# Review Comments and Resolution:
# Cloud Resource Scheduling Taxonomy

Gregor von Laszewski[1,1,**], Rajni Aron[1], Geoffrey C. Fox[1]

[a][1] *Intelligent Systems Engineering Dep., Indiana University, Bloomington, IN 47408, USA.*
[b]*School of Computer Science and Engineering, Lovely Professional University, Punjab, India*

---

[*]Corresponding author

# Review Comments and Resolution:
# Cloud Resource Scheduling Taxonomy

Gregor von Laszewski[1,1,**], Rajni Aron[1], Geoffrey C. Fox[1]

[c1] *Intelligent Systems Engineering Dep., Indiana University, Bloomington, IN 47408, USA.*
[d]*School of Computer Science and Engineering, Lovely Professional University, Punjab, India*

---

---

## Appendix A. REVIEW

### Appendix A.1. Reviewer 1

This work is a survey of resource scheduling researches in cloud computing area. The authors design a resource scheduling taxonomy from their experience in utilizing and managing multi-cloud environments.

As an academic paper, rather than a technical report, the professionalism and rigor of language needs to be improved. The authors should check their sentences in this work carefully and make clearer and correct expressions.

- Resolution: Grammar and sentences have been corrected.

### Appendix A.1.1. 1. Abstract:

The authors should clearly illustrate the brief contributions of this work. In "It justifies our model and provides an overview of existing scheduling techniques in cloud computing.", the mentions about "our model" is confusing for readers to understand the intent of this paper.

- Resolution: We clarified the terminology and explicitly added a section which liste the contributions of the paper

### Appendix A.1.2. 2. Introduction:

As mentioned in the Abstract part, the authors should make their descriptions more professional and logical. In particular, they should **highlight their own** contributions clearly.

- Resolution: A new section with a list of contributions was added

### Appendix A.1.3. 3. General Scheduling Terminology for Clouds:

In my own opinion, it is not necessary to use a section to put the terminologies used in a paper. A table can be used to summarize the terminologies that you should explain. Also, a present of the definition such as "Cloud Resource: Is a resource offered......" is not professional and looks strange.

- Resolution: We experimented with tables to place definitions in it but found it did not increase readability. of the paper as the table would have been over multiple pages. Hence we left the definitions in the main text. If however this were to be an issue that would prevent publication, we certainly can provide a table instead.

4. The structure of Sec.3 is confusing. The first paragraph of this section should give readers a clear guide about what they are gonging to read.

- Resolution: We have introduced an introduction section for Section 3 to describe what the reader is going to read.

### Appendix A.2. Reviewer 2

### Appendix A.2.1. Summary

This paper presents a taxonomy to approach resource scheduling from a perspective that can be seen as a standard to be followed when implementing resource scheduling frameworks. This taxonomy takes into account the different layers of infrastructure on which it is possible to deploy and schedule workloads, several metrics that can guide such scheduling decision and finally, the challenges of resource scheduling from different point of views. Containers and functions are added to the study which is of interest. An extensive literature review is also presented.

### Appendix A.2.2. Content Section 2

+ Section 2, which introduces the terminology later used throughout the paper, may be too brief for the paper's own sake. Only a handful of terms are described

---
[**]Corresponding author

while I believe many others that the reader may need may be left out. For example, although the paper centers on schedulers and its policies to implement applications on the Cloud, neither a basic description of what a scheduler is nor a description of the policy concept are given. Throughout the paper several schedulers as several different policies are presented, thus, I think it would be interesting to make the distinction between scheduler and scheduler's policy with a definition.

- Resolution: We added a significant amount more definitions including the once pointed out by the reviewer

*Appendix A.2.3. Content Section 3*

+ Regarding Section 3, I believe that a single big topic, "scheduling" and two subtopics, 1) "taxonomies applied to Cloud" and 2) "Cloud challenges", have been mixed on this Section with no clear connection which overall leads to confusion to the reader. While Subsections 1 and 3 describe scheduling design and models, several taxonomies are introduced in Subsections 2,7 and 8 and challenges are introduced in Subsections 4, 5 and 6. Although Subsection 4 is titled as "Taxonomy of Challenges in Cloud Scheduling", I believe it is not correct to describe as a taxonomy a set of challenges, as they do not possess any hierarchy among themselves that allows to build such 'taxa'. This is not the case with, for example, Subsection 7, where scheduling unit are presented in a hierarchical manner. Nevertheless, for this latter Subsection I would re-assess the resource unit taxonomy presented. The "Deployment" unit is defined by using the term Job, which belongs to another classification. In a similar manner, the unit 'Scheduler' is defined as a process, thus, a running program and because of this, if considered, it should not be described as a resource but rather as a task (or this may even be the definition lacking in Section 2). For this Section I recommend a better organization, possibly by even creating different Sections for each topic as they can be addressed separately.

- Resolution: We have removed the scheduling chalanges from the diagram and clarified in the text why it is important to look at them as they provide requirements for scheduling algorithms.

*Appendix A.2.4. Content use of theory*

+ Both Sections 2 and 3 lay some theoretical ground work that is very slightly used afterwards in the rest of the paper to guide the reader or contrast the literature reviews presented.

- Resolution: In sections 2 and 3, we have mentioned the basic terminology and proposed taxonomy. Section 4 presents the literature survey of cloud scheduling algorithms and comparison tables are also presented. One column Taxonomy classification is included in the table to justify the proposed taxonomy. To increase the visibility of the Taxonomy in the table we highlighted the column that motivated us to include this classification into the taxonomy. We added a section in the literature review that makes this clear.

*Appendix A.2.5. Content In Section 4:*
*Appendix A.2.5.1. Subsection 4.1.* Reference 15 is completely unrelated to the citation context.

- Resolution: Reference 15 is cited in Table 1

*Appendix A.2.5.2. Subsection 4.2.1.* reference 22 is missing in its respective table (Table 2), even though it is an algorithm.

- Resolution: Reference 22 has been added to Table 2

*Appendix A.2.5.3. Subsection 4.4.* section may be unrelated to the paper's topic or may address too many topics, some of which may be unrelated. One of the topics are the HPC services and bare-metal provisioning offered by Cloud providers, both of which may rely on simple queue schedulers or the user's own infrastructure deployment choice, respectively, with little room for resource scheduling algorithms. Another topic is the Cloud but as an extension of HPC systems for bursting. Finally both using HPC infrastructure to run containers or otherwise Cloud platforms such as Hadoop may be unrelated to any scheduling algorithm study overall.

- Resolution: A) We find it important to address cloud bursting and to highlight that especially for academic resoures cloudbursting as a well established strategy that is integrated in the schedulers that run on HPC resources.

  B) We find it also important to point out that Platforms such as Hadoop that are often run in the cloud can also be run while leveraging schedulers from HPC computing centers. These systems leverage fully existing schedulers and offer its users a cloud like service as showcased for example at SDSC Comet, one of the largest academic compute resource in the US offering cloud services. We realize that other institutions have not yet leveraged such cloud offereings and it is thus important to point to these capabilities that can be offered on-demand.

*Appendix A.2.5.4. Subsection 4.5.* Section 4.5 which refers to workflows, uses references that may be too old (they range from 2000 to 2010) for the reader's interest. This is further supported by the fact that many of the references are for workflows on the Grid, while this paper tries to address scheduling for the newest technologies and environments such as containers and FaaS in the Cloud. There has to be more recent research which addresses workflows, the Cloud, containers, FaaS....

- Resolution: The section has been expanded and it was explicitly made clear that the current workflow systems have been updated, but are based on workflow systems that were introduced a while ago. However, the application to clouds is new and thus we updated the references.

*Appendix A.2.5.5. Subsection 4.6.* Subsection 4.6 is centered around the topic of Cloud pricing and the comparison of different Cloud provider models. The scheduling of instances is addressed but such scheduling is reduced to simple operations of starting and stopping instances or whole services, which may not be of interest to the reader.

- Resolution: We expanded the section and included the explanation that pricing is not only applied to compute but also to data, network, platforms and functions

*Appendix A.2.5.6. Section 5.* + In the conclusions in Section 5, I find some of the presented lessons as unrelated to the paper's work.

Both the "Analytics Services" and the "Edge Computing" lessons belong more as part of a future work section, as they have not been addressed anywhere in the paper.

- Resolution: New section is added.

In other lessons such as "More than VM scheduling" or "integration for data", technologies like FaaS or Big Data are mentioned even though the scheduling aspects for both have been only slightly described. Considering that the addition of FaaS to the Cloud scheduling state of the art is one of the paper's selling points, more citations describing algorithms or policies for FaaS would be appreciated, mainly in Subsection 4.8.

- Resolution: We have added more information about this aspect throuout the paper and made it clear that this may result in research activities.

In regards to Big Data and its 'management of data', to support this lesson a sort of data-based scheduling study would need to be mentioned, according to Figure 5 "Data-based scheduling model" and in accordance to the sections devoted to "energy-aware" or "network-aware".

- Resolution: A new section about scheduling considering decision based on data was added

*Appendix A.2.6. Language*
English should be greatly improved for this paper as numerous errors are present (e.g., "distingtion", "and this play a significant roll") as well as grammatically incorrect or ambiguous sentences and misleading punctuation.

- Resolution: Grammar, spelling and punctuation have been improved.

*Appendix A.2.7. Layout, figures, and tables*
+ There are multiple broken references to figures and tables.

- Resolution: the references have been fixed

+ Figure 3 is not properly displayed in the printed form. Although in the digital form it may be more easy to analyze, I would still recommend an alternative palette of colors, font size or a different format of mindmap. The main problem overall is the fact that the labels are difficult to read due to the fontsize and strong background colors.

- Resolution: Figure 3 color scheme has been replaced to a black font on light colors for easier readability. The figure has also been increased in size.

- Resolution: In addition to Figure 3, we also increased the size of Figure 9 for better readability.

+ Due to the content length some tables are difficult to read as the font sizes are scaled down and end up being too small for a comfortable reading. If all the table's content is maintained, I would suggest displaying the tables in a landscape mode using a whole page.

- Resolution: According to the reviewers feedback all tables have been included as sideways tables.

+ The citations inside the tables are not ordered making it difficult to correlate the citations in the text (ordered) to the ones in the table (unordered).

- Resolution: All tables have ben soted within that table to have asending citations. Naturally some citations could also be used in other sections as many frameworks have multiple matching classifications.

+ Table 9 is not referenced in the paper and I can not place where it could be.

- Resolution: Reference to Table 9 has been added in text

+ In Section 4.2 there is a broken Figure reference that I deem could be important. I do not know if the Figure is missing or if it is any of the ones referenced previous to that section, as there are no more Figures in the rest of the paper. At any rate I can not imagine which figure would it be.

- Resolution: The missing figure reference has been added

+ In Table 1 reference number 21 is misplaced, it belongs to and it is placed on Table 2.

- Resolution: Reference 21 has been moved to the correct table.

+ Throughout all the tables a normalization of terms and style would be needed (e.g., use of lower and upper case indistinctly, same terms written in different way like DC Sim and DCSim, Energy-aware and Energy-aware)

- Resolution: DCSim, Energy-aware = > Energy-aware

- Resolution: other inconsistencies have been removed also

*Appendix A.2.8. References*

+ References 103/115, and 102/112 may be analogous

- Resolution: Although they were pointing to different sections in the same manual. We have reduced the references and no only point to a single reference.

+ References with typos that I detected: 31, 149

- Resolution: Fixed references 31, 149

+ Broken references I detected: 11, 145

- Resolution: The references are updated

+ References 19, 27, 28, 42, 61, 68 are missing the year

- Resolution: Years were added to. However, as we added new references, the numbers are not the same in the new version. 19, 27, 28, 42, 61, 68

- Resolution: In addition, we went through all publications and checked the year

+ Reference 66 is completely unrelated to the paper, topic or even knowledge area.

- Resolution: Refernce 66 has been removed

*Appendix A.3. Reviewer 3*

*Appendix A.3.1. Major Comments:*

I would like to see the inclusion of the most popular workloads, benchmarks, simulation tools used by the researchers while implementing different scheduling policy in Cloud. Example TPC-H, BigDataBench, AMPLab Big data benchmark, Google Cluster traces, CloudSim etc.

- Resolution: A new section was added to the paper. All AMPlLab pages from berkeley are no longer available.

It would be great to have a separate section only describing different algorithmic approaches used in scheduling. The papers shown in different tables to cover various aspects, objectives of scheduling algorithms are sufficient already. However, there should be a clear discussion on when to use what algorithms. For example, the authors can start from linear programming models and how it is used to solve the scheduling problems, how the computational complexity involved in finding optimal solution led the researchers to use heuristic-based approaches, how meta-heuristics can improve the result, when we should use data-driven approaches and use prediction models in conjunction with scheduling for better resource management, how some algorithms might become system-specific and we need to tune it for every system, how AI can aid in this situation and automate the scheduling process (future direction).

- Resolution: A new section has been added to the paper. It describes a framework on how to make the selection. However we believe this is beyond the scope of this paper, as in our view it motivates future work and an additional paper.

There should be a separate challenges and future directions section showing the open challenges, and future research directions for researchers.

- Resolution: A new section was added.

I really missed some of the promising research done recently which use AI-based approaches for scheduling. I think like many other domains, research in resource management and scheduling in the cloud is also heading towards AI. For example, Deep Reinforcement Learning (DeepRL)-based approaches can automatically learn to schedule more efficiently and can also adapt to any system changes. As we have more compute resources available now-a-days, both simulation and real experimental approaches can use AI-based approaches. Some good papers to study and include:

- Resolution: A new section about ML and Deep Learning was added

DRL-cloud: Deep reinforcement learning-based resource provisioning and task scheduling for cloud service providers by Mingxi Cheng.

- Resolution: The paper is included in the updated version

Learning Scheduling Algorithms for Data Processing Clusters by Hongzi Mao

- Resolution: The paper is included in the updated version

*Appendix A.3.2. Minor Comments:*

In section 2, terminologies such as task scheduling, job scheduling, application scheduling should be discussed to provide the user with a clear understanding of the key concepts before going need.

- Resolution: We added additional terminology.

From the cloud perspective, it is often very confusing to define what level of scheduling is actually used in research (job, task or resource, VM, physical host?). Perhaps, the author can try to define these terms from their own experience.

- Resolution: We have added these terms.

This paper needs to be carefully revised to fix all the grammatical mistakes or typos.

- Resolution: We have carefully proofread the paper

Missing figure references in many cases: 3.3, 4.2, 4.2.1

- Resolution: All tables and figures have been cited in the text with the appropriate figure number.