether cloud computing is scalable, elastic and internet-based services.

A report from the University of California Berkeley [8] claims that "cloud computing refers to both the applications delivered as services over the internet and the hardware and systems

software in the datacenters that provide those services" [9]. This report considered that the datacenter hardware and software constitutes what we call a cloud.

Buyya et al. [10] have defined cloud computing as follows: "a cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers." This definition claimed that cloud computing is the result of development and adoption of existing technologies and paradigms, such as parallel and distributed computing.

Foster et al. [11] characterized cloud computing as "a large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over internet." This definition focuses on the technical features that distinguish cloud computing from other distributed computing paradigms. For instance, resources are virtualized and delivered as services on demand.

3. OVERVIEW OF CLOUD COMPUTING

The first definition given above (NIST definition) describes cloud computing as having five essential characteristics, three service models, and four deployment models (see Figure 1). In the following, we describe these models in detail and review the major service providers for each model.

3.1 Service Delivery Models

In general, cloud computing services are categorized into three different groups according to the abstraction level of the capability provided and the service model of cloud suppliers, namely, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

- **Infrastructure as a Service (IaaS)**: Infrastructure services are considered to be the base layer of cloud computing systems [12]. Infrastructure as a Service (IaaS) delivers processing, storage space, network resources, and other fundamental computing resources to consumers. IaaS customers can deploy arbitrary application, software, operating systems on the infrastructure, which is capable of rapidly scaling up and down dynamically. Examples of the major providers of cloud IaaS include Eucalyptus Community cloud [13], GoGrid, HP, Amazon Web Services [14], IBM, SoftLayer, and Rackspace.

- **Platform as a Service (PaaS)**: Platform as a Service (PaaS) provides a high-level integrated environment and solution stacks to develop, test, deploy and host customer-created or acquired applications. While PaaS permits consumers to deploy and control applications and their hosting environment configurations, consumers have no control over the underlying cloud infrastructure including network, servers, operating systems, and storage. Examples of the major providers of PaaS include Google AppEngine [15], Windows Azure [16], VMforce, Amazon Web Services, Engine Yard, and Heroku, etc.

- **Software as a Service (SaaS)**: Software as a Service (SaaS) is a software delivery model in which applications are hosted by a provider and are made accessible through a simple interface such as a web browser over the internet. The customers are not concerned with the underlying cloud infrastructure including networks, servers, operating systems, storage, platforms, and so forth. In other words, this model frees the customers from the need to install the software locally and thus to provide the required resources themselves. In this model, consumers have no control over the infrastructure and software configuration they use. Examples of the major providers of SaaS include SalesForce.com [17], OfficeLive, NetSuite, Oracle, IBM, CloudNumbers, and Microsoft, etc.

Currently, there are many other services emanating from these main services. For instance, storage as a service (STaaS), communications as a service (CaaS), database as a Service (DBaaS), network as a service (NaaS) and monitoring as a service (MaaS).

3.2 Deployment Models

Although the term cloud computing refers in general to the delivery of services on demand over a computer network, cloud services can be deployed in four different ways depending on the organizational structure and the provisioning location. The four major models for deploying and accessing cloud computing environments are as follows: Public cloud, Private cloud, Community cloud, and Hybrid cloud.

- **Public cloud**: Public clouds (also called "external clouds") are the most common deployment models in which a third-party service provider makes resources, such as computing, storage, networks, virtualization, and applications, available to the general public over the internet. In this model, the services are charged on the basis of the resources actually used in the corresponding period. Examples of public cloud providers include Amazon Web Services, Windows Azure Services Platform, VMWare, IBM's Blue Cloud, Google AppEngine and Sun Cloud.

- **Private cloud**: Private cloud (also called "internal cloud") is a cloud computing environment, in which the infrastructure and platform are operated solely for an organization. In this model, data resources and applications can only be accessed by permitted clients. This eliminates the need for a trust model and provides more flexibility. Governmental institutions and banks that have high security, privacy and regulatory concerns prefer to build and utilize their own private clouds. Examples of private cloud suppliers include Amazon Web Services, VMware, Rackspace and HP CloudStart.

- **Community cloud**: In a community cloud, organizations with similar requirements (e.g., security policies and compliance considerations) share a cloud infrastructure. Where this model enables these organizations to combine assets and share computing resources, data storage, and other capabilities. The community cloud model can be managed by the member organizations or by a third party provider. Thus, it is more trusted than the public cloud model and less expensive for the participating members than having a private cloud.

- **Hybrid cloud**: A hybrid cloud is a combination of two or more distinct cloud models (public, private, or community). A hybrid cloud model provides a cloud environment in which resources are managed with a mix of internal and external cloud groups. The hybrid model stores sensitive data internally and takes its backup externally in the public cloud so that, if the system fails, backup data is available somewhere. By combining the advantages of the other models, the hybrid model offers organizations the most flexibility.

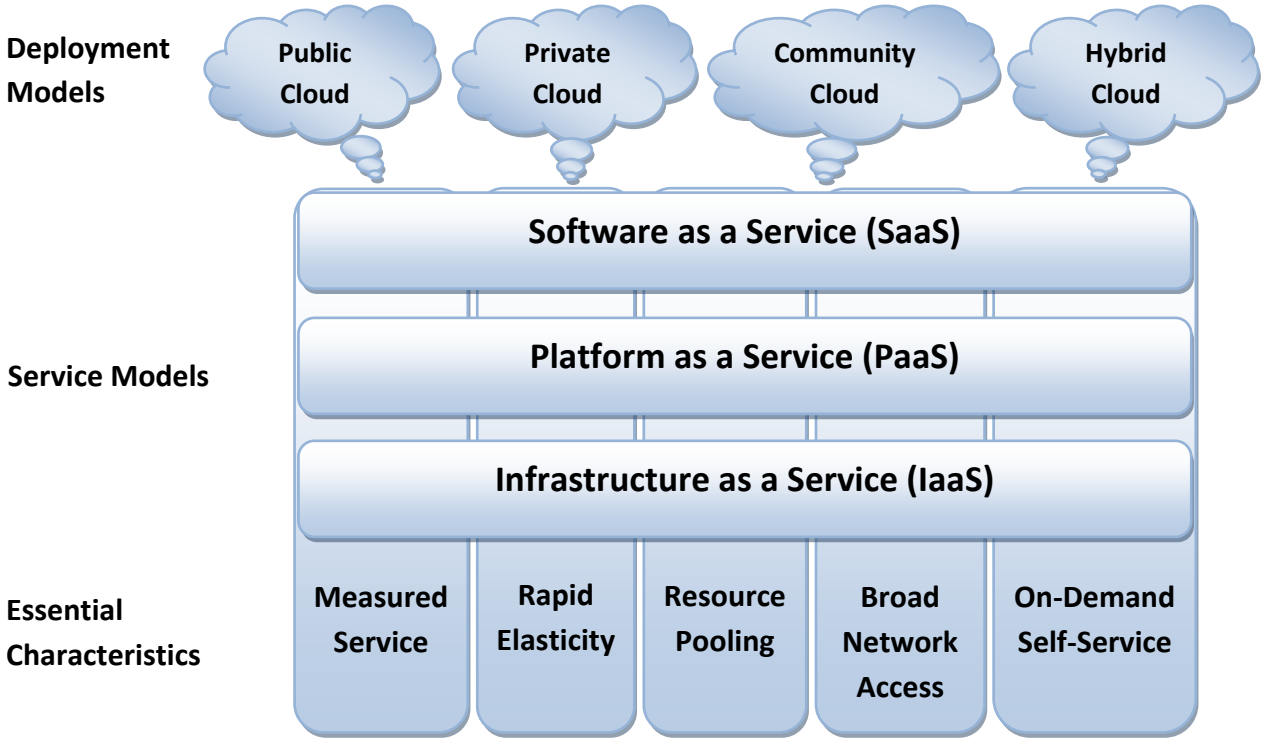

Fig. 1: Cloud Computing Reference Model [NIST]

4. ADVANTAGES OF ADOPTING CLOUD COMPUTING TECHNOLOGY

Cloud Computing is the further advancement of existing technologies and paradigms. It is expected to fix the issues with the technologies that it evolved from, and bring new features by integrating technologies. Here we explore some of the features and benefits associated with cloud computing.

1) **On-demand Self-service**: Cloud computing depends on the concept of dynamic provisioning, which is applied not only to services but also to IT infrastructure (compute capability, storage, and networking) in general [18]. In other words, cloud services and computing resources can be provided unilaterally and automatically as needed to consumers without requiring human intervention by the cloud service provider.

2) **Increased Scalability and Elasticity**: Cloud computing provides flexibility in scaling cloud resources up and down according to business dynamics. Consumers can access additional resources rapidly and easily when they need them and then scale back to previous levels when those resources are no longer required. To the customer, the resources available for provisioning often appear to be boundless and can be purchased in any quantity at any time [19].

3) **Resource Pooling**: In cloud computing, resources such as processing power, storage, memory, and network bandwidth are pooled to serve multiple consumers using a multi-tenant model. This can lead to optimizing resources usage and availability, and reducing operational expenses.

4) **Quick Deployment**: Cloud computing allows consumers to get their applications up and running more quickly due to improved manageability and lower maintenance requirements. Hence, cloud computing gives you the advantage of quick deployment.

5) **Easy Access to Resources**: Consumers can easily access and configure their cloud services and computing resources over the internet. Cloud services and resources can be accessed from anywhere, at any time, and through multiple devices.

6) **Unlimited Storage**: Storing data and information in the cloud gives you almost unlimited storage capacity and can provide significant cost savings as there is no need to purchase storage or in some instances even provision it before storing data. You only pay for the amount of storage space that your data is actually consuming.

7) **Reduce Initial Investment**: Small and mid-sized businesses do not need to own the infrastructure. Instead of purchasing and maintaining the infrastructure for their computing needs [20], a third party provides and maintains the infrastructure.

8) **Reduce Capital Expenditure**: The real opportunity of cloud computing is the ability to pay as you go and only for what you use. Users only pay for what resources or services they use and only for as long as they use them.

9) **Disaster Recovery**: Cloud computing offers cost-effective models that utilize cloud resources to provide a simple and reliable disaster recovery for your data and applications.

10) **Automatic Software Integration**: In cloud computing, software integration is usually something that occurs automatically. This means that your software is automatically updated to the latest version, without needing to manage updates and installations yourself.

11) **Easier Collaboration**: Cloud computing facilitates the ability for multiple staff to access, edit and share folders and files that they are currently working on. This means that collaboration between colleagues can be greatly improved, and no time is wasted on uploading and emailing files individually.

12) **Energy Efficiency**: Cloud computing has the ability to reduce the consumption of unused resources. It can lower energy consumption by turning off the redundant infrastructure and services. This, in turn, reduces carbon emissions and expenses for energy supply.

5. CHALLENGES OF ADOPTING CLOUD COMPUTING TECHNOLOGY

As there are many advantages indicated above, there are also disadvantages of cloud computing. Let us now explore some of the disadvantages of cloud computing:

1) **Security and Privacy**: Although cloud computing nowadays provides a wide range of policies, technologies, and standards to protect data, applications, and the associated infrastructure of the cloud, data stored cannot be a 100% secure. Moreover, because the data stored in the cloud is accessible from anywhere on the internet, it is possible to gain unauthorized access to the sensitive or business data and information. There are still serious security concerns that need to be resolved.

2) **Possible Downtime**: Sometimes, we face a situation in which the servers or services are out of our reach. This technical issue is called downtime. Downtime is again an issue that even the best service provider of cloud computing cannot absolutely guarantee. Also, recall that the whole setup of the cloud system is internet-based. Accordingly, any downtime on the internet side will lead to a connectivity issue. Therefore, downtime is another challenge yet to be resolved.

3) **Interoperability and Portability (Data Lock-in)**: Dependency on the service provider is one of the major concerns of cloud computing. This is what we call "data/vendor lock-in" since it is difficult to move data and applications out from one service provider to another one. The reason can be due to the lack of standardization of interfaces (APIs) among different cloud providers. As a result, this may also leads to risking the security and privacy of the data. In the current situation, there is no interoperability between clouds and consumer data are not portable. Hence, the challenge of interoperability and portability presents another open research problem for the researchers.

4) **Service Availability and Reliability**: In cloud computing, services and applications must be reliable and available to support 24/7 operations. Customers will always have expectations on the service availability and reliability once their applications are migrated to the cloud. These expectations include high availability of the service, system performance, what measures are to be taken when something goes wrong in the system, and what emergency plans are to be taken in the event of failure or blackouts. Therefore, service availability and reliability are also a major concern.

5) **Lack of Flexibility**: Lack of flexibility and control is another reason concerning why not to go for cloud computing options. Most of the third party virtual environment and services are operated remotely. This aspect makes companies and consumers have reduced control over the execution, function and other relevant configurations of interlinked software and hardware. Additionally, during remote operations, the feature also lacks the consideration of an application running locally. Therefore, it is still needed that cloud computing should be flexible, and a lot of research work is still expected to meet the required level of flexibility.

6. OPEN SOURCE CLOUD COMPUTING SOFTWARE

Open source cloud computing software refers to software with source code that is made available to the general public for use, modification, enhancement and redistribution free of charge. Open source software can offer distinct advantages to consumers, developers, researchers, and organizations. First, open source projects provide tremendous opportunities for developers to work, share and learn through collaboration. Second, with open source software, users, developers and researchers are granted unlimited (unrestricted) access to the source code with the freedom to study, modify, distribute and adapt the software for any purpose. Third, open source software can help lower software costs for small and mid-sized businesses as well as help eliminate the bother of deploying software on their own servers. Fourth, using open source software can also help enterprises and small businesses competing with large-scale businesses that are actually running the same open source software. Finally, the open source project can help pushing the innovation forward and increase knowledgeable community support.

In this survey, we have collected some of the most popular and successful open source cloud computing applications and solutions, which includes infrastructure as a service (IaaS), platform as a service (PaaS), software as a service (SaaS), and other cloud-related projects. We also classified them into eight major groups according to their corresponding class of service as follows:

- **Open Source Compute Clouds (IaaS)**: Examples of projects in this category include OpenStack [21], CloudStack [22], Eucalyptus, OpenNebula [23], Nimbus [24], FOSS-Cloud [25], openQRM [26], Synnefo [27], and Scalr [28].

- **Open Source Cloud Storage Software (STaaS)**: Some major projects belonging to this category are Ceph [29], CloudStore [30], Gluster [31], Seafile [32], Sheepdog [33], Syncany [34], GlusterFS, OpenStack, Pydio [35], Cozy [36], StackSync, and NAS4Free.
- **Open Source Platform as a Service (PaaS)**: Some of the popular solutions belonging to this category are AppScale [37], OpenShift [38], Cloud Foundry [39], Appcelerator Titanium [40], WSO2 Stratus, Stackato, and Cloudify [41].
- **Open Source Virtualization/Hypervisor Tools**: This category includes, for example, Xen [42], KVM [43], VirtualBox [44], LXC [45], and OpenVZ [46].
- **Open Source Software Networking Tools (NaaS)**: Popular tools belonging to this category are Floodlight [47], Indigo [48], OpenStack Networking "Neutron", and Open vSwitch [49].
- **Open Source Internet of Things Tools**: Tools belonging to this category are, for example, Devicehub.net [50], OpenHAB [51], OpenIoT [52], Particle [53], and OpenPicus [54].
- **Open Source NoSQL Databases (DBaaS)**: The most common applications belonging to this category are Apache Cassandra [55], CouchDB [56], HBase [57], Hypertable [58], MongoDB [59], and Redis [60].
- **Open Source Big Data Tools**: Typical applications and solutions belonging to this group are Hadoop [61], MapReduce, Apache Storm [62], Zeppelin [63], TensorFlow [64], and Apache Beam [65].

7. CONCLUSIONS AND FUTURE TRENDS

With the growing popularity of the internet, the availability of more powerful computing resources along with the lowering costs of computation and communication, the emphasis of computing has been pushed recently to the cloud-centric. As an emerging paradigm with its main features: utility computing, virtualization, availability and accessibility, scalability and elasticity, cloud computing is the most needed for current fast growing business world. With cloud computing, we can focus on design, simulation, analysis, and discovery, instead of spending much time building, configuring and maintaining complex IT infrastructures. Some of the major concerns related to adopting cloud computing are the security and privacy of consumer data, availability and reliability of services, lack of standards, interoperability and portability of services between different clouds, fault tolerance and disaster recovery strategies. To this point, future research could investigate and explore these issues in more detail.

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9. REFERENCES

[1] Buyya, R., Broberg J., and Goscinski, A. M. 2011. Cloud Computing Principles and Paradigms. Wiley Publishing.

[2] Jeong, H. and Park, J. 2012. An efficient cloud storage model for cloud computing environment. In Proceedings of the 7th international conference on Advances in Grid and Pervasive Computing (GPC 12). Springer, 370-376.

[3] Manvi, S. S. and Shyam, G. K. 2014. Resource management for infrastructure as a service (IaaS) in cloud computing: A survey. J. Netw. Comput. Appl. 41, 424-440.

[4] Mustafa, S., Nazir, B., Hayat, A., Khan, A. R., and Madani, S. A. 2015. Resource management in cloud computing: taxonomy, prospects, and challenges. Comput. Electr. Eng. 47, 186-203

[5] Mell, P. and Grance, T. 2009. The NIST Definition of Cloud Computing. Technical Report. National Institute of Standards and Technology, Information Technology Laboratory, Version 15.

[6] Plummer, D., Cearley, D., and Smith, D. 2008. Cloud Computing Confusion Leads to Opportunity. Technical report. Gartner Research, G00159034.

[7] Bento, A. M. and Aggarwal, A. K. 2012. Cloud Computing Service and Deployment Models: Layers and Management. IGI Global Publishing.

[8] Armbrust, M., Fox, A., Griffith, R., Josoph, A., Kath, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., and Zaharia, M. 2009. Above the Clouds: A Berkeley View of Cloud Computing. Technical Report. University of California at Berkeley, USA, UCB/EECS-2009-28.

[9] Fu, J., Hao, W., Tu, M., Ma, B., Baldwin, J., and Bastani, F. B. 2010. Virtual services in cloud computing. In Proceedings of 2010 6th World Congress on Services. IEEE, 467-472.

[10] Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., and Brandic, I. 2009. Cloud computing and emerging IT platforms: vision, hype, and reality for delivering computing as the 5th utility. Futur. Gener. Comput. Syst. 25, 599-616.

[11] Foster, I., Zhao, Y., Raicu, I., and Lu, S. 2008. Cloud computing and grid computing 360-degree compared. In Proceedings of Grid Computing Environments Workshop (GCE 2008). IEEE, 1-10.

[12] Nurmi, D., Wolski, R., Grzegorczyk, C., Obertelli, G., Soman, S., Youseff, L., and Zagorodnov, D. 2009. The Eucalyptus open-source cloud-computing system. In Proceedings of IEEE/ACM International Symposium on Cluster Computing and the Grid (CCGrid 2009). IEEE, 124-131.

[13] Eucalyptus, http://www8.hp.com/us/en/cloud/helion-eucalyptus.html, last accessed on December 4, 2016.

[14] Amazon Web Services, http://aws.amazon.com/, last accessed on December 4, 2016.

[15] Google AppEngine, http://code.google.com/appengine, last accessed on December 4, 2016.

[16] Windows Azure, https://azure.microsoft.com/en-us/, last accessed on December 4, 2016.

[17] Salesforce.com http://www.salesforce.com/, last accessed on December 4, 2016.

[18] Buyya, R., Vecchiola, C., and Selvi, S. T. 2013. Mastering Cloud Computing: Foundations and Applications Programming. Morgan Kaufmann.

[19] Galante, G. and De Bona, L. C. E. 2012. A survey on cloud computing elasticity. In Proceedings of the 2012 IEEE/ACM Fifth International Conference on Utility and Cloud Computing (UCC 12). IEEE, 263-270.

[20] Attiya, I., Zhang, X., and Yang, X. 2016. TCSA : A dynamic job scheduling algorithm for computational grids. In Proceedings of the 2016 First IEEE International Conference on Computer Communication and the Internet (ICCCI). IEEE, 408-412.

[21] OpenStack, http://www.openstack.org/, last accessed on December 9, 2016.

[22] CloudStack, http://cloudstack.apache.org/, last accessed on December 9, 2016.

[23] OpenNebula, https://opennebula.org/, last accessed on December 10, 2016.

[24] Nimbus, http://www.nimbusproject.org/, last accessed on December 10, 2016.

[25] FOSS-Cloud, http://www.foss-cloud.org/, last accessed on December 10, 2016.

[26] OpenQRM, http://www.openqrm-enterprise.com/, last accessed on December 4, 2016.

[27] Synnefo, https://www.synnefo.org/, last accessed on December 4, 2016.

[28] Scalr, http://www.scalr.com/, last accessed on December 10, 2016.

[29] Ceph, http://ceph.com/, last accessed on November 27, 2016.

[30] CloudStore, http://cloudstore.codewizards.co/, last accessed on November 27, 2016.

[31] Gluster, https://www.gluster.org/, last accessed on November 27, 2016.

[32] Seafile, https://www.seafile.com/en/home/, last accessed on November 25, 2016.

[33] Sheepdog, http://sheepdog.github.io/sheepdog/, last accessed on December 9, 2016.

[34] Syncany, https://www.syncany.org/, last accessed on December 4, 2016.

[35] Pydio, https://pyd.io/, last accessed on November 27, 2016.

[36] Cozy, https://cozy.co/, last accessed on November 27, 2016.

[37] AppScale, http://www.appscale.com/, last accessed on December 4, 2016.

[38] OpenShift, https://www.openshift.com/, last accessed on November 27, 2016.

[39] Cloud Foundry, https://www.cloudfoundry.org/, last accessed on December 10, 2016.

[40] Appcelerator Titanium, http://www.appcelerator.org/, last accessed on December 10, 2016.

[41] Cloudify, http://getcloudify.org/, last accessed on December 9, 2016.

[42] Xen, https://www.xenproject.org/users/cloud.html, last accessed on December 10, 2016.

[43] KVM, http://www.linux-kvm.org/page/Main_Page, last accessed on December 10, 2016.

[44] VirtualBox, https://www.virtualbox.org/, last accessed on November 27, 2016.

[45] LXC, https://linuxcontainers.org/, last accessed on December 9, 2016.

[46] OpenVZ, https://openvz.org/Main_Page, last accessed on December 10, 2016.

[47] Floodlight, http://www.projectfloodlight.org/floodlight/, last accessed on December 10, 2016.

[48] Indigo, https://www.goindigo.in/, last accessed on November 25, 2016.

[49] Open vSwitch, http://openvswitch.org/, last accessed on November 25, 2016.

[50] Devicehub.net, https://www.devicehub.net/, last accessed on November 25, 2016.

[51] OpenHAB, http://www.openhab.org/, last accessed on December 10, 2016.

[52] OpenIoT, http://www.openiot.eu/, last accessed on November 27, 2016.

[53] Particle, https://www.particle.io/, last accessed on December 10, 2016.

[54] OpenPicus, http://www.openpicus.com/, last accessed on December 10, 2016.

[55] Apache Cassandra, http://cassandra.apache.org/, last accessed on December 10, 2016.

[56] CouchDB, http://couchdb.apache.org/, last accessed on December 4, 2016.

[57] HBase, https://hbase.apache.org/, last accessed on December 9, 2016.

[58] Hypertable, http://www.hypertable.org/, last accessed on November 25, 2016.

[59] MongoDB, https://www.mongodb.com/, last accessed on December 9, 2016.

[60] https://redis.io/, last accessed on November 27, 2016.

[61] Hadoop, http://hadoop.apache.org/, last accessed on December 9, 2016.

[62] Apache Storm, http://storm.apache.org/, last accessed on November 25, 2016.

[63] Zeppelin, https://zeppelin.apache.org/, last accessed on December 4, 2016.

[64] TensorFlow, https://www.tensorflow.org/, last accessed on December 9, 2016.

[65] Apache Beam, https://beam.apache.org/, last accessed on December 9, 2016.