International Journal of Computer (IJC)
ISSN 2307-4523 (Print & Online)

http://ijcjournal.org/

# Autonomic Cloud Computing: A Review

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**Abstract**

The wide acceptability of cloud computing and its adoption, though remarkable, also gave the technology its greatest challenge in 'user expectation'. These challenges include; Reliability and availability, integration and interoperability, scalability, virtual machine migration policies, failure prediction, and resource management. In this paper, a general review of cloud computing was done highlighting its challenges. Autonomic Cloud computing was also reviewed. Future research areas were identified.

***Keywords:*** Cloud Computing; Autonomic Cloud.

## 1. Introduction

Cloud computing is a large scale distributed network system which is implemented on servers in a data centre(s). That is, it refers to the applications that are delivered over the internet and the hardware and system software that provide it in data centres. This is largely viewed as a layer of services that are offered to users. The data centre(s) form a network of servers which serve as the main backbone to the cloud infrastructure. The Infrastructure as a service layer (IaaS) provides the necessary infrastructure for storage, servers, and networking components. Platform as a service (Paas) provides the necessary environment for building, deploying and testing custom applications. Software as a service (SaaS) layer supports distribution of software base on client's requirements [1,2].

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| Software as a Service (Microsoft's Live Mesh) |
|---|
| Platform as a Service (Google App Engine, Microsoft azure) |
| Infrastructure as a Service |
| Data Centres |

**Figure 1:** Cloud Computing Architecture

### *1.1. Data Center*

As illustrated in Fig 1 above. Data centre is the first layer of the cloud computing architecture. It is where the resources (hardware and infrastructure) needed to form the cloud are housed. These are typically servers connected via high speed networks to provide services to customers. Most Data centres are located in places with low disaster risk, high power stability, and low population [1].

#### *1.1.1. IaaS*

The second layer is the infrastructure as a service layer (IaaS). IaaS provides hardware (processing, storage, networks etcetera) and software (operating systems and utilities) that are typically provided by a standalone server. The difference is, instead of having physical devices and environment, you have a virtual setting for the resources [3][4]. Infrastructure as a service is focused on operations. Example includes Amazon Elastic Compute Cloud (EC2) and Amazon Simple Storage Service (Amazon S3**)** [5].

#### *1.1.2. PaaS*

PaaS provides the enabling environment for consumer developed technologies to be available to the cloud architecture. That is, it allows developers to build solutions that are supported by the cloud provider infrastructure. The developers, have no idea, how many servers are available by the cloud provider. PaaS serves as a middleware between IaaS and SaaS. Examples are AppFog, Microsoft Azure and Google App Engine [4,6].

#### *1.1.3. SaaS*

Saas are applications that are made available over the internet by cloud providers. These applications simplify maintenance and cuts costs of running the applications by business and individuals. These can range from typical everyday applications used by consumers like Office 365 and Gmail [4].

### *1.2. How the Cloud Works*

Cloud computing allows computing resources to be readily available to consumers on a pay-as-go option. It gives this notion of limitless computing resources. Cloud computing allows these resources, data centre, IaaS, PaaS and SaaS to be available to the consumer as a service. However, paying for services, requires a contract, a negotiation of the services that will be available and the standard to be maintained. This is achieved via Service

Level Agreement (SLA). SLA is an agreement between cloud provider and cloud consumer. It specifies the type of applications the consumer wants to run or use, the data flow, the response time, time lag if any, security, availability, etcetera. In other words, SLAs are legal documents that are agreed upon by service provider and consumer [7,8].

### *1.3. Challenges of Cloud Computing*

The wide acceptability of cloud computing and its adoption, though remarkable, also gave the technology its greatest challenge in 'user expectation'. Cloud providers are emerging by the day and all sorts of services are also made available [7]. Authors in [6] gave a more detailed explanation of the challenges of cloud computing. These challenges include; Reliability and availability, integration and interoperability, scalability, virtual machine migration policies, failure prediction, and resource management. The study in [5] and [7] also supported [6] view regarding the challenges of cloud computing. Authors in [9] further asserted that security and resource management are the major challenges to cloud computing. These challenges necessitated the need for intelligent systems be incorporated to manage data centres and the cloud. This gave rise to Autonomic Cloud Computing [10]. Section headings

## 2. Autonomic Cloud Computing

Autonomic Computing is the ability of distributed system to manage its resources with little or no human intervention. It involves intelligently adapting to environment and requests by users in such a way the user does not even know. It was started in 2001 by IBM to help reduce complexity of managing large distributed systems [4]. This (autonomic computing) was instituted in cloud computing to address the challenges of cloud computing. Autonomic cloud computing helps address challenges related to QoS by ensuring SLA are met. QoS is maintained by mostly scaling up or down resources automatically depending on demand by client's business. In addition, autonomic cloud computing helps reduce the carbon footprint of data centres and cloud consumers by automatically scaling up or down energy usage base on cloud activity. Autonomic monitoring are mostly implemented on specific layers of the cloud computing architecture. Authors in [10] implemented an autonomic management system on the PaaS to ensure SaaS layer meets SLA, energy efficiency and maintains security. Authors in [11] developed fuzzy Q-Learning for knowledge evolution. It is a self-learning. Self-adapting cloud controller that auto scales (down or up) the number of virtual machines that support the cloud. It uses data collected at run-time and automatically continues to tune the data in order to achieve desired goals. This is particularly favourable, when there is not enough knowledge at design time. Additionally [12] implemented a QoS autonomic information delivering system for delivering agricultural information systems to farmers. This was achieved at IaaS layer using Cuckoo optimisation algorithm and fuzzy logic to attain autonomic resource allocation. Reference [13] presented a decentralised autonomic architecture for managing wireless sensor networks. They identified automatic operation, aware operation and adaptive operation as properties that each autonomic system must have. An automatic operation property ensures that the system can control its functions and internal resources without human intervention. Aware operation property allows the system to be aware of its resources and capabilities, this allows the system to monitor itself and use feedback mechanism to adapt to its environment. Adaptive operation property allows the system to continuously adapt to environment on short term

and long term basis to control its operations. Reference [14] further asserted that feedback loop in a system helps gives such a system the level of awareness for adapting to environmental and operational changes. While identifying autonomous computing as the best solution to open and non-deterministic environments, [14,15] lamented that there is no particular standard to developing autonomous solutions. Hence, they extended the JADE (Java Agent Development Environment) to support autonomous computing in a Multi-Agent System (MAS). In order to address the development and deployment bottleneck of context aware systems, [15] proposed a service-oriented framework that assists in developing and managing context for pervasive systems. Their work focused on collecting, modelling, processing and distributing information. Though successful, they admitted to having a number of limitations to their work. The work is still centred around feasibility of the approach, there are performance issues in terms of memory and operational issues in terms of automatic creations of application entities and relations. Reference [16] proposed a methodology for implementing power aware runtime systems. They achieved this by proposing an algorithm to mange memory and optimal memories, their work may be used to address memory issues identified by [15]. References [17,18,19] observed that most autonomic solutions are based on frameworks that provide support for dynamic nature of the system environment but fail to achieve in providing full autonomic capabilities. Reference [17] further explained the four self-star (self-*) properties of autonomic computing defined by IBM. These (self-configuration, self-optimisation, self-healing, self-protection) properties form the foundation for any autonomic applications. In order to address the lack of standard method of developing autonomic solution for the cloud, British Telecoms and Bournemouth University offered a studentship, titled *Best Practice Design for Autonomic Applications in the Cloud* [20]. This will largely help address the problem.

## 3. Discussion

Autonomic computing has been widely adopted by academia, Information Technology society and the business world. This is due to computing systems increasing complexity. Complexity implies more functionalities and capabilities are demanded by users and businesses. This resulted in need to set-up or quickly integrate a new solution into an existing system. With new devices and increased mobility, interoperability is also a major concern. Cloud computing has provided a solution that allows users of this technology to have a perception of limitless computing power and functionality by subscribing to services they need on the go. This is distributed and available according to terms agreed in SLAs, SLAs ensure QoS are maintained. This has pushed the industry into providing a solution that is self-star, self-optimisation, self-healing, self-protection and self-configuration. Hence, the autonomic cloud computing. Autonomic cloud computing solutions have largely been deployed to solve issues that arise from managing existing cloud service(s). Autonomic solutions have so far been based on frameworks that support dynamic nature but have failed to achieve full autonomic capabilities.

## 4. Recommendations

Autonomic solutions have so far been based on frameworks that support dynamic nature but have failed to achieve full autonomic capabilities. For full autonomic capabilities to be achieved, the industry and academia must come up with a standard means of developing and deploying autonomic applications. Cloud computing has so far been adopted and accepted by industry, academia and business world. It provides the best platform to

implement autonomic applications due to various technology involved. More studentship like the one provided by Bournemouth University and British Telecoms should be encouraged.

## 5. Conclusion

This work reviewed cloud computing architecture, describing its layers and further explaining how the cloud works. It then discusses the challenges to cloud computing and proposed solution in the form of autonomic cloud computing. The autonomic cloud provides a rich and interesting area of research. It has broad reach, as much of the technology is built on internet technology. It covers pervasive and ubiquitous computing, interoperability, machine learning, and middleware. As seen in related literature, most of the solutions provided, were done so on specific layers of the cloud computing architecture. They all dealt with resource allocation and largely ensure QoS metrics are maintained. Most of the literature [13-19] showed that there is no standard template for design and development of autonomic applications. This prompted Bournemouth University in collaboration with British Telecoms to offer studentship in *Best Practice Design for Autonomic Applications in the Cloud*. The studentship offered by Bournemouth University has been the prime motivator of this work. This is first of many work, intention is to first understand, autonomic cloud computing and then study standard methods of developing and deploying autonomic solutions for the cloud using best practice design.

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