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SCHEDULING TECHNIQUES IN ON-DEMAND GRID AS A SERVICE CLOUD: A REVIEW

[1]SHAFI'I MUHAMMAD ABDULHAMID, [2]MUHAMMAD SHAFIE ABD LATIFF AND [3]MOHAMMED BAKRI BASHIR

[13]PhD Scholar, Faculty of Computing, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia.
[2]Assoc Prof, Faculty of Computing, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia.
[1]Lecturer, Department of Cyber Security Science, Federal University of Technology Minna, Nigeria.
E-Mail: [1]mashafii2@live.utm.my, [1]shafii.abdulhamid@futminna.edu.ng, [2]shafie@utm.my and [3]mhmdbakri@yahoo.com

ABSTRACT

The Infrastructure as a service (IaaS) Cloud is a customer oriented cloud environment that offers user with computing infrastructures on-demand to be used based on the Cloud computing paradigm of pay-per-use. When the IaaS is now utilized to build a traditional Grid network within the cloud environment, it is now called an on-demand Grid as a service (GaaS) Cloud. In the on-demand GaaS Cloud, a user may use hundred of thousand of Grid nodes to implement a job, therefore manual scheduling is not a feasible scheduling solution. The main objective of this review is to study the various concepts and scheduling algorithms used for the on-demand GaaS Cloud in relation to the scheduling parameters used by existing researches. We also survey the Cloud infrastructures, Grid middlewares and the issues addressed by different researchers in the past within this domain of research. Our contribution will thus be of assistance in understanding the key scheduling algorithms and parameters for potential future enhancements in this evolving area of research.

Keywords: *Cloud Computing, GaaS Cloud, On-Demand Grid, On-Demand GaaS Cloud, IaaS Cloud, Virtualization*

1. INTRODUCTION

These days, Cloud Computing is broadly utilized to deliver services over the cyberspace for both technical and economical purposes. The quantity of Cloud-based services is constantly increasing robustly in the last few years, and therefore improved the complexity of the infrastructures behind these services. In order to appropriately control and supervise such multifaceted infrastructures effective and efficient monitoring and scheduling is continuously needed [1]. The technology is rapidly emerging and moving towards the direction of becoming the de facto standard of internet computing, storage and accommodating infrastructures, platforms and software both in the industries and the academia. The huge scalability prospects offered by cloud infrastructures can be easily harnessed not only for services and applications hosting but also as an on-demand grid computing resource.

On-demand computing is a paradigm whereby computing resources are made available to customers as at when needed. It is an easy solution for organisations that require a very large number of computing resources, in other to reduce the total time to solution, and may not be able to afford the costs of hardware. Specifically, these hardware costs increases when the required computing resources are provided by specialized systems, like the High Performance Computing resources used for Grid and Cloud computing.

The Cloud computing environment has different services depending on the resources offered to the user on-demand. If the provided resources to the cloud user are computing virtual machine nodes and storage, Cloud Computing service is called Infrastructure as a Service (IaaS). But if the computing resources service includes application software developing environments, the Cloud computing service is called Platform as a Service (PaaS), while if the specific software applications are the resources it is called Software as a Service (SaaS). These three Cloud services are the fundamental services which the Cloud computing environment proves. But, when the IaaS Cloud virtual machine nodes are used or converted to traditional Grid network to be provided to users

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on-demand, it implies that the Cloud service is now called Grid as a Service (GaaS) Cloud.

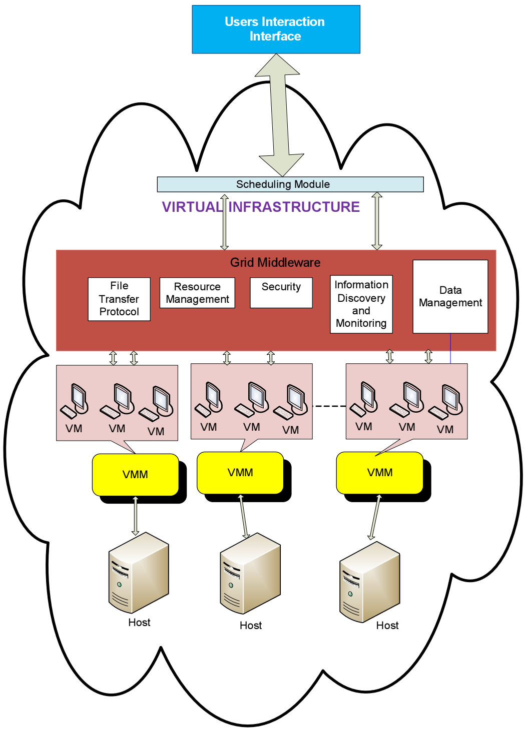

Fig. 1: Virtual Infrastructural Cloud For On-Demand Gaaas

Fig. 1 above shows a typical architecture of the on-demand GaaS Cloud. The virtual machine manager (VMM) otherwise known as the hypervisor is hosted within some high capacity physical storage systems. The VMM is used to host and monitor the Cloud virtual machine (VM) nodes built within the Cloud computing environment. To build the GaaS, the VM nodes are now used to configure a typical Grid computing network using a Grid middleware. What makes a Grid computing environment is just the Grid middleware and without it, what you have is just a simple computer network. Therefore, ones the Grid middleware (e.g. Globus, DIET-Solve, Condor, Askalon, etc) is built with the VM nodes, this platform can be issued to Grid user on-demand with the help of the pay per use Cloud computing paradigm. Even though, most Grid middlewares have in-built schedulers, it has been observed that it did not perform well in this present setup because of some new conditions that has been introduced. This is attributed to the reason why many researchers surveyed in this paper proposed new scheduling techniques for the on-demand Grid as a service Cloud.

In conventional scheduling, a middle control decision maker is always there ready with all the appropriate information about the issues, therefore requested to obtain a solution that completes all the required side constraints, optimizing an overall performance condition. The setup of the on-demand GaaS Cloud environment is such that conditional decisions are taken by a number of autonomous components and the components may be aiming at optimizing their own objectives rather than the performance of the structure in total [2]. Entities in the on-demand GaaS Cloud setup are self-interested and always ready to distribute their resources. The on-demand GaaS Cloud environment calls for models and algorithms that take the premeditated activities of individual entities into account, and concurrently keep track of all the overall performance of the structure.

The main aim of this survey is to focus on the various concepts, tools, parameters and scheduling techniques used for on-demand Grid as a service Cloud. Section II discusses the related works. Section III discusses the existing scheduling algorithms used in on-demand GaaS Cloud. The section IV presents a detailed discussion of the scheduling techniques tabulated earlier. While the section V tabulated the scheduling metric parameters used in researches presented in this review. The section VI concludes the paper with a summary of our contributions and future works.

2. RELATED WORKS

Aceto, et al. [1] thoroughfully studied and discussed the characteristics of a monitoring system for the Cloud, the issues arising from such characteristics and how such issues have been tackled in previous researches. The research also explained existing platforms, and services for Cloud monitoring, highlighting how they relate with the characteristics and problems identified previously. The researchers then identify open problems, main disputes and potential directions in the area of Cloud monitoring. But the paper did not address issues related to scheduling in the Cloud computing environment. Abdulhamid, et al. [3] surveys the different models for on-demand Grid using infrastructural Cloud, the problems it tries to address and the implementation tools. The paper also, proposed an extended classification for the virtualization technology used and a new classification for the Grid-Cloud integration which was based on the architecture, communication flow and the user demand for the Grid resources. Other researches that reviewed different issues within the

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Cloud environment but overlooked scheduling as an important Cloud issue are [4-9].

One of the important scheduling surveys in the Cloud computing domain was done by Vijindra and Shenai [10]. The research surveyed the comprehensive method of several types of scheduling techniques in Cloud computing environment, which also includes the workflow scheduling as well as the Grid scheduling. The paper also gives a detailed idea about Grid, Cloud and workflow scheduling. Bala and Chana [11] also reviewed several types of workflow scheduling techniques and tabulated a range of metric parameters along with tools, scheduling factors, scheduling algorithms, method and environment. And then shows that, existing workflow scheduling models does not take in to account parameters like reliability and availability.

Mandloi and Gupta [12] reviewed many proposed optimization algorithms for process scheduling in grid computing such as ant colony optimization algorithm, genetic algorithm and fuzzy logic. They showed that these optimization techniques decreased the amount of failure and execution time of the grid system. The research paper discusses many different methods of grid computing related to resource allocation and task scheduling based on meta-heuristic function. Pandey and Buyya [13] surveyed a number of scheduling workflow application based on multi-source parallel data retrieval in distributed systems. The paper proposed to leverage the presence of replicated data sources, retrieve data in parallel from multiple sites and therefore attained time-efficient schedules. They came up with two multi-source data-retrieval-based scheduling heuristic that allocates mutually dependent jobs to compute resources based on both data retrieval time and task-computation time. They also showed that the heuristic generates time-efficient schedules that are more enhanced than the existing heuristic-based techniques for scheduling application workflows. Other researches that surveyed different scheduling algorithms within the Grid environment or Cloud environment or both includes [14-19]. It is important to point out that these scheduling algorithms have not been tested in the Grid as a service Cloud environment as some specific parameters are peculiar to such environment.

Barone, et al. [20] presented a research work titled "*GaaS: Customized Grids in the Clouds*" which attempt to eliminate the paradigm mismatch between Cloud and Grid Computing environments, enabling the utilization of Cloud-provided resources with well-established Grid-like interfaces, circumvent the need for clients to discover new resources access and use models. The projected method was tested by developing a prototype implementation and its integration in a working Grid environment. Even though this research was the first to appropriately use the acronym "*GaaS*", but the research work did not consider any scheduling algorithm that will fit into this new approach. Other related researches are to include [2, 21-25] and also those tabulated below.

3. EXISTING SCHEDULING ALGORITHMS USED IN ON-DEMAND GAAS CLOUD

Table 1 below presents a survey of scheduling algorithms, Grid middlewares and Cloud infrastructures established in the area of on-demand Grid as a service (GaaS) cloud. A detailed discussion of these systems and the issues addressed by the outlined researches are also discussed from the table.

Table 1: Scheduling Algorithms Used In The Existing On-Demand Gaas Cloud

Ref.	Grid Middleware	Cloud Infrastructure	Area/Issue	Scheduling Algorithm	Year
[26]	DIET-Solve	EUCALYPTUS	Resource Management & On-demand Grid	-	2009
[27]	-	EUCALYPTUS	Cloud to Extending Clusters, Cost-Benefit Evaluation & Scheduling	Na¨ıve scheduling Algorithm & FCFS with Aggressive Backfilling	2009
[28]	-	Amazon EC2	Harnessing Cloud for Virtual Distributed Infrastructure	-	2009
[29]	Globus	Amazon EC2	On-Demand Resource Provisioning, Workflows & Scheduling	Globus Scheduler	2009
[30]	-	Amazon EC2 & S3	Using Clouds to Provide Grids Higher-Levels of Abstraction	-	2009
[31]	ASKALON	EUCALYPTUS	Extending Grids with Cloud Resource Management &Scheduling	ASKALON scheduler	2009
[32]	Globus	-	Secure On-Demand Grid	Advanced Reservation	2009
[33]	Globus	Amazon EC2, GoGrid & Globus	Dynamic Provision& Scheduling	GridWay Metascheduler	2009

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		Nimbus			
[34]	-	Amazon EC2	On-Demand Resource, Pattern Matching & auto-scaling algorithms	-	2010
[35]	-	Amazon EC2 & EUCALYPTUS	cost-benefit analysis & Job scheduling	Backfilling, Naïve, Shortest queue, Weighted queue& Selective Algorithms	2010
[36]	Globus	Amazon EC2	On-Demand Grid Resource Provisioning& Scheduling policies	-	2010
[37]	Globus & Condor	-	Cloud on Grid, Provisioning, Autonomic leasing & Scheduling	Condor Scheduler & Naive Greedy Watchdog Algorithm	2010
[38]	Globus	-	Self-provisioned clouds on the grid, Scheduling	Simple greedy scheduling algorithm	2010
[39]	Globus	Amazon EC2	On-Demand Grid on Cloud	-	2010
[40]	GridSAM	Amazon EC2 & Eucalyptus	Provide Virtual Distributed Environments &On-Demand Grid	-	2010
[41]	-	-	Scheduling Grid Applications on Clouds	Task & Virtual Machine Scheduler using DAG	2010
[42]	GEMBus	Composable Services Architecture (CSA)	On-Demand Provisioning of Cloud and Grid	-	2011
[43]	Condor	Amazon EC2 & Nimbus	HPC, grid & Cloud Computing & Scheduling	Deadline-based &best-effort jobs Scheduling	2011
[44]	Globus	Nimbus	Grid Resource Provisioning & Scheduling	Meta-scheduling	2011
[45]	Condor, Nimrod & Sun Grid Engine	Amazon EC2 & Google App Engine	Grids, Clouds, and Virtualization	-	2011
[46]	Globus/GRAM, GumboGrid & Condor	Amazon EC2, Nimbus & Eucalyptus	Application-Level Interoperability Across Grids and Clouds with SAGA	-	2011
[47]	Globus	Amazon EC2	Architectures & on-demand provisioning	Meta-scheduling	2011
[48]	-	CICA GRID solution	On-Demand cloud	-	2012
[49]	-	Eucalyptus	Integrated Provisioning of Cloud and Grid Resources	Workload and resource management systems (WRMSs)	2012
[50]	Condor	RESERVOIR project	On-demand cloud provisioning	-	2012
[51]	DIET-Solve	Nimbus & Eucalyptus	Clouds to scale grid resources & economic model	-	2012
[52]	Condor & Bonjour Grid	Grid5000	On-demand Self-Configurable Desktop Grid	Condor, Boinc and Xtreweb job schedulers	2012
[53]	-	Grid5000	On-Demand VM Multi-Deployments in IaaS Clouds	-	2013
[54]	Globus	Eucalyptus	Extending Grid Infrastructure Using Cloud Computing	-	2013
[55]	Globus	Nimbus	Cloud Grid Security and performance evaluation	-	2013
[20]	gLite-EMI	OpenNebula	GaaS Cloud	-	2013
[2]	Globus	-	Decentralized Resource Scheduling in Grid/Cloud Computing	Combinatorial Allocation Problem &Proposed an Adequate Economic-Based Optimization Model & Winner Determination Algorithm	2013

Key: - (not specified)

4. DISCUSSION

Researches in this domain of on-demand Grid as a service Cloud started within the year 2009. A number of searches [26-33] tries to address different issues with different nomenclatures within this domain of research. While some of these researches viewed it as necessary to also address scheduling issues because of changing conditions, others defend on the built-in schedulers of the Grid middleware to handle resource allocation and distribution. From the Table 1 above, [27] addressed issues related to extending Cloud to clusters, cost benefit evaluation and resource

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scheduling. They also used the Na¨ıve scheduling Algorithm & FCFS with Aggressive Backfilling in solving the resource scheduling problems. The research paper [32] presented a new approach for enabling Grid clients to independently install and use custom software on demand using an image creation station. The Advanced Reservation scheduling algorithm was used for resource scheduling purposes. Some of the researches that defend on the in-built Grid schedulers includes [29, 31, 33] which uses; Globus scheduler, ASKALON scheduler and GridWay Metascheduler respectively. Other papers in this area that addressed other issues but failed tackle resource scheduling problem, either by developing a scheduling algorithm or by stating a scheduler used includes [26, 28, 30].

The year 2010 saw more researches coming out in this domain of research addressing different areas of concern as it can be seen from the Table 1 above. In an attempt to improve their previous work a year before, [35] evaluated the cost benefit of seven (7) scheduling algorithms used by organisations that operates a cluster managed by virtual machine technology and requests to make use of resources from a remote IaaS Cloud provider to decrease the response time of its user requirements. Among other algorithms used in this work are; the Backfilling, Naïve, Shortest queue, weighted queue and Selective scheduling algorithms. The paper [37] presented an autonomic Cloud on the Grid system in addressing provisioning issues and also presented a scheduling strategy in tackling that. The Naive Greedy Watchdog algorithm was used in solving the job scheduling issue that arose from this new setup. Also [38] presented a self-provisioned clouds on the grid in a virtual organisation clusters (VOC). A Simple greedy scheduling algorithm was also used in this work. Another very import scheduling research in this domain was [41], that introduced a scheduler for grid applications in clouds that account for not only resource demands, but also software requirements of the applications. It also accounts for network link availability that was generally ignored in the previous works of grid scheduling. The scheduler that was designed in this work was the Task and Virtual Machine Scheduler using Directed Acyclic Graphs (DAG). Other researches that are worth mentioning but failed to address scheduling issues are [34, 36, 39, 40].

From the Table 1 above, in the year 2011 another research titled "*Hybrid computing—where HPC meets grid and cloud computing*" was carried out [43]. The researchers argued for architecture that will merge the advantages of HPC, Grid and Cloud computing technologies. And then named the building blocks of this design, Elastic Cluster which they described the model and showed how it can be used to achieve efficient and expected execution of HPC workloads. The deadline-based and best-effort jobs scheduling algorithms were used in the research. The Meta-scheduling strategy was also used in [44, 47] to address issues related to Grid resource provisioning, architectures and on-demand grid provisioning respectively. Other researches that addressed the issue of grid provisioning but failed to consider scheduling are; [42] which presented the on-demand provisioning of Grid in cloud system, [45] that explained the concept of Grid, Cloud and virtualization, and [46] that also explained the application-level interoperability across Grids and Clouds with SAGA.

As it can be seen from the Table 1 above, in 2012 a Eucalyptus was used [49] to demonstrate an architecture that supported the integration of the diverse computing models and infrastructures for the dynamic on-demand provisioning of resources from various providers as an interconnected aggregate, leveraging the service-based architecture. The paper also, proposed a design aimed at endorsing a flexible, modular, workflow-based computing model for e-Science. The workload and resource management systems (WRMSs) algorithm was used in the research. The Condor and Bonjour Grid [52] was used with Condor, Boinc and Xtreweb job schedulers in the work titled "*A Self-Configurable Desktop Grid System On-demand*". Other similar researches to includes; [48, 50] which addressed issues related to on-demand cloud provisioning and [51] which addressed issues related to Clouds computing to scale grid resources and its economic model.

From the Table 1 above, in 2013 the thesis "*Decentralized Resource Scheduling in Grid/Cloud Computing*" [2] used the combinatorial allocation problem and propose an adequate economic-based optimization model and winner determination algorithm tackled the scheduling problems in the open Grid/Cloud environment. The thesis started by surveying the Grid/Cloud computing technologies, environment characteristics and structure and pointed out the issues within the resource scheduling. It also detailed a Grid/Cloud scheduling model based on the complete requirement of the environment. Even though the term "*Grid as a service*" was first used in the taxonomy paper [56] but its acronym "*GaaS*" was first introduced by [20]. The research paper presented a way to eliminate the paradigm disparity between Cloud and Grid Computing, enabling the

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use of Cloud-provided resources with well-established Grid-like interfaces, avoiding the need for clients to learn new resources access and use models. The proposed approach is validated through the development of a prototype implementation and its integration in a working Grid environment. The gLite-EMI and OpenNebula were used as Grid and Cloud infrastructures respectably. Other similar researches in the same domain explained the On-Demand VM Multi-Deployments in IaaS Clouds[53], extending Grid infrastructure using Cloud Computing [54] and Cloud/Grid security and performance evaluation [55].

5. SCHEDULING PARAMETERS USED

From the scheduling algorithms used in this domain of research (i.e. on-demand GaaS Cloud), a scheduling strategy can be implemented with different parameters. The Table 2 below shows the scheduling algorithms and the corresponding scheduling parameters used in previous researches.

Table 2: Scheduling Parameters Used In Existing Algorithms In On-Demand (Gaas) Cloud

No.	Algorithm and Ref. Paper	Execution Time	Response Time	Makespan	Scalability	Trust	Energy Consumption	SLA	Reliability	Load Balancing	Resource Utilization	Cost
1	Na¨ıve Scheduling Algorithm & FCFS with Aggressive Backfilling [27]	√	√	×	×	×	×	√	×	×	×	√
2	Globus Scheduler [29]	√	√	×	√	×	×	×	×	√	×	√
3	ASKALON scheduler [31]	√	×	×	×	×	×	×	×	×	×	√
4	Advanced Reservation Algorithm [32]	√	×	×	×	√	×	×	×	×	×	×
5	GridWay Metascheduler [33]	×	×	×	×	×	×	√	×	×	×	√
6	Aggressive Backfilling, Conservative Backfilling, Naïve, Shortest queue, Weighted queue, Selective Algorithms & conservative backfilling with support for advance reservation of resources [35]	√	√	×	×	×	×	√	×	×	×	√
7	Condor Scheduler & Naive Greedy Watchdog Algorithm [37]	√	√	√	×	×	×	×	×	×	×	×
8	Simple greedy scheduling algorithm & Condor Scheduler [38]	√	×	√	×	×	×	×	×	×	×	×
9	Task & Virtual Machine Scheduler using DAG [41]	√	×	√	×	×	×	×	×	×	×	×
10	Deadline-based & best-effort jobs Scheduling [43]	×	√	×	√	√	×	×	√	√	×	√
11	Meta-scheduling [44]	×	×	×	×	×	×	√	×	×	×	√
12	Meta-scheduling [47]	×	×	×	×	×	×	√	√	×	×	√
13	Workload and resource management systems (WRMSs) [49]	√	×	×	√	×	×	×	×	×	×	×

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14	Condor, Boinc and Xtreweb job schedulers [52]	√	×	×	×	×	×	×	×	×	×	×
15	Combinatorial Allocation Problem &Proposed an Adequate Economic-Based Optimization Model & Winner Determination Algorithm [2]	√	×	×	×	×	×	×	×	×	√	√

6. CONCLUSION

The on-demand Grid as a service (GaaS) Cloud is one of the many services of the user oriented cloud computing technology in which client faces virtualized Grid resources be accessed on-demand. The GaaS takes advantage of the pay-as-you-use paradigm of the Cloud technology to task users for the Grid resources they use. In this review paper, we survey the various research works carried out within this domain to identify the different scheduling algorithms that had been used for on-demand GaaS Cloud (as it can be seen in Table 1 above).

Our main contribution in this work was presented in Table 2 above, which shows the exiting scheduling parameters that had been used to couple a framework for the resource allocation, job distribution and scheduling schemes in the on-demand GaaS Cloud. The scheduling framework should take into account the customer input constraints such as execution cost, execution time, response time, energy consumption, makespan, scalability, trust, SLA, reliability, load balancing and resource utilization. It has been revealed that none of the proposed scheduling algorithms reviewed here fulfill the entire scheduling parameter requirements. However, that is not unexpected as the area of "on-demand GaaS cloud" is still in its early stages and again considering all the parameters in one framework will only make the scheme very complex. This paper thus helps to understand the key scheduling algorithms and parameters for possible future enhancements in this area of evolving research.

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