Modeling and Simulation Strategies for Performance Evaluation of Cloud Computing Systems

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ABSTRACT: *This paper presents a novel evaluation study of various strategies for modeling and simulating cloud computing systems in order to assess their performance. Considering the exponential growth in the deployment of cloud computing systems worldwide and the need for their proper evaluation, this work provides three major contributions through comprehensive performance evaluations. Firstly, it proposes a novel 10-point performance evaluation framework for existing Cloud Storage infrastructure and applies it for evaluating major Cloud Storage Service Providers. Secondly, it presents a detailed evaluation of 18 most popular Cloud Storage Hardware vendors with respect to the storage technologies they incorporate. Thirdly, it provides a comprehensive survey of prominent simulation tools which are used for simulation and modeling of Cloud Computing systems. In conclusion, it takes stock of the current trends on optimizing storage infrastructure for Cloud Computing and predicting future research possibilities in this rapidly growing technology.*

Keywords: Storage Infrastructure, Cloud Computing, Modeling and Simulation

Received: 4 May 2012, Revised 3 June 2012, Accepted 3 June 2012

1. Introduction

In the last several years there are a number of changes to the way that computing facilities are organized and used. The Internet became a driving force to decentralize computing and storage facilities. The new distributed computing architectures have emerged that enable combining multiple, sometimes geographically distributed resources to create powerful data centers. The Virtualization techniques and modern trends like Cloud Computing have added new concepts in distributed resource management of data centers [1] [2] [3].

The different building blocks of this new generation data centers represent a mix of core networking, computing and storage technologies. The ability to design and manage such data center environment requires a deep understanding of theory and implementation procedures associated with each of the technologies.

In the last three decades data is continuously expanding in all data centers (private or public) all over the world, as shown in Figure 1 [4]. An exponential growth in world's data has become an imminent challenge for storage space providers as cloud storage will play a critical role in the near future to provide data storage access to millions of enterprise customers and common subscribers to store their structured and unstructured data on a day to day basis as per *pay as you go* scheme to keep IT overhead as low as possible with highly available, scalable, reliable and fully optimized storage infrastructure solutions [5].

Storage can be leased to store variety of data/information contents on private or public Storage Cloud. Infrastructure as a Service is one of the element of Cloud Computing which covers the data center services for private or public clients as per its service scope. Figure 2 shows the trend of prices of storage space from various vendors [6].

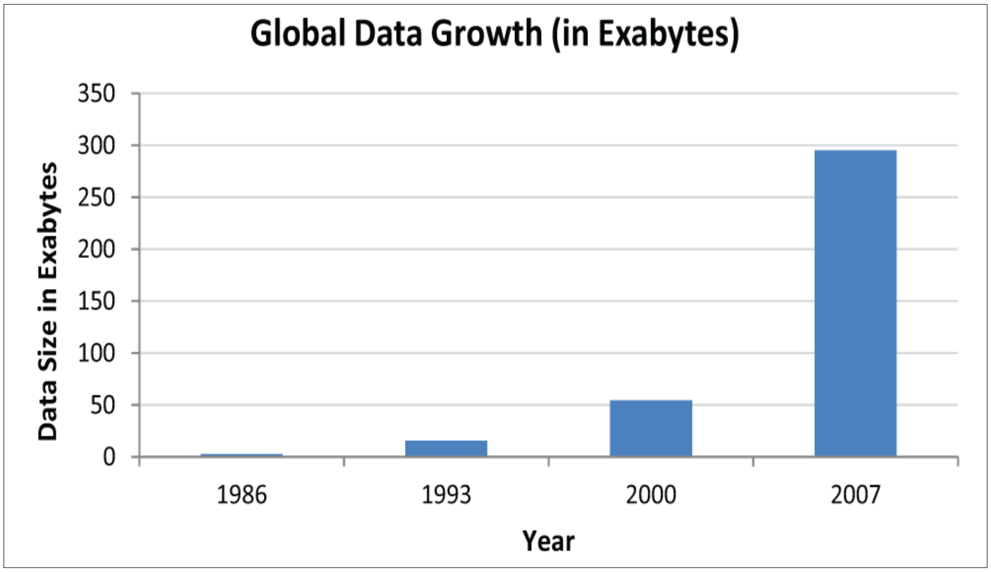

Figure 1. Global Data Growth Trend ([4])

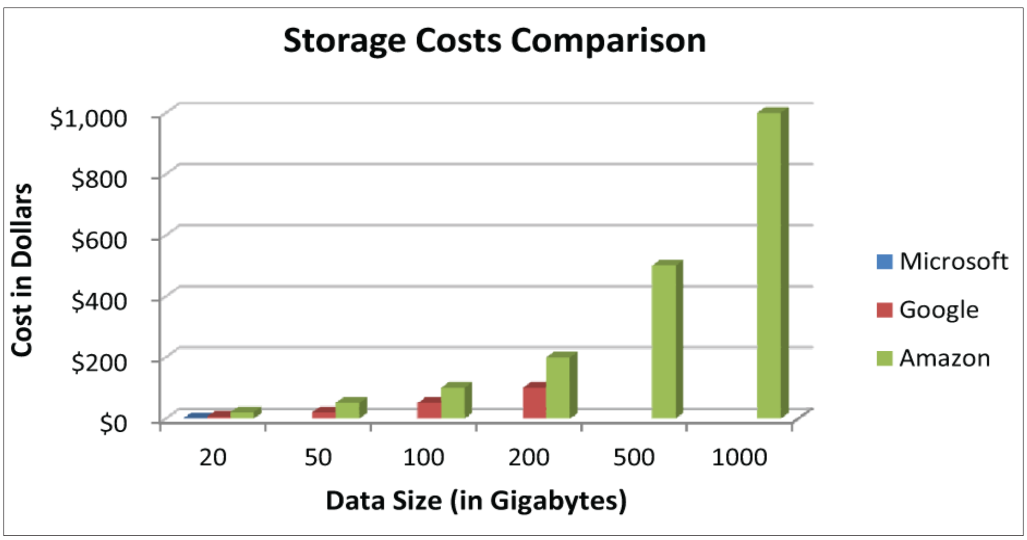

Figure 2. Data Storage Prices by Prominent Vendors ([6])

Several studies have been presented in the literature related to the research and development in the domain of Cloud Computing [7] [8] [9] [10] [11]. However, this paper focuses on the storage aspect of the Cloud Computing taking into account the critical role played by it. The novelty of this work lies in answering the following research questions.

• What are the data requirements of the current Cloud Computing implementations and their economic aspects?

• What are the core issues which dictate the evaluation criteria for contemporary Cloud Computing implementations?

• How the current Cloud Storage Technologies can be compared to each other based on the evaluation criteria proposed in this paper?

• Which are the prominent Cloud Storage hardware vendors and their qualitative comparison in terms of Cloud Computing storage?

The rest of this paper is structured as follows. In Section II we provide the required background related to Cloud Storage technologies. In Section III we present the proposed evaluation criteria in the context of Cloud Storage. The details of various Cloud Hardware vendors will be presented in Section IV. Section V presents the results and discussions of the research findings of this paper. Finally, Section VI concludes the paper by summarizing the key contributions and providing pointers to future work.

2. Cloud Storage Technologies

In order to appreciate the research presented in this paper, it is crucial that we look into the background and development of various Cloud Computing implementations in general and more specifically into the Cloud Storage technologies. Considering the current implementation of Cloud Computing infrastructure, the Cloud Storages can be classified into two major classes:

• *Cloud Storage as a Service*: Usually offered by Cloud Service Providers such as Google, Amazon, Microsoft, etc.

• *Cloud Storage as an Infrastructure*: Usually offered by Cloud Infrastructure Providers such as EMC, IBM, Hitachi, Oracle, Dell, etc.

Since Cloud Computing finds application in different businesses, there are broadly speaking three major Cloud Storage deployment methods:

1) *Private Cloud Storage* or Corporate internal IT group.

2) *Public Cloud Storage* or third party Cloud Storage service.

3) *Hybrid Cloud* or combination of above two strategies.

Now, we present the technical details of the three major Cloud Storage technologies mentioned above.

2.1 Private Cloud Storage Service

Private Cloud is an internal/corporate cloud, a typical example of which is shown in Figure 3. It is a marketing term for private and proprietary computing infrastructure architecture that offers hosted services to a limited number of corporate users behind a firewall.

The growth in virtualization technology allows corporate network and data center administrators to play a role of service providers up to corporate level. There are two types of private clouds:

• *On-Site* managed by local IT administrators

• *Offshore* managed by third party services like *www.rackspace.com*

2.2 Public Cloud Storage Service

This type of implementation is also known as a shared cloud, as depicted in Fig. 4. Such type of services are provided *as a service* over the Internet with little or no control over the underlying technology infrastructure. This cloud is more common nowadays as it reduces complexity and long lead times in testing and deploying new products. Considering the economic aspect of Public Cloud implementation it is generally less expensive than the Private Cloud.

2.3 Hybrid Cloud Storage Service

This is an integrated approach, combining the power of both public and private clouds. Customized rules and policies govern areas such as security and the underlying infrastructure. In this scenario, activities and tasks are allocated to internal or external clouds as required. Such a scenario is depicted in Figure 5.

3. Proposed Evaluation Framework

The study of various implementation strategies in the previous section helps us in understanding the need and ways to optimize the performance of Cloud Storage. Optimization of Cloud Storage performance is critical, since the optimum functioning of the storage solution is the basis of a successful Cloud Computing service. Hence, we now focus on the core issues which impact on

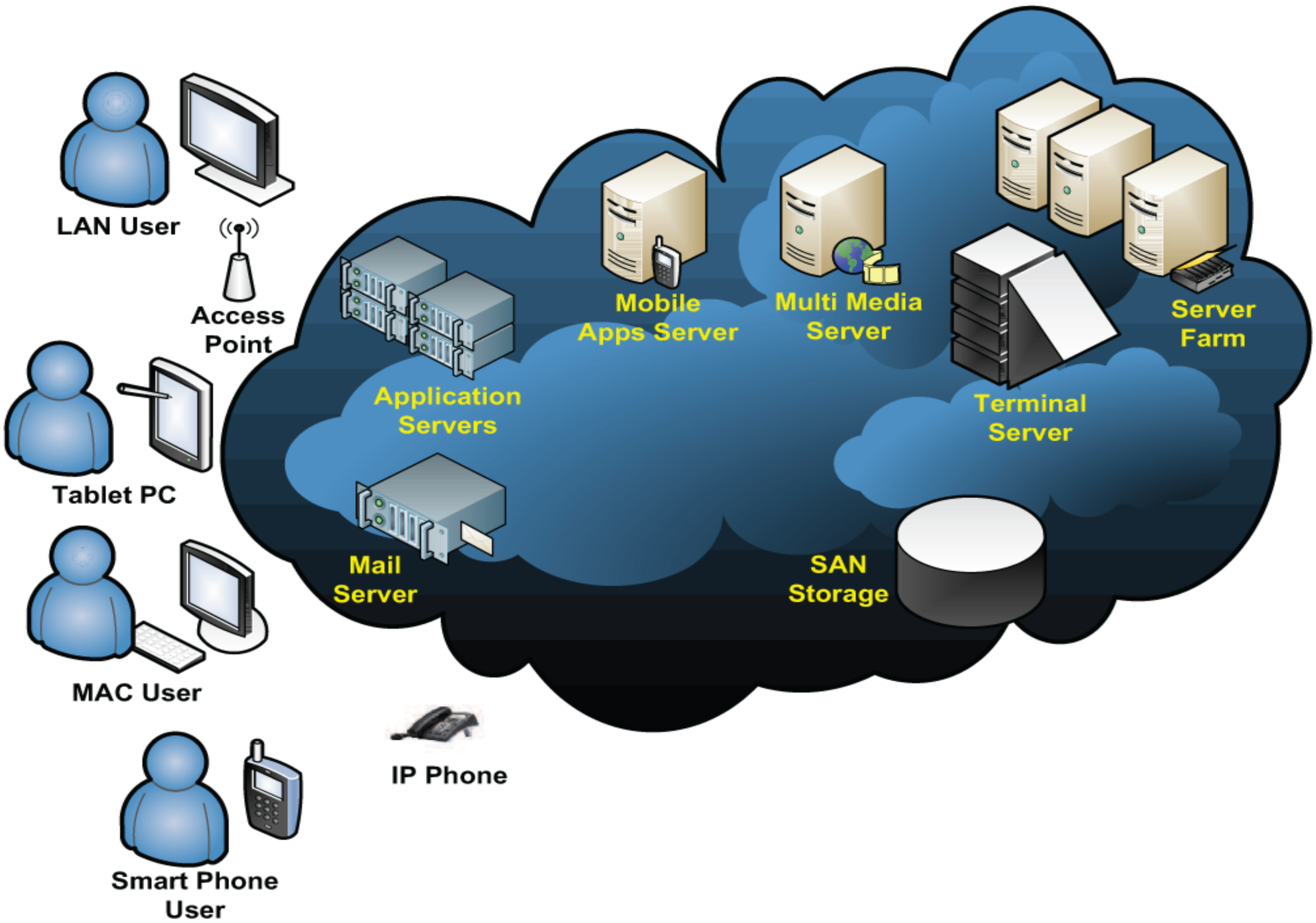

Figure 3. Private Cloud Implementation

service optimization and an economical delivery of the services provisioned on the Cloud solution. To this end, we propose and analyze the following criteria which should be taken into consideration when evaluating any Cloud Storage implementation. By no means, this is a comprehensive list of criteria which can exist, however, we felt these ten criteria are crucial to study and evaluate an existing Cloud Storage implementation. Another benefit of this enlisting is that it gives us a benchmarking tool to propose further enhancements in the existing solutions.

1) ***Energy***: Cloud computing is said to be energy efficient if energy consumed in data transport stays lower than the energy consumed by cloud computation servers. In recent years, there is exponential improvement in the energy efficiency of servers, storage equipment, routers and switches [12].

2) *Design Review*: Traditional storage technologies are not scalable for multi-Exabyte scale. Storage technologies need to be re-designed with additional rows of arrays to meet current capacity requirement by Cloud Computing as a public/private service utility [13].

3) *Latency*: Latency is a key consideration in Hybrid or Public Clouds. The latency issue makes the Cloud most suited as a storage infrastructure for latency-tolerant applications such as back-up, archive, and disaster recovery.

4) *Throughput*: Throughput is another important factor for the optimization of Cloud hardware and software to establish smooth synchronization and optimal communication between various end points.

5) *SSD Drives*: Solid State Hard Drives are storage devices that use semiconductors for memory. They are referred to as disks because they effectively replace the traditional hard disk drives. They include a memory bus board, battery card, CPU and a

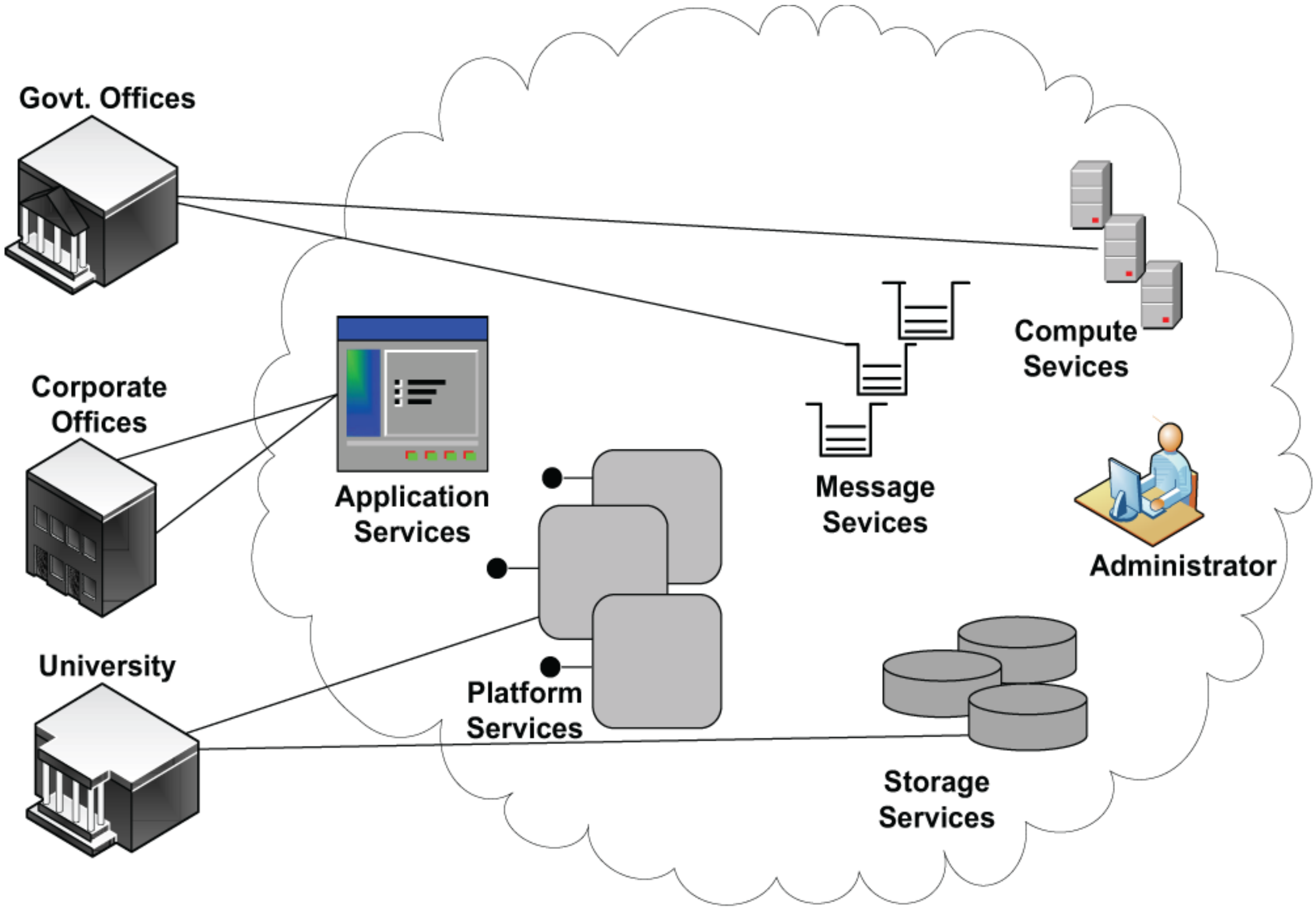

Figure 4. Public Cloud Implementation

DRAM. They have a long life because they do not contain any moving parts inside. So there is no wear and tear, and no loss of data, since they have their own CPUs that are much faster, and are capable of avoiding bottlenecks in situations where the I/O rates are high.

6) ***Scalability*****:** The core idea behind a successful cloud storage infrastructure is scalability. Cloud storage requires high level of scalability, far greater than what is required for scalability in enterprise level storage. While typical enterprise definitions of scalability range from 2× to 10×, cloud storage scalability should be designed for 100× or even 1000× scalability. Enterprises typically make active use of only 30-40% of capacity so they have a large cushion to handle growth and demand spikes.

7) ***Reliability*****:** One has to make sure the Cloud service being used must be capable to offer durable, performanceguaranteed, sustainable and optimal utilization of storage resources and back-to-back reliable connection between various storage nodes at different geographical locations [14].

8) ***High Availability*****:** A redundant hardware set-up is essential for virtual servers and desktops and storage infrastructure for high availability. For example, Twin-Strata CloudArray support for VMware High Availability (HA), is an important component of VMware infrastructure. VMware HA works by moving all VMs that run on a failed ESX server to another ESX server in the same fail over cluster.

9) ***Security*****:** It is essential to build a secure Cloud storage service on top of the cloud storage infrastructure in order to have complete faith and trust of Cloud service customers in corporate world and normal end users. Cryptography plays a major role in defining security scope and limit on Cloud communication channel's security as well as data integrity and full safety from unauthorized users.

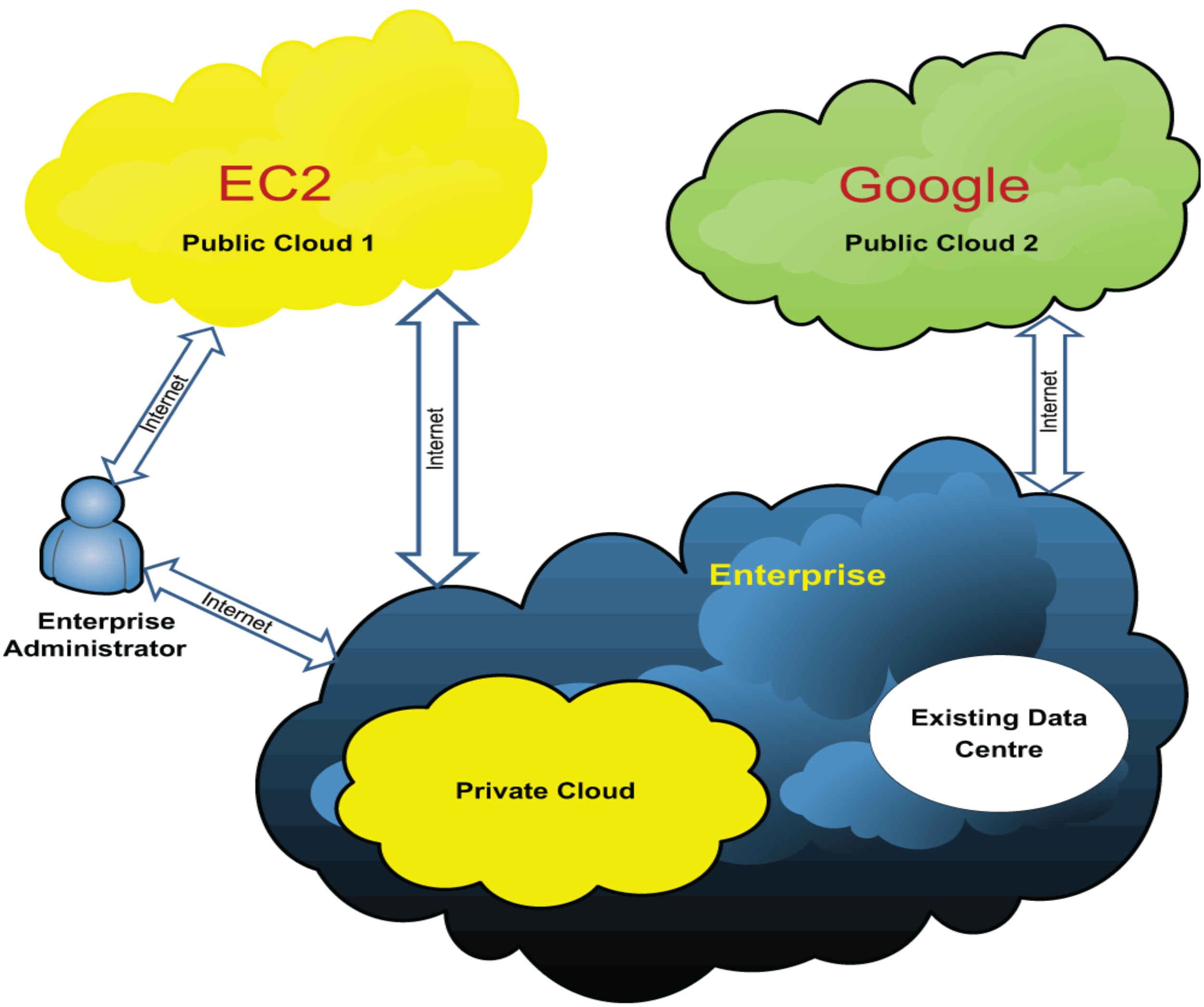

Figure 5. Hybrid Cloud Implementation

10) ***Accessibility*****:** All cloud infrastructures must be accessible by Web browsers. All applications must be compatible to work with common web browsers including Internet Explorer, FireFox, Google Chrome and Safari on PC platform.

The above mentioned criteria play an important role in evaluating an existing Cloud Storage implementation as they touch upon the various aspects of any Cloud Storage infrastructure. In Section VI, these ten criteria will be used to evaluate various Cloud Storage technologies that exist in the market today. This, we believe is an unique and outstanding contribution of our research work presented in this paper.

Before we conclude this section, we would like to focus on the scalability issue concerning the cloud infrastructure. Figure 6 shows a typical architecture of cloud infrastructure. As we know, Cloud Computing offers computation facility on single or multiple vCPUs and vServers with server clustering and load balancing techniques to achieve fastest delivery of contents. Also, the changes in network topology, hardware, software configurations to suit scalability requirements should not impact on QoS or performance. In any situation Cloud infrastructure should maintain high level of availability with full consistency of service and complete reliability. To achieve this the cloud infrastructure should be elastic and scalable.

4. Storage Hardware Technologies

This section provides the details of the Storage Hardware Technologies, after having enlisted the major criteria for evaluating a Cloud Storage implementation. This is essential in order to assess the state-of-the-art storage technologies which are manufactured

Cloud Vendor	Platform Type	Status	Technology Mode	Production Status	Comments
3Tera	Server	Not a provider	Software based	Production	Hosting Solution
Adobe Air	Application	Not a provider	Backbone	TBD	Desktop Play
Akamai	Server	Not a provider	Software based	Production	CDN
Amazon EC2	Server	Provider	Backbone	Beta	-
Amazon S3	Storage	Provider	Backbone	Beta	-
Amazon SimpleDB	Database	Provider	Backbone	Beta	-
Apache CouchDB	Database	Not a provider	Software based	Production	IBM involvement
Apache Hadoop	Database	Not a provider	Software based	Production	-
Areti Internet	Application	Provider	3Tera	Production	-
Box-Net	Storage	Provider	Backbone	Production	-
Cassatt Corp.	Server	Not a provider	Software based	Production	Provisioning play
Citrix	Utility	Not a provider	Software based	Production	-
CohesiveFT	Utility	Not a provider	Amazon EC2	Beta	Supports XEN and VMWare
Dell DCS	Server	Provider	Backbone	TBD	-
Elastra	Server	Provider	Amazon EC2	Beta	-
EMC Mozy	Storage	Provider	Backbone	Production	Cloud Services play
Enki	Server	Not a provider	3Tera	Production	Services play
Enomaly	Server	Not a provider	Amazon EC2	Beta	Services play

Table 1. Assessment of Various Cloud Hardware Vendors

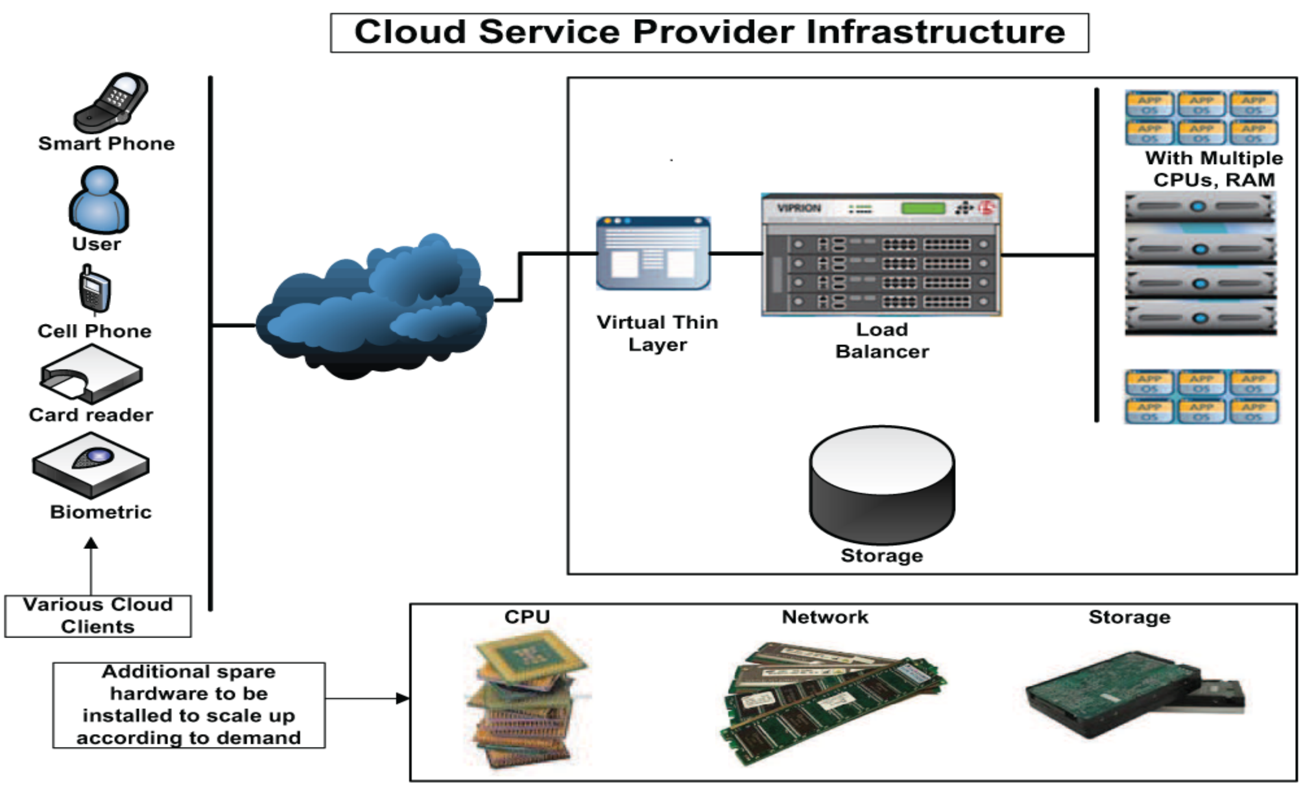

Figure 6. Scalable Cloud Infrastructure

and supplied from these hardware vendors. This will in turn provide a realistic picture of the sophistication which can be incorporated into any practical Cloud Storage setup. To this end, we evaluate eighteen most prominent hardware vendors on the features like *Platform*, current *Status* as a service provider, the *Technology Mode* and current *Production* status. The findings are summarized in Table 1.

It can be observed from Table 1 that the Cloud Hardware is used to support different platform types ranging from pure *storage* to high end *server* implementations, *database* services, *application* and *utility* services. This is certainly a major flexibility and a crucial factor in the success and popularity of Cloud Computing services.

It is also interesting to observe that some Cloud Hardware vendors who actually claim to be service providers are not actually providing the services in a direct way. Instead they are acting as a partner with some of the established service providers who have managed to attain a reputation in the Cloud Services market.

The mode of technology varies from vendor to vendor from being *Software* based to that based on *Backbone*. A point of interest here is that proprietary technologies (such as Amazon EC2 and 3Tera) have become popular implementations with certain not-so-popular cloud vendors. This suggests that such an established vendor technology could lead the market dynamics in the coming years and could possibly be adapted as a standard.

The presence of *Beta* status in terms of production of the Cloud Services suffices to say that the Cloud Computing technology is on a path to higher sophistication and development. It would not be an exaggeration to say that this technology is here to stay for few decades to come.

Vendor	Dell	Oracle	Hitachi	IBM	EMC	NetApp
Technology	Equallogic	Exalogic	HDS Silver Lining	IBM Smart Cloud	Atmos	NetApp Cloud Solution
Platform	Virtual	Physical	Virtual	Physical	Physical	Virtual
Energy	Low	N/A	N/A	N/A	N/A	Low
Design Review	N/A	N/A	Simplified	N/A	N/A	Open APIs
Latency	Low	Low	Medium	Low	Low	N/A
Throughput	Medium	High	N/A	N/A	High	N/A
SSD	Yes	Yes	No	Yes	Yes	N/A
Scalability	Yes	Yes	Yes	Yes	Yes	Yes
Reliability	Medium	High	High	Medium	High	N/A
Availability	High	High	Medium	Medium	High	Low
Security	Medium	N/A	High	High	Medium	High
Accessibility	Low	High	N/A	N/A	High	N/A

Table 2. Evaluation of Various Cloud Storge Technologies and Platforms

5. Cloud System Modeling

This section deals with modeling aspects of cloud systems. A generic approach of such a modeling is depicted in Fig. 7. Cloud Infrastructure comprises of multiple individual nodes such as OS servers of various major OS vendors such as Microsoft, HP, IBM, SUN, Red Hat and many open source OSs.

Besides OS nodes, a cloud network needs the best networking nodes such as core routers, edge routers, switches, firewalls, SAN and NAS storage facility for providing physical storage space as well as an environment to setup complete virtualized segments of Cloud services such as:

• IaaS (Infrastructure as a Service)

• PaaS (Platform as a Service)

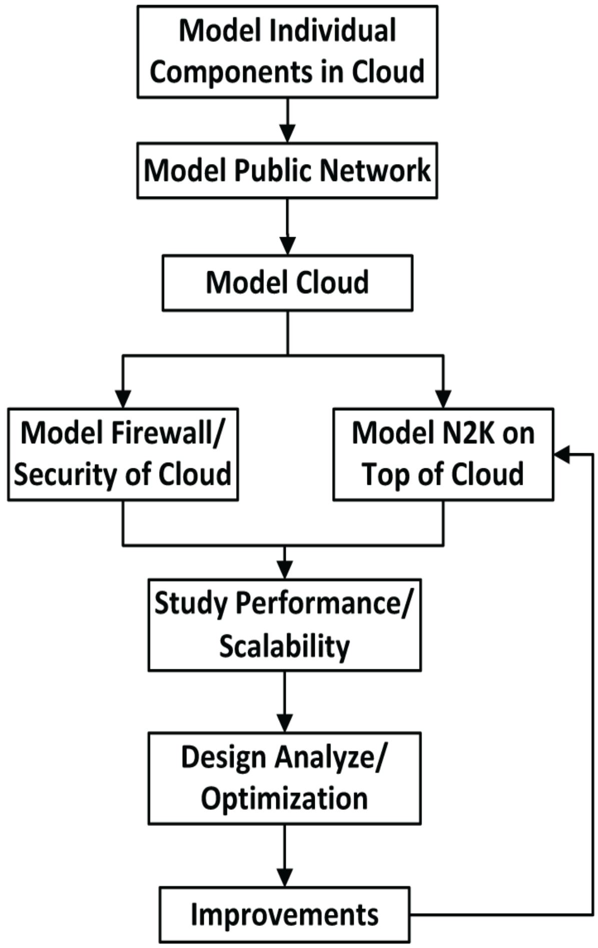

Figure 7. Flowchart of Cloud Modeling

• SaaS (Software as a Service)

• CaaS (Computing as a Service)

• DaaS (Data as a Service)

Cloud services mostly serve remote users through public access networks such as Broadband Internet services, 3G, 4G Mobile Internet access, WiFi and WiMax Internet access, local and public Internet domains. Moreover we need to evaluate different LAN, WAN links such as Ethernet, Fast Ethernet, ISDN, DSL, Sonnet and FDDI.

Cloud infrastructure has to be provisioned in such a way that it is equipped with sustainable, accessible, scalable and reliable features with flexibility and smooth operation of service and robust design. Security of infrastructure, information, physical and virtual objects and resources is equally important. Firewall is a conventional way of blocking illegal intrusion in local cloud service domain. Whereas N2K (Need to Know) is an evolving concept to support large scale networks and infrastructure working in a multi protocol environment.

In cloud modeling and simulations, we will concentrate more on design complexities, as well as determine performance issues, especially when infrastructure scales go up/down, as per customer needs and demands. Key tasks in these experiments is to achieve best performance by optimizing hardware and software resources of cloud service provider with statistical analysis and changing configuration to improve cloud services.

Simulators	Programming Language	GUI	License	Features	Comments
OPNET	C/C++	Yes	Required	Wired and Wireless Networks Simulation	Difficult to model new devices
ns-2	C++	No	Free	Wired and Wireless Networks Simulation	Lacks some of the standard models
GlomoSim	C	Yes	Free	Mostly wireless networks	Suitable for wireless only
Bricks	Java	Yes	Free	Scheduling algorithms support	Lacks complete network support
GridSim	Java	Yes	Free	Multi-layered design architecture	Suitable for distributed resource simulation
SimGrid	C/Java	Yes	Free	Scheduling algorithms	Not suitable for comprehensive topology

Table 3. Evaluation of Simulation and Modeling Tools for Cloud Environment

In order to conduct lab experiments based on the given flow chart (Figure 7) for Cloud Computing environment, we need proper modeling and Simulation tools. In this paper we critically evaluate prominent simulation and modeling tools, to setup and achieve Cloud modeling and simulation results. It is essential to determine best Simulation strategy to achieve results very near to the real time practical experiments. A summary of the findings related to the simulation and modeling tools is presented in Table 3.

6. Results and Discussion

We now present a summary of the results obtained from the detailed analysis conducted by us for the Cloud infrastructure providers. They are evaluated against the criteria specified in Section III and the findings are detailed in Table 2. Apart from the proposed criteria, we also provide the details of the *Technology* and *Platform* which these service providers are currently using in their services. We provide a brief summary of the technologies to begin with.

6.1 Storage Technologies

***Equallogic*:** Dell Equallogic FS7500 works with Dell Fluid File System which works well with NAS storage. FS7500 can scale up with existing Equallogic iSCSI arrays. FS7500 perform file services through CIFS/SMB and NFS protocols over standard Ethernet interfaces.

***Exalogic*:** Exalogic is designed to provide a very high performance, reliable, easy to use versatile system. Exalogic is the realization of a new way of looking at the role of IT in the modern enterprise. Exalogic is the advanced form of Oracle's Grid architecture. Exalogic combined with Exadata can form a Private Cloud, an ideal solution for mission-critical applications.

***HDS*:** Hitachi Data Storage (HDS) system can provide basic infrastructure to host all Clouds (Public, Private and Hybrid). HDS provides robust integration facility between edge and core components, strong security, seamless and automated storage tiering.

***Smart Cloud*:** IBM's core objective is to deploy technology as a service, through which users can access resources on a demand basis.

***Atmos*:** Atmos is centralized system for management. It is seamlessly scalable, very flexible in accessing and good for Storage as Service.

Current Trend: *It can be observed that each of the hardware vendors have their own proprietary storage technology. This is surely a concern if the Cloud Storage needs to be made popular and the technology needs to be made ubiquitous.*

Future Possibility: *In future, there is dire need to standardize and unify the storage technology which can then be used in the existing as well as future Cloud Computing implementations.*

6.2 Storage Platforms

The storage platform is observed to be both *Physical* and *Virtual*. Physical implementations tend to be more of a traditional way of providing storage services to the end users. However, with the application of virtualization technology, virtual storage mechanisms can be realized which are more efficient.

Current Trend: *Current storage platforms are a combination of both physical and virtual implementations.*

Future Possibility: *It is foreseen that the majority of the future storage platforms will shift towards virtual implementationsconsidering the benefits of this approach.*

6.3 Energy
Considering the current thrust on energy savings and efficiency in the Information and Computing Technology (ICT) arena, the Cloud Storage infrastructure should be designed for energy efficient operation and performance. However, the goalof saving energy and the need for 24×7 availability of Cloud Services is a challenging problem with needs considerable efforts to be solved.

Current Trend: *Energy-efficiency for Cloud Storage is a ongoing research area and hence restricted information is available in this regard.*

Future Possibility: *It is however expected that to meet the challenges of energy scarcity, more and more future Cloud Storage implementations will be made highly energy-aware.*

6.4 Design Review
There is pressing need to make a significant shift in the way current hardware storage technology functions. At the physical level, the hardware needs to be robust enough to handle the vast amount of data storage and more importantly the supported data access mechanisms.

Current Trend: *SSD hard drives are being extensively used in order to benefit from the semiconductor technology and large scale integration mechanisms.*

Future Possibility: *It is very much possible to go for higher density storage which is robust, efficient and failure-proof.*

6.5 Latency
Latency is a key concern for real-time applications which demand high speed data read or write from/to the Cloud Storage. In order to meet this demand, the current Cloud Storage needs a hardware which supports high speed reads and writes.

Current Trend: *It is encouraging to see that the current Cloud Storage implementations are providing very low latency support.*

Future Possibility: *The bottleneck which exists at the hardware level can be eliminated up to some extent with a focused research in the area of solid state devices for storage systems.*

6.6 Throughput
As the Cloud Computing services cater to geographically distributed clients, throughput achieved across the clients over a network of inter-connections is a prime factor in the success of such a service. The boundary between the Cloud Storage system and Cloud Networking system is required to be highly permeable for high speed data transfers.

Current Trend: *Current throughput rates range from 'medium' to 'high', which are positive indications to the growth of Cloud Storage implementations.*

Future Possibility: *Higher throughput rates are very much a reality considering the enormous research efforts in the area of high speed data transfer technology used in optical networks and the supported storage hardware.*

6.7 SSD
The technology behind the success of Cloud Storage is the implementation of the hard disks which are made of Solid State Devices, as we have seen earlier. This technology differs significantly from the traditional magnetic disk drives in terms of speed and efficiency.

Current Trend: *Almost all Cloud Storage implementations are based on array of SSD disk drives.*

Future Possibility: *Another direction in which these SSD drives can progress, is a further increase in the density of storage* (*data per physical area*).

6.8 Scalability

Cloud Storage implementations need to be scalable in order to cater to the ever-increasing demand from the customers for more disk storage for storage-demanding applications such as High Definition video content.

Current Trend: *Hundred percent of the current Cloud Storage infrastructure was found to be highly scalable in nature, as it is evident from this assessment.*

Future Possibility: *The scalability factor of future Cloud Storage could reach up to* 1000×.

6.9 Availability, Accessibility and Reliability

Cloud Storage implementations need to be available round the clock, have easy accessibility through existing software clients and must be reliable enough, so as to absorb the shockwave of unexpected failures.

Current Trend: *Most of the current Cloud Storage implementations score in the 'low' and 'medium' range.*

Future Possibility: *Intelligent, robust and user-friendly approaches are needed to improve on these issues, which can be possible through collaboration between physical and virtual domains.*

6.10 Security

Security is of prime concern to the end users who risk storing their confidential data on the Cloud Storage. A highly secure environment founded on unbreakable cryptic algorithms are the need of the hour.

Current Trend: *More than 50% of the current Cloud Storage security feature score in the 'medium' and 'high' range.*

Future Possibility: *In order for the Cloud Computing to be a successful technology, authentication, authorization and accounting mechanisms need to achieve a fool-proof status, which is an ongoing research area.*

7. Conclusion

This paper presented a novel treatment to the subject of Cloud Computing technology from the perspective of how Cloud Storage mechanisms are impacting the successful growth of current and future Cloud Services. It presented a concise description of the current Cloud Storage technologies through a discussion on Private, Public and Hybrid Cloud Storage implementations. It then proposed a novel 10-point performance evaluation framework for a thorough evaluation of current Cloud Storage infrastructure. A detailed analysis was presented in relation to a comparison among 18 mostpopular Cloud Hardware vendors with respect to the storage technologies they are currently implementing. The unique and outstanding contribution of this paper was to evaluate 6 different Cloud Storage service providers against the 10- point criteria proposed in this research work. Another important contribution of this research was, to take stock of the current trends on optimizing Storage Infrastructure for Cloud Computing and providing pointers to future possibilities in this progressive technology. Finally, it presented a comprehensive survey of various modeling and simulation tools which are available for studying the performance of cloud computing systems.

8. Acknowledgment

The authors would like to acknowledge the support of King Abdulaziz University and Prince Mohammad Bin Fahd University for funding this joint research work.

References

[1] Pathway Communications, Cloudpath, http://cloudpath.pathcom.com/plans/, (Last accessed: May 2012).

[2] Cisco Systems Inc., Bringing Managed IT Services to Saudi Arabia, http://www.cisco.com/en/US/solutions/collateral/ns340/ns517/ns224/STC V7 Customer 020311.pdf, (Last accessed: March 2012).

[3] Institute for International Research, Cloud Business Saudi Arabia, http://www.iirme.com/cloudbusinessksa, (Last accessed: May 2012).

[4] Wikipedia, World's Information Storage Capacity, http://en.wikipedia.org/wiki/Exabyte, (Last accessed : May 2012).

[5] Technology Executives Club, Control application data growth before it controls your business, http://www.technologyexecutivesclub.com/ Articles/itintegration/applicationgrowth.php, (Last accessed : March 2012).

[6] CSP, Cloud Storage Providers, http://cloudstorageproviders.net/, (Last accessed : May 2012).

[7] Dewan, H., Hansdah, R. C. (2011). A Survey of Cloud Storage Facilities, *In*: *IEEE World Congress on Services*, July, p. 224–231.

[8] Pan, J., Paul, S., Jain, R. (2011). A survey of the research on future internet architecture, *IEEE Communications Magazine*, 49 (7) 26–36, July.

[9] Mahjoub, M., Mdhaffar, A., Halima, R., Jmaiel, M. (2011). A Comparative Study of the Current Cloud Computing Technologies and Offers, *In*: *First Symposium on Network Cloud Computing and Applications* (*NCCA*), Nov., p. 131 –134.

[10] Rimal, B., Choi, E., Lumb, I. (2009). A Taxonomy and Survey of Cloud Computing Systems, *In*: *Fifth International Joint Conference on INC, IMS and IDC, 2009* (*NCM* '09), Aug. p. 44 –51.

[11] Sakr, S., Liu, A., Batista, D. M., Alomari, M. (2011). A Survey of Large Scale Data Management Approaches in Cloud Environments, *IEEE Communications Surveys & Tutorials*, 13 (3) 311–336, July.

[12] Baliga, J., Ayre, R., Hinton, K., Tucker, R. (2011). Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport, *In*: *Proceedings of the IEEE*, 99 (1) 149–167, Jan.

[13] McClure, T. (2012). Hitachi Data Systems' Silver Lining, http://www.technologyexecutivesclub.com/Articles/ infrastructure/cloudstorage.php, (Last accessed : May 2012).

[14] Jain, A. (2012). Enabling the Path to Private Cloud: Automation, http://www.iplogic.com/Files/Admin/White Papers/DCV/EnablingthePathtoPrivateCloudAutomationwhitepaperWP7130MAY11%5B1%5D.pdf, (Last accessed: May 2012).