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Cloud Computing with Related Enabling Technologies

Abah Joshua*, Francisca N. Ogwueleka**
* Departement of Computer Engineering, University of Maiduguri, Maiduguri, Nigeria.
** Departement of Computer Science, Federal University of Technology, Minna, Nigeria.

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ABSTRACT

Cloud Computing is a concept that has been defined differently by many and there seem not to be a consensus. Despite these views, cloud computing is not a complete new idea as it has intricate connections to technologies or domain such as the Grid Computing paradigm, and the general distributed computing. This overview gives the basic concept of cloud computing, and highlights the relationship between Cloud computing and other cloud enabling technologies by providing their similarities and differences. This insight into the essential characteristics of cloud and its enabling technologies provides a good foundation for understanding and a hint on how to leverage desirable strengths of these technologies in the cloud by way of extension and or inheritance.

Corresponding Author:

First Author,
Departement of Computer Engineering,
Faculty of Engineering, University of Maiduguri,
PMB 1069, Maiduguri, Borno State, Nigeria.
Email: jehoshua_a@yahoo.com

1.0 INTRODUCTION

Several technologies are related to cloud computing, and the cloud has emerged as a convergence of several computing trends. It seeks to address certain key aspects that may have been lacking in each of these trends, individually. In this paper, the features of each of these related technologies and how they compare and or relate with cloud computing is discussed.

Cloud computing is a paradigm shift to computing [1] that sees and delivers computing as a service rather than as a resource. Cloud computing encapsulates several layers of computing provisioning that include the hardware resources located at the data centres of cloud providers, the operating system and virtualization software on top of that hardware, and the applications that are delivered as services over the internet. These services are provided as utility to customers who are billed based on usage, similar to the billing scheme of traditional public services such as electricity, telephone and water.

Cloud Computing is a realization of computing pioneer John McCarthy’s prediction back in 1961, that “computation may someday be organized as a public utility”; and went on to speculate how this might occur [2]. Cloud computing is not unconnected with Grid Computing and other related technologies.

In the mid 1990s, the term Grid was coined to describe technologies that would allow consumers to obtain computing power on demand. Ian Foster and others [3],[4] posited that by standardizing the protocols used to request computing power, we could spur the creation of a Computing Grid, analogous in form and utility to the electric power grid. Researchers subsequently developed these ideas in many exciting ways, producing for example large-scale federated systems (TeraGrid, Open Science Grid, caBIG, EGEE, Earth System Grid) that provide not just computing power, but also data and software, on demand. Standards organizations (e.g., OGF, OASIS) defined relevant standards. This term was co-opted by industry as a marketing term for clusters. But no viable commercial Grid Computing providers emerged, at least not until recently [2].

This article aims to explain the key concepts, and underlying technologies as well as discussing the relationships in terms of similarities and differences of cloud computing to other domain which has contributed to the evolution of cloud computing. This will help deliver a much broader understanding and appreciation of cloud computing.

The rest of this paper is organised as follows: Section 2 discusses the theoretical baselines, section 3 provides an overview of cloud computing, section 4 discusses cloud computing related technologies which are regarded as enabling technologies of the cloud, section 5 summarizes and section 6 concludes.

2.0 THEORETICAL BASELINES

Cloud computing today is the beginning of "network based computing" over Internet in force. It is the technology of the decade and the beginning to the end of the dominance of desktop computing such as that with the Windows. It is also the beginning of a new Internet based service economy: the Internet centric, Web based, on demand, Cloud applications and computing economy [5].

2.1 Distributed Computing

Distributed computing refers to the very idea of using distributed systems that are generally multiple computers connected to each other via computer networks to collaboratively process a common goal. Those computers communicating can be homogeneous or heterogeneous, distributed globally or locally. According to the characteristics of localization or equality, distributed systems have different subsets, such as supercomputers, grids, clusters, web 2.0 and clouds [2].

Before going further into the subsets of distributed computing, an illustration is provided to visualize the interconnection between the concepts that will be explained in the following:

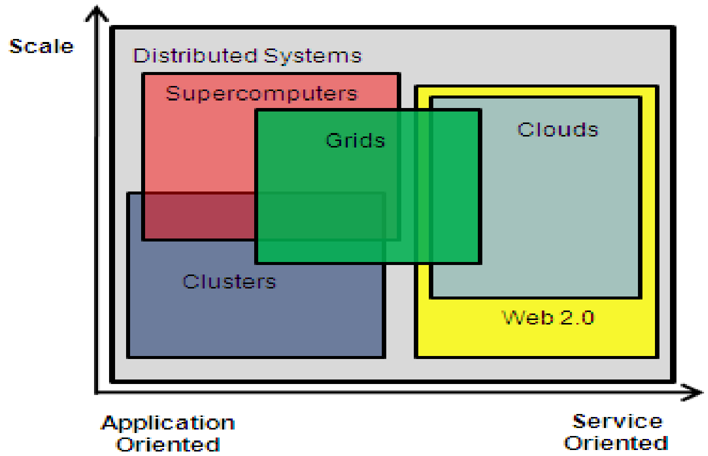

Figure 2.0: Distributed Computing and its subsets [2].

Every participanting machine in a distributed system is able to download the peace of software and then interconnect to a centralized server. The servers provide the input from their sensors with a huge amount of data, making the calculation of this data normally very complicated. While a single computer would not be able to do that in an appropriate amount of time, millions of computers that are interconnected anywhere in the world would be able to achieve that.

2.1.1 Clusters

Characteristics of clusters are that the computers being linked to each other are normally distributed locally, and have the same kind of hardware and operating system. Therefore cluster work stations are connected together and can possibly be used as a super computer [21].

2.1.2 Supercomputers

Supercomputers can be easily compared to clusters, because it follows the same concept, except the fact that it is merged into one box already and is not locally interconnected with other machines [21]. IBM is constructing those machines consisting with a lot of processors that are merged into one machine with high performance capabilities [22]. The only disadvantage is that they are usually expensive and have the necessity of a huge amount of energy.

2.1.3 Grids

When defining grid computing it is necessary to differ it from clusters. While clusters are distributed locally and obliged to use the same hardware and Operating System (OS), grids involve heterogeneous computers that are connected to each other and distributed globally. The OS and hardware that run on those machines can also be different from each other [21].

The computers that are interconnected over the internet can come from anywhere while there is usually no obligation to pay. For this reason already it is obvious that grids being connected are not nearly as expensive as the supercomputers that are offered from IBM and other technology companies.

2.1.4 Clouds

Together with virtualization, clouds can be defined as computers that are networked anywhere in the world with the availability of paying for the used clouds in a pay-per-use way, meaning that just the resources that are being used will be paid for [18]. In the following, clouds will be introduced.

3. CLOUD COMPUTING OVERVIEW

There is no absolute consensus on the meaning of the term "Cloud computing" as noted by [23], "*A lot of people are jumping on the [cloud] bandwagon, but I have not heard two people say the same thing about it. There are multiple definitions out there of 'the cloud.'*"

Hence, many definitions have been given by different researchers to the term. We shall adopt the America National Institute of Standards and Technology (NIST)'s definition of the cloud. According to NIST [6], Cloud computing is *"A pay-per-use model for enabling available convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."*

3.1 Cloud Computing Features

The summary of the features of Cloud Computing described by [7], [9] is:

- Cloud Computing is a new computing paradigm.
- Infrastructure resources (hardware, storage and system software) and applications are provided in everthing-as-a-service (XaaS) manner. When these services are offered by an independent provider or to external customers, Cloud Computing is based on pay-per-use business models.
- Main features of Clouds are virtualization and dynamic scalability on demand.
- Utility computing and SaaS are provided in an integrated manner, even though utility computing might be consumed separately.
- Cloud services are consumed either via Web browser or via a defined API.

3.2 Cloud Computing Characteristics

There are five essential characteristics of Cloud Computing which explains their relation and difference from the traditional computing. These are;

- *On-demand-self-service:* Consumer can provision or un-provision the services when needed, without the human interaction with the service provider.
- *Broad Network Access:* It has capabilities over the network and accessed through standard mechanism.
- *Resource Pooling (Multi-tenancy):* The computing resources of the provider are pooled to serve multiple consumers which are using a multi-tenant model, with various physical and virtual resources dynamically assigned, depending on consumer demand.
- *Rapid Elasticity:* Services can be rapidly and elastically provisioned.
- *Measured Service:* Cloud Computing systems automatically control and optimize resource usage by providing a metering capability to the type of services (e.g. storage, processing, bandwidth, or active user accounts) [7], [8].

3.3 Cloud Service Models

Three Cloud Services Models are defined, these fundamental classifications are often referred to as "SPI model" that is; software, platform or infrastructure as a service.

- *Cloud Software as Service:* This is a capability in which the consumer can use the provider's applications running on the cloud.
- *Cloud Platform as Service:* In this type of service, the consumer can deploy the consumer created or acquired applications created by using programming languages or tools provided by provider, on the cloud infrastructure.

- *Cloud Infrastructure as Service:* This is a capability provided to the consumer by which, it can provision processing, storage, networks and other fundamental computing resources where the consumers can deploy and run the software (that is, operating systems, applications) [7], [8].

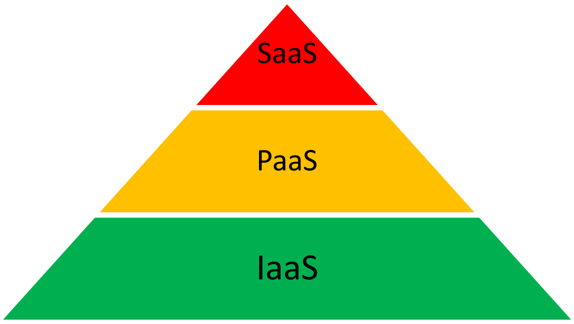

Figure 3 :SPI Model Pyramid

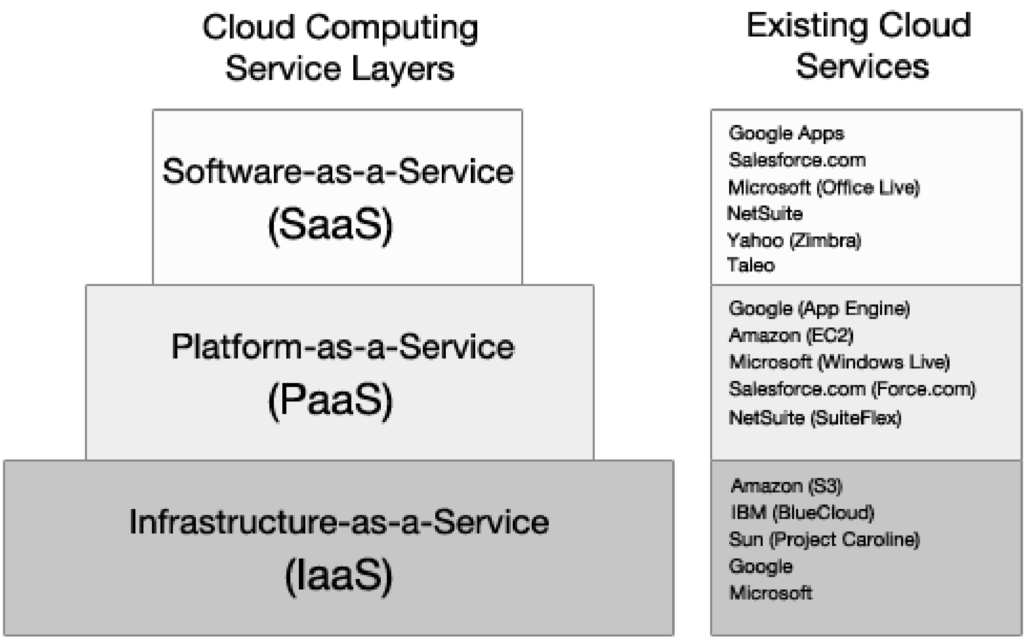

Figure 3.1: Showing the Cloud Computing Stack and Existing Cloud Services [20].

3.4 Cloud Deployment Models

Cloud services are provisioned in different ways, this are referred to as deployment models [7]. They include;

- *Public Cloud:* The cloud infrastructure is available to the general public.
- *Private Cloud:* The type of the cloud, that is available solely for a single organization.
- *Community Cloud:* In this type of cloud deployment model, the infrastructure of the cloud is shared by several organizations and supports a specific community with shared concerns.
- *Hybrid Cloud:* This is a cloud infrastructure that is a composition of two or more clouds that is, private, community or public [7], [8].

4. CLOUD COMPUTING RELATED TECHNOLOGIES

Several technologies are related to cloud computing, and the cloud has emerged as a convergence of several computing trends. It seeks to address certain key aspects that may have been lacking in each of these trends, individually.

Clouds extend the capabilities of other domains with the specific goal to achieve scalability/ elasticity, availability with optimal resource utilisation, which is as such only partially addressed in other domains. Specifically, clouds belong to the wider areas of Internet of Services (including Web Services, Web3.0, Service Oriented Architecture (SOA) etc.) and Utility Computing (including Grid, Virtual Organisations etc.) and implicitly inherit multiple aspects from these domains, such as virtualisation and outsourcing. Depending on usage, they may extend these characteristics, in particular by adding a new business model. What is important to stress again in this context is that not all cloud characteristics exclusively belong to the cloud domain; extrinsic features that generally belong to other domains enable service and utility computing are naturally taken over in clouds. Specifically, we can distinguish (Figure 4.0) between

- Characteristics exclusive to the Cloud (intrinsic features)
- Characteristics belonging to other domains but having to be adapted in order to meet the cloud relevant specifics (extrinsic extended)
- Characteristics that belong to other domains and just act as enablers to cloud systems, that is, do not have to be extended (extrinsic inherited)

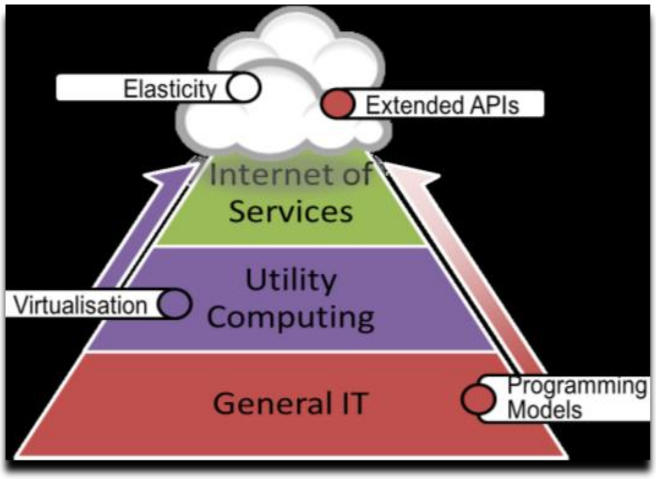

Figure 4.0: Inheritance and Extension of Characteristics across the Related Domains [10]

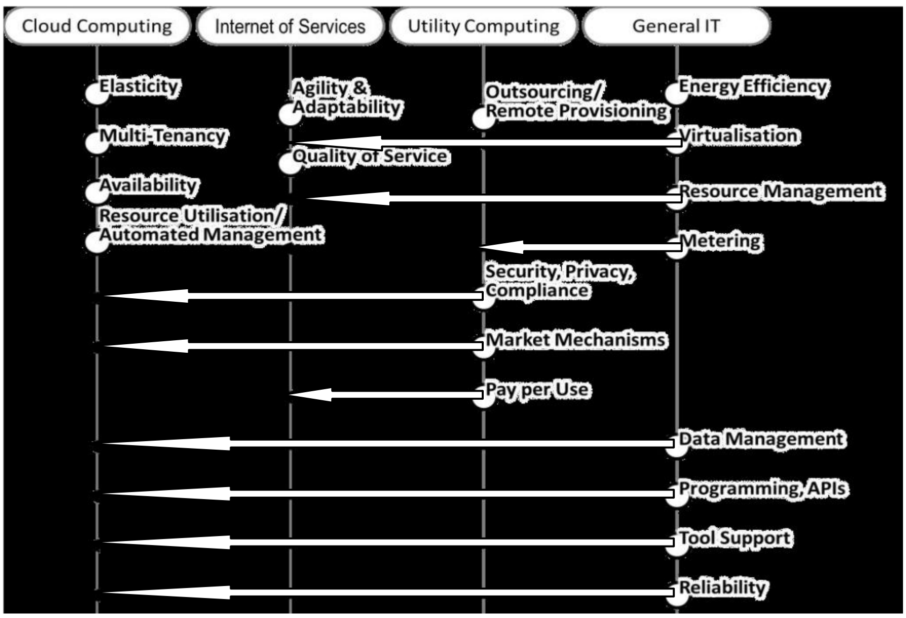

Figure 4.1: Overview of the Cloud Characteristics and their Relationship to other Domains. Inheritance is from Right to Left. The Further Left is Characteristics Advances, the more it needs to be adapted for the respective domain(s), [10].

We refer here in particular to three related domains, though the list can be easily extended and refined:

- Internet of Service: covering areas such as Web Services, Web 3.0, and SOA etc. In other words, individual service provisioning without specific means for dealing with availability, that is, just network load balancing.

- Utility Computing: including Grids, Virtual Organisations, and also High Performance Computing (HPC) to some degree, as they were originally conceived and realised.
- General IT or more correctly "non-web" IT, including all computer science aspects concerning isolated machines, i.e. without making explicit use of the web. This includes theory of computation, hardware architectures, operating systems etc.

More specifically, the characteristics identified above can be classified with respect to the domains they were originally conceived in and to the ones which take up/extend them (see Figure 4.1). The Columns denote the domain to which the concepts apply, so that any entry within an according column implies that the respective characteristic is specifically adjusted and or extended to meet the domain's requirements. In other words, single column entries imply that all domains to the left inherit the characteristics without significant adaptations, whilst domains to the right do not support this characteristic. If an entry spans multiple columns, it means that the base concept is [10] conceived in the right-most domain and that all domains to the left adapt the concept to their respective needs.

It will be noted that this classification is subject to many discussions due to the overlap in terminologies across domains. It is worth mentioning in this context that the classification is oriented towards the left, that is, "which domain provides capabilities that can be exploited on higher-level domains", but there is a noticeable right-orientation, too, where for example utility computing is improved by availability methodologies of the Cloud, without necessarily turning the respective domain into a Cloud system.

4.1 Cloud Computing Vs. Grid Computing

There has always been a debate about the evolution of Cloud Computing and the most important point in that is Grid Computing. Some people call Cloud Computing and Grid Computing the same phenomena while others call Cloud Computing an extension of Grid computing. To find out the truth we need to know about Grid computing [7], [9].

Grid Computing is a complex phenomenon which has evolved through earlier developments in parallel, distributed and high performance computing (HPC) [12], [11]. One of the most cited definitions of Grid computing was from [1]

"A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities." [9]

After that, the development of support for generic IT resource sharing started to be measured as the real Grid problem; according to Foster,

"The real and specific problem that underlies the Grid concept is coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations. The sharing that we are concerned with is not primarily file exchange but rather direct access to computers, software, data, and other resources, as is required by a range of collaborative problem-solving and resource brokering strategies emerging in industry, science, and engineering" [3].

Virtual organizations in this definition can be defined as the dynamic group of individuals, groups, or organization who define the conditions and rules for sharing resources [13]. Some of the organizations have also defined the Grid computing with respect to the features. According to IBM,

"Grid computing allows you to unite pools of servers, storage systems, and networks into a single large system so you can deliver the power of multiple-systems resources to a single user point for a specific purpose. To a user, data file, or an application, the system appears to be a single enormous virtual computing system." [14].

The description of Cloud computing earlier and of Grid computing here shows that Cloud computing and Grid computing have many similarities. This leads to discussion about the differences in these two technologies. The table below shows the technical differences among Cloud computing and Grid computing [9].

Table 1: Grid and Cloud Computing Technically Compared [7], [9], [2].

	Grid Computing	Cloud Computing
Means of utilization (e.g. [16])	Allocation of multiple servers onto a single task or job.	Virtualization of servers; one server to compute several tasks concurrently.
Typical usage pattern (e.g. [17])	Typically used for job execution, i.e. the execution of a program for a limited time	More frequently used to support long-running services
Level of abstraction	Expose high level of detail	Provide higher-level abstractions
Business Model (e.g. [2])	project-oriented	Pay-per-use
Architecture (e.g. [2])	Defines a five-layered architecture(Fabric, Connectivity, Resource, Collective and Application layers)	Defines a four-layered architecture (Fabric, Collective Resource, Platform and Application layers)
Compute Model	Uses a batch-scheduled compute model	The compute model is interactive-real-time shared. Resources in the Cloud are being shared by all users at the same time.
Virtualization	Grids do not rely on virtualization as much as Clouds	Relies Heavily on virtualization
Security Model	Have tighter security	Currently, the security model seems to be relatively simpler and less secure than the security model adopted by Grids.

4.2 Virtualization in Cloud Computing

The description of Cloud computing earlier and that of Grid computing here shows that Cloud computing and Grid computing have many similarities but also differ in many respects. The most differentiating concept is the use of virtualization in cloud giving rise to multi-tenancy. Cloud computing technologies could never exist without the use of the underlying technology known as Virtualization [20].

As presented in the Table 1, what makes Cloud computing different from Grid computing is "virtualization". Cloud computing leverages virtualization to maximize the computing power; Virtualization, by separating the logical from the physical, resolves some of the challenges faced by Grid computing [7], [15]. While Grid computing achieves high utilization by the allocation of multiple servers onto a single task or job, the virtualization of servers in Cloud Computing achieves high utilization by allowing one server to compute several tasks concurrently [7], [16].

With virtualization, applications and infrastructure are independent, allowing servers to be easily shared by many applications where applications are running virtually anywhere in the world. This is possible as long as the application is virtualized [18]. Virtualizing the application for the cloud means to package the bits of the application with everything it needs to run, including pieces such as a database, a middleware and an operating system; this self-contained unit of virtualized application can then run anywhere in the world [18]. Virtualization also allows building so-called sandboxes. Sandboxes assure a higher degree of security and reliability by providing a mechanism to run programs safely. It is commonly used to "execute untested code or programs from unverified third-parties, suppliers and untrusted users" [19].

Along with the differences in technology among Grid computing and Cloud computing, usage patterns are also different between them. Grid is usually used for job execution while clouds are more frequently used to support long-running services [17]. As mentioned above, there is a debate in the technology world that Cloud computing has evolved from Grid computing and that Grid computing is the foundation for Cloud computing, [2] for example describe the relationship between Grid and Cloud computing as follows:

"We argue that Cloud Computing not only overlaps with Grid Computing, it is indeed evolved out of Grid Computing and relies on Grid Computing as its backbone and infrastructure support. The evolution has been a result of a shift in focus from an infrastructure that delivers storage and compute resources (such is the case in Grids) to one that is economy based aiming to deliver more abstract resources and services (such is the case in Clouds)." [2].

Another observed remarkable difference between cloud and grid computing is cloud's broad network access feature. This is depicted in figure 4.2 and figure 4.3 respectively. Other differences include the business model where the business model for Grids (at least that found in academia or government labs) is project-oriented in which the users or community represented by that proposal have certain number of service units (ithat is, CPU hours) they can spend while Cloud utilizes a pay-as-you-go business model.

It is worth noting that in the architecture of these two technologies, Cloud defines a four-layed architecture while Grid defines a five-layered architecture but both technologies have the same base and topmost layer (being the fabric as the base and application as the topmost layer). This makes the security model in Grid computing more stringent and more secured, the reson is that security is provided by the protocol at each of the layers in the architecture thus, security has been engineered in the fundamental Grid infrastructure compared to cloud's security model which seems to be relatively simpler and less secure than the security model adopted by Grids. Cloud infrastructure typically rely on Web forms (over SSL) to create and manage account information for end-users, and allows users to reset their passwords and receive new passwords via Emails in an unsafe and unencrypted communication.

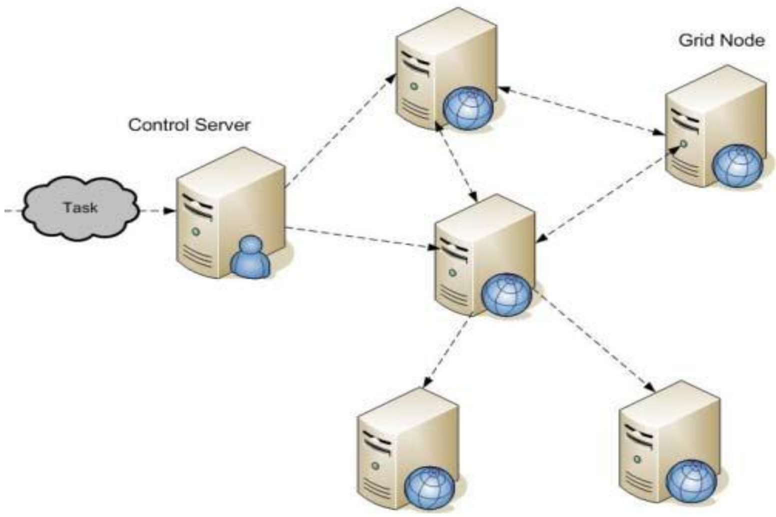

Figure 4.2: Grid Computing [5].

Figure 4.3: Cloud Computing [5].

5. SUMMARY

The vision of Cloud computing and Grid computing is the same [2] and that is to (i) reduce the cost of computing, (ii) increase reliability, and (iii) increase flexibility by transforming computers from something that we buy and operate ourselves to something that is operated by a third party even though the scale are different; clouds are operating at a different scale, and operating at these new, more massive scales can demand fundamentally different approaches to tackling problems.

The problems are mostly the same in Clouds and Grids. There is a common need to be able to manage large facilities; to define methods by which consumers discover, request, and use resources provided by the central facilities; and to implement the often highly parallel computations that execute on those resources. Details differ, but the two communities are struggling with many of the same issues. Thus we can summarize that Grid computing is the starting point and basis for Cloud computing. Cloud computing essentially represents the increasing trend towards the external deployment of IT resources, such as computational power, storage or business applications, and obtaining them as services [9].

6. CONCLUSION

In information technology, it is observed that technology scales by an order of magnitude, and in the process reinvents itself. Such is the case with Cloud computing. Cloud computing is a paradigm shift in computing that completely realized the predictions of John Mcarthy. It inherited and also extended the features of preceeding technologies such as Grid computing. Thus, Cloud computing possess to a high degree, features of the Grid but it is still not with some differences. One of these outstanding differences between Cloud and Grid is virtualization which has given rise to multi-tenancy in Cloud computing environment. It is believed at this advocacy level of Cloud computing that adopting key strengths of Cloud enabling technologies such as the Grid especially in areas of its security model will help advance the adoption of cloud computing.

REFERENCES

[1] Voas, J., & Zhang, J. (2009). Cloud Computing: New Wine or Just a New Bottle? *IT Professional*, 15-17.

[2] Foster I. et al. (2008). Cloud Computing and Grid Computing 360-Degree Compared. IEEE Grid Computing Environment Workshop (GCE '08), pp 1-10.

[3] I. Foster, C. Kesselman, S. Tuecke. (2001). The Anatomy of the Grid: Enabling scalable virtual organization. The International Journal of High Performance Computing Applications, vol. 15(3), pp. 200-222.

[4] I. Foster, C. Kesselman, J. Nick, S. Tuecke (2002). The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration. Globus Project.

[5] Srinivasa et al. ().Cloud Computing: An Overview. Journal of Theoretical and Applied Information Technology, vol. pp. 71-79. www.jatit.org.

[6] NIST (2010) NIST Definition of Cloud Computing v15. US Department of Commerce, Washington.

[7] Rehan S. (2011) "Cloud Computing's Effect on Enterprises", Dept of Informatics, Lund University Unpublished Master's Thesis 1-89.

[8] Cloud Security Alliance. (2009). *Security Guidance for Critical Areas of Focus in Cloud Computing*.

[9] Stanoevska-Slabeva, K., Wozniak, T. (2009). *Grid Basics. In: Stanoevska-Slabeva, K., Wozniak, T., and Ristol, S., Grid and Cloud Computing A Business Perspective on Technology and Applications*. Springer Berlin Heidelberg, 2009.

[10] Lutz S & Keithe J. (2012): Advances in Clouds: Research in Future Cloud Computing, Expert Group Report. Information Society and Media, European Union, Belgium.

[11] Harms, U., Rehm, H-J., Rueter, T., Wittmann, H. (2006) *Grid Computing für virtualisierte Infrastrukturen.* In: Barth T, Schüll A (eds) Grid Computing: Konzepte, Technologien, Anwendungen, pp. 1-15. Vieweg+Teubner, Wiesbaden.

[12] Weishäupl T., Donno F., Schikuta E., Stockinger H., Wanek H. (2005). *Business In the Grid: The BIG Project.* In: Proceedings of the 2nd International Workshop on Grid Economics and Business Models (GECON 2005). http://hst.home.cern.ch/hst/publications/gecon-2005-BIGproject.pdf. Accessed 5th May, 2010.

[13] Joseph J, Ernest M, Fellenstein C (2004) *Evolution of Grid Computing Architecture and Grid Adoption Models.* IBM Syst. J. 43(4):624-644.

[14] Kourpas E (2006) *Grid Computing: Past, Present and Future – An Innovation Perspective.* IBM white paper.

[15] Lynch, M. (2008) The Cloud Wars: $100+ billion at stake. Merrill Lynch research note, May 2008. Retrieved May 15, 2010 from http://web2.sys-con.com/node/604936.

[16] Harris D (2008) Why 'Grid' Doesn't Sell. On-Demand Enterprise blog, 24 March 2008. http://www.on-demandenterprise.com/blogs/26058979.html. Accessed 20 August 2009.

[17] EGEE (2008) An EGEE Comparative Study: Grids and Clouds – Evolution or Revolution? Enabling Grids for E-sciencE (EGEE) report, 11 June 2008. https://edms.cern.ch/document/925013/. Accessed 1st May 2010.

[18] Armbrust, M., Fox, A. & Griffith, R. (2009). Above the Clouds: A Berkeley View of Cloud Computing. *Electrical Engineering and Computer Sciences University of California at Berkeley, pp.*1-8.

[19] Intel Corporation (2007). From Virtualization vs. Security to Virtualization based Security. *Intel Leap Ahead.* Available at: http://event.isacantx.org/_event_files/346_Lunch_Orrin_VirtSec_Part2_v1 .pdf. Accessed on 23 March 2010.

[20] Sean C. & Kevin C. (2012). Cloud Computing Technologies International Journal of Cloud Computing and Services Science (IJ-CLOSER) Vol.1, No.2, June 2012, pp. 59-65. *Journal homepage: http://iaesjournal.com/online/index.php/ IJ-CLOSER.*

[21] Buyya, R., Yeo, C., Venugopal, S., Broberg, J. & Brandic, I. (2009). Cloud Computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. *Future Generation Computer Systems,* 25, 599-616.

[22] IBM (2009). IBM continues TOP500 lead. *IBM Systems.* Available at: http://www 03.ibm.com/systems/deepcomputing/top500.html#a1. Accessed on: 17 September, 2012.

[23] Andy Isherwood, quoted in ZDnet News, December 11, 2008

BIOGRAPHY OF AUTHORS

Joshua Abah is a Ph.D fellow in Computer Science at the Federal University of Technology, Minna, Nigeria. He is currently working in the academia where he has been for over five years now. His research interests include Networks, Cloud Computing, and virtualization, Scheduling Algorithms, QoS and Computer Education. He has over seven journals both local and international and has authored five textbooks to his credit.

Dr (Mrs) Francisca N. Ogwueleka is a Senior Lecturer and Head of Department of Computer Science, Federal University of Technology, Minna, Nigeria. She has worked for over thirteen years in the academia and her research interests include Applications of Data Mining and its Techniques, Cloud Computing, Virtualization in Cloud, Data Transfer Security and Network Security. She has published over forty five articles in both national and international journals and has authored textbooks.