Workflow Scheduling Algorithms in Grid and Cloud Environment – A Survey

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***Abstract* — With the development of computer and internet, new challenges are arising day by day. One of those challenges is increasing in demand of connectivity and resource handling. Cloud computing is an emerging technology which handles these data and resources dynamically with the help of internet and central servers. Workflow has been used for effective execution of various grid and cloud application. Workflow has been defined as directed acyclic graphs (DAGs) that allows proper management of resources with use of efficient scheduling approach. Scheduling focused on execution of tasks of workflow in a correct sequence according to some constraint defined. In this paper, we have surveyed various existing workflow scheduling algorithms in the grid and cloud environment on the basis of different scheduling parameters. Most of these existing algorithms focused on makespan and cost as the scheduling parameter. So there is a need to consider another scheduling parameters such as maximum number of relationships between the parent and child tasks of a workflow and proper resource utilization.**

***Keywords*— Grid Computing, Cloud Computing, Workflow Management System, Workflow Scheduling, Scheduling parameters.**

I. INTRODUCTION

Cloud computing is an emerging technology which replaced the old methods of performing computational tasks. With the help of cloud computing, users can store their data on clouds and can access this data from clouds without carrying their own storage and computational devices. Cloud computing provides data, services and applications on demand and this demand of resources can be scale up and scale down by the need of the users. The services and resources are used on the pay-per-use based model. User has no need to purchase the resources completely, but they have to pay on the rent bases for uses of these resources provided by cloud service providers. These resources can be some computational, storage, platform, application and hardware. So Cloud computing provides, Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [1] [2]. There are basically four types of cloud deployment models which has been defined as private cloud, public cloud, community cloud and hybrid cloud [2] [3] [4].

These business application can be represented with the help of Directed Acyclic Graph (DAG) in which each node represents the computational tasks and directed edge between these nodes represents the control dependency between the tasks of the application. Tools and models for performing tasks listed as specification, analysis, and execution are provided by workflow management system [5]. It forms a framework in which tasks of different nature and relationships among them are capture to automate the execution in such a way that it does not violate the business logic. Main issue in workflow management system is workflow scheduling.

The remaining paper is structured as section II describes the workflow scheduling, section III describes the related work, and section IV describes the conclusions and future scope.

II. WORKFLOW SCHEDULING

Mapping and management of workflow task's execution on shared resources is done with the help of workflow scheduling. So workflow scheduling finds a correct sequences of task execution which obeys the business constraint. The elements of workflow scheduling are shown in the Figure 1.

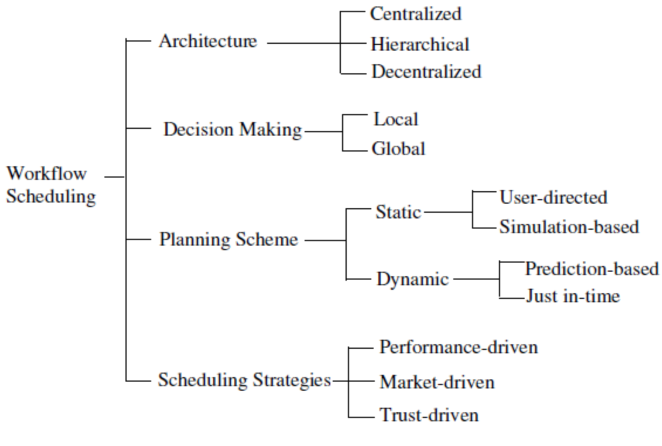

Figure 1: Elements of Workflow Scheduling [6]

Scheduling Architecture is very important in case of quality, performance and scalability of the system. In the centralized workflow environment, scheduling decisions for all the tasks in the workflow is done by a single central scheduler. There is no central controller for multiple schedulers in decentralized approach but communication between scheduler is possible. In hierarchical scheduling, there is a central manager. Not only workflow execution is controlled by this manager but also the sub- workflows are assigned to the lower-level schedulers [7].

Scheduling decisions which are taken on the basis of task or sub workflow are known as local decisions and which are taken by keeping in mind the whole workflow at the same are called global decisions. Global decisions based scheduling gives better overall results because only one task or sub workflow is considered in local decision scheduling.

Transformation of abstract models to concrete models is done in two ways: static and dynamic Static schemes further categorized in two types; user-directed and simulation-based. In the former, decision about resource mapping and scheduling is done on the basis of user's knowledge, preferences and performance criteria. But in case of simulation based, a best scheduled can be achieved by simulating task execution on resources before the workflow execution starts. Both static and dynamic information about resources used for making scheduling decisions at run-time are consider in case of dynamic scheme.

Scheduling strategies are categorized into three categories mainly performance driven, market driven and trust driven. In case of performance driven strategies, focus is to achieve the highest performance for the user defined QoS parameter. So the workflow's tasks mapped with resources gives the optimal performance. Most of the performance driven scheduling strategies focuses to maximize the makespan of the workflow. Market driven Strategies focuses on resource availability, allocation cost and quality for the budget and deadline. A market model is used to schedule the workflow tasks to the available resource dynamically which results in less cost. Trust driven focuses on security and reputation of the resources and tasks are scheduled based on the trust by considering these two parameters [7].

III. RELATED WORK

In this section most of the workflow scheduling strategies exists in the grid and cloud environment has been reviewed briefly with respect to the technique/algorithm description, scheduling parameter considered and tools/platform used for the implementation for result analysis. The summary of all these algorithms is summarized in the Table 1. These existing scheduling algorithms are classified in the following categories:

1. **Heterogeneous Earliest Finish Time:** Wieczorek [8] and Juan J. Durillo [30] focused on makespan and cost. In [8] average communication time and average execution time of each task of workflow is calculated first and then rank is assigned on the basis of these two parameters. The task having highest rank is scheduled first. This algorithms works in the grid environment. MOHEFT [30] extends HEFT in the cloud environment by using the SPEA2*[36] for bi-objective scheduling criteria to optimize both makespan and the economic cost.
2. **Optimizing parameter based Scheduling:** This category include mainly [9] [11] [12] [14] [17] [23] [27] [29] [34], In these algorithms two or more parameters are considered for scheduling in which one parameter is fixed and on the basis of this another parameters are optimized. These algorithms works in the both Grid and Cloud Environment.
3. **Market Oriented Scheduling:** In market oriented approach the resource are available in the market and user have to buy the resource by bidding procedure to schedule their tasks [10] and in [35] on the basis of budget the tasks are scheduled with minimum execution time.
4. **Genetic Algorithms:** This category mainly includes [11] [24] [31] in which various different parameters are considered for scheduling such as makespan, time, cost and reliability etc. Genetic algorithms uses the mutations and crossover functions to optimize a parameter by considering the other parameters.
5. **Critical Path based Scheduling:** This category mainly includes [13] [15] [16], these algorithms focuses on makespan and schedules the task by dynamically identifying the critical path which gives the lowest execution time for the workflow. Some variation of critical path algorithm focuses on identifying the predecessors of a task for critical path creation.
6. **Multiple QoS with Multiple workflow:** Meng Xu[18] focused on makespan and cost. This algorithm calculates the mean execution time and mean execution cost of all the workflows and schedules the task having minimum covariance of time and cost is scheduled first to optimize both the makespan and cost.
7. **Ant Colony Optimization (ACO) based scheduling algorithms:** There are various version based on ACO such as [20] [21]. The basic ACO algorithms is based on the foraging behavior of ants. Whenever any ant searched a food, then it spread the chemical known as pheromone to make the shortest path from the food to their destination. Others ants follow this path with the help of pheromone and reached to the food as soon as possible by following the shortest path. The algorithm based on ACO consider many QoS and objective of these algorithm is to find a best optimized solution by considering the user preferred QoS parameter.
8. **Particle Swarm Optimization (PSO) based Scheduling Algorithms:** Suraj Pandey [22] proposed a PSO based heuristic which consider the computational and transmission cost as the scheduling parameters. The algorithm calculates the average computational and average transmission cost of each task and schedules tasks to the resource with minimized cost.
9. **Priority based scheduling algorithms:** Shamsollah Ghanbari [28] proposed a priority based job scheduling algorithm by considering makespan as the scheduling parameter in the cloud environment by considering three levels of Analytical Hierarchy Process which are

represented with three types of job priority which are objective level, scheduling level and job level.

10. **Hierarchical scheduling strategy:** Zhangjun Wu [32] includes GA, ACO and PSO heuristics for the job level and resource level scheduling known as the assignment of task-to-service scheduling by considering makespan, cost and resource utilization as the scheduling parameters.

11. **Trust based Scheduling algorithm:** Yuli Yang [33] schedules the task by verifying resource failure probability during the transmission of task with security and reliability constraint.

Table 1: workflow scheduling strategies exists in the grid and cloud environment

Author & Year	Algorithm/ Technique	Scheduling Parameter	Description	Tools/ Platform	Environ ment
Wieczorek (2005) [8]	Heterogeneous Earliest Finish Time	Makespan	(i) Calculates average communication time and average execution time. (ii) Task having highest rank scheduled first.	ASKALON	Grid
Gurmeet Singh (2005) [9]	Optimizing based grid scheduling	Makespan	(i) Minimizes the various cost related to resource matching, task submission and updating in the ready queue. (ii) Restructure the workflow for multiple submission host.	Condor and TeraGrid	Grid
Chia Hung (2005) [10]	Market Oriented Scheduling	Resource utilization	(i) The resource are available in the market and user have to buy the resource by bidding procedure to schedule their tasks.	Real environ-ment consists of 15 CPU, 10 network connection and 15 memory units with 30 discs.	Grid
Jia Yu (2006) [11]	Genetic algorithm	Time and Cost	(i) One factor constraint are considered and on the basis of this other factor is optimized.	GridSim	Grid
Yongcai Tao (2007) [12]	Reliability Cost Grid Scheduling	Reliability and Cost	(i) Big sized task has assigned higher ranks (ii) Tasks are grouped in decreasing order of rank and finally scheduled using max-min or min-min heuristics.	Real testbed at Cluster and Grid Computing Lab	Grid
Bogdan Simion (2007) [13]	Improved Critical path using Descendant Prediction	Makespan and Load balancing	(i) As Late As Possible (ALAP) time for each task is calculated (ii) Task having minimum ALAP is scheduled first by considering the descendants along the critical path.	Mon-Alisa farms and ApMon	Grid
Rizos Sakellariou (2007) [14]	Budget based scheduling technique	Makespan and Budget	(i) The algorithm works on two approaches, LOSS and GAIN. In the LOSS approach, the cost exceeds over the available budget (ii) In the GAIN approach cost remains less than available budget and minimizes the overall execution time of workflow.	GridSim	Grid
Mustafizur Rahman (2007) [15]	Dynamic Critical Path	Makespan	(i) Schedules the task by dynamically identifying the critical path which gives the lowest execution time for the workflow.	GridSim	Grid
Marek Wieczorek (2008) [16]	Dynamic Constraint Algorithm	Bi-criteria	(i) Uses variable parameter pair and slicing constraint to optimize one parameter by slicing the second parameter dynamically.	ASKALON	Grid
Rajiv Ranjan (2008) [17]	Decentralized and Co-operative Scheduling	Makespan and Scalability	(i) Calculates the average execution time, average response time and average Coordination delay. (ii) Schedules the task with the resource co-operation to decrease the probability of failure.	GridSim and PlanetSim	Grid
Meng Xu (2009) [18]	Multiple QoS with Multiple	Makespan and Cost	(i) Calculates mean execution time and mean execution cost of all the workflows.	Simulation environment	Cloud

	Workflow		(ii) The task having minimum covariance of time and cost is scheduled first to optimize both the makespan and cost.	with 20 services and 5-25 users.	
Sanchez Santiago (2009) [19]	Dynamic Balanced Scheduler	Response time	(i) Splits the whole workflow into balanced partitions so that all partitions are executed within the same time.	GridSim	Grid
Wei Neng Chen (2009) [20]	ACO approach with various QoS	Time, Cost and Reliability	(i) Optimizes one parameter according to user constraint given for remaining two parameters.	GridSim	Grid
Ruay shiung Chang(2009) [21]	Balanced Ant Colony optimization (BACO)	Makespan	(i) Selects the job having less computational time and schedule it on corresponding balanced resource which gives mini-mum completion time	UniGrid	Grid
Suraj Pandey (2010) [22]	Best Resource Selection(BRS) using PSO	Computational and Transmission cost	(i) Calculates the average computational and average transmission cost of each task. (ii) Schedules tasks to the resource with minimized cost.	JSwarm	Cloud
Wang yong (2011) [23]	Deadline and budget constraint scheduling algorithm	Makespan, budget and relative cost	(i) Sorts the tasks in increasing order of size. Then equal sized chunks are created and theses chunks are scheduled according to increasing order of relative cost.	GridSim	Grid
Xiaofeng Wang (2011) [24]	Look ahead genetic algorithm	Makespan and Reliability	(i) Works in two steps namely evolution and evaluation. During the evaluation step itself algorithm provides the order of execution of workflow instead of evolution step.	GridSim	Cloud
El-Sayed (2012) [25]	Extended Max-min Algorithm	Execution time	(i) Schedules the jobs having minimum time on slower resources and jobs having maximum time on faster resources. So in this way overall waiting time of jobs is reduced and there is improvement in the execution time of workflow.	Java 6	Cloud
Hamid Mohammadi Fard (2012) [26]	Multi-objective workflow scheduling	Makespan, Reliability, Energy consumption and Cost	(i) Considers any three parameter and optimizes the fourth parameter. (ii) Works in two ways either minimizing the optimal parameter by maximizing the remaining parameters or vice versa.	ASKALON	Grid/ Cloud
George Amalarethinam (2012) [27]	Minimum Makespan Grid Workflow Scheduling	Makespan	(i) Reserves the resources in advance. (ii) Does resource preference statically and resource allocation dynamically.	Simulation environment consist of 4-8 resources with speed 1, 1.25, 1.5 and 1.75.	Grid
Shamsollah Ghanbari (2012) [28]	Priority Job Scheduling Creteria	Makespan	(i) Based on three levels of Analytical Hierarchy Process which are represented with three types of job priority which are objective level, scheduling level and job level.	Cloud environment consists of 3 resources.	Cloud
Arash Ghorbannia (2012) [29]	Reliable Scheduling Distributed Technique	Makespan	(i) Calculates the request time of task and acknowledgement time of resource independently and in the shared mode. (ii) Calculates the difference between above two approaches to increase the efficiency.	Java	Cloud
Juan J. Durillo (2012) [30]	MOHEFT	Makespan and Cost	(i) Extends HEFT [13] and merge with SPEA2* [36] for bi-objective scheduling criteria to optimize both makespan and the economic cost	GridSim	Grid/ Cloud

Somayeh Kianpisheh (2012) [31]	Genetic Algorithm	Makespan	(i) Minimizes the overall completion time of the workflow by considering the communication and computational cost.	GridFlow	Grid
Zhangjun Wu (2013) [32]	Hierarchical scheduling strategy	Makespan, Cost and Resource utilization	(i) Includes GA, ACO and PSO heuristics for the job level and resource level scheduling known as the assignment of task-to-service scheduling.	SwinDeW-C	Cloud
Yuli Yang(2013) [33]	Trust based Scheduling algorithm	Reliability and Security	(i) Schedules the task by verifying resource failure probability during the transmission of task with security and reliability constraint.	CloudSim	Cloud
Dong-ki kang (2014) [34]	Cost based heuristic scheduling scheme	Cost	(i) Tasks assigned to resources are allocated in sequence to the virtual machine instance (ii) Tasks assigned in the first step to different VM are combined in a single VM instance and executes in parallel (iii) Less resources are used and there is nearly 30% of reduction in the cost	Openstack	Cloud
Hamid Arabnejad (2014) [35]	Heterogeneous Budget Constrained Scheduling Algorithm	Execution time and Cost	(i) Calculates the minimum execution time with highest cost (ii) Calculates the minimum cost with the corresponding deadline. (iii) Reduction in 30% of execution time with same budget level.	Real cloud simulation by sharing bandwidth	Cloud

IV. Conclusion

It has been analyzed that most of the existing algorithms in the grid and cloud environment focused on the makespan as the scheduling parameter. Some other algorithms focused on the cost and budget. But very less consideration is given to the parameters such as scalability, scheduling success rate, speed and availability etc.

There is need to implement some workflow scheduling algorithms which will focus on scalability and speed and availability etc.

There is no algorithm in the grid and cloud environment which considers the maximum number of relationship between the parent and child as the scheduling parameter. So there should be some algorithm which consider this dependency relationship to improve the resource utilization.

References

[1] The Future of Cloud Computing: Opportunities for European Cloud Computing Beyond 2010:--expert Group Report. European Commission, Information Society and Media, 2010.

[2] O. Brian, T. Brunschwiler and H. Dill, "White Paper Cloud Computing", *Swiss Academy of Engineering*, June 2012.

[3] B.P. Rimal, E. Choi, and I. Lumb, "A taxonomy and survey of cloud computing systems," *in NCM '09: Proceedings of the* 2009 *Fifth Int'l Joint Conference on INC, IMS and IDC*. Washington, DC, USA: IEEE Computer Society, pp. 44–51, 2009.

[4] T. Dillon, C. Wu, and E. Chang, "Cloud Computing: Issues and Challenges," *24th IEEE Int'l Conference on Advanced Information Networking and Applications (AINA), 2010*, IEEE, 2010.

[5] Q. Zhang, L. Cheng, and R. Boutaba, "Cloud Computing: State-of-the-Art and Research Challenges," *Journal of Internet Services and Application*, Springer, pp. 7–18, 2010.

[6] S. Subashini, and V. Kavitha. "A survey on security issues in service delivery models of cloud computing," *Journal of Network and Computer Applications* 34.1, pp. 1-11, 2011.

[7] J. Yu and R. Buyya, "A Taxonomy of Workflow Management Systems for Grid Computing," journel of Grid Computing, Springer, pp. 171-200, 2005.

[8] M. Wieczorek, R. Prodan and T. Fahringer, "Scheduling of scientific workflows in the ASKALON grid environment," SIGMOD Record, 34(3), pp. 56–62, 2005.

[9] G. Singh, C. Kesselman, and E.Deelman, "Optimizing grid-based workflow execution," Journal of Grid Computing 3, no. 3-4, pp. 201-219, 2005.

[10] C. Chien, P. H. Chang, and V. Soo, "Market-oriented multiple resource scheduling in grid computing environments," Proceedings in 19th International Conference on Advanced Information Networking and Applications, AINA 2005, vol. 1, pp. 867-872. IEEE, 2005.

[11] J. Yu and R. Buyya, "Scheduling scientific workflow applications with deadline and budget constraints using genetic algorithms," Scientific Programming, vol. 14.3, pp. 217–230, 2006.

[12] Y. Tao, H. Jin, and X. Shi, "Grid workflow scheduling based on reliability cost," In *Proceedings of the 2nd international conference on Scalable information systems*, p. 12. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2007.

[13] B. Simion, C. Leordeanu, F. Pop and V. Cristea, "A Hybrid Algorithm for Scheduling Workflow Applications in Grid Environments (ICPDP)," OTM Confederated International Conferences, pp. 1331-1348, Springer Berlin Heidelberg.

[14] R. Sakellariou, H. Zhao, E. Tsiakkouri, and M.D Dikaiakos, "Scheduling workflows with budget constraints," *Integrated Research in GRID Computing, Springer US*, pp. 189–202, 2007.

[15] M. Rahman, S. Venugopal and R. Buyya, "A Dynamic Critical Path Algorithm for Scheduling Scientific Workflow Applications on Global Grids," *E- Science and Grid Computing, IEEE International Conference*, pp. 35-42, 2007.

[16] M. Wieczorek, S. Podlipnig, R. Prodan and T. Fahringer, "Bi-criteria scheduling of scientific workflows for the grid," *In 8th IEEE International Symposium on Cluster Computing and the Grid, CCGRID'08*, pp. 9-16. IEEE, 2008.

[17] R. Ranjan, M. Rahman, and R. Buyya, "A decentralized and cooperative workflow scheduling algorithm," *In 8th IEEE International Symposium on Cluster Computing and the Grid, CCGRID'08*, pp. 1-8. IEEE, 2008.

[18] M. Xu, L. Cui, H. Wang, and Y. Bi, "A multiple QoS constrained scheduling strategy of multiple workflows for cloud computing," *IEEE 11th Int'l Symposium on Parallel and distributed Processing with Applications,* Chengdu, China, pp. 629–634,2009.

[19] A. Santiago, A. Yuste, J. Expósito, S. Galán, J Marín, and S. Bruque, "A dynamic-balanced scheduler for Genetic Algorithms for Grid Computing," *WSEAS Transactions on Computers* 8, no. 1, pp. 11-20, 2009.

[20] W. Chen and J. Zhang, "An ant colony optimization approach to grid workflow scheduling problem with various QoS requirements," *IEEE Transaction on Systems, Man, and Cybernetics*, vol. 39, no. 1, pp. 29–43, 2009.

[21] R. Chang, J. Chang, and P. Lin, "An ant algorithm for balanced job scheduling in grids," *Future Generation Computer Systems* 25(1), pp. 20-27, 2009.

[22] S. Pandey, L. Wu, S. Guru and R. Buyya "A particle swarm optimization based heuristic for scheduling workflow applications in cloud computing environments," *24th IEEE Int'l Conference on Advanced Information Networking and Applications (AINA), Perth, Australia,* pp. 400–407,2010.

[23] Y. Wang, R. Bhati and M. Bauer, "A Novel Deadline and Budget Constrained Scheduling Heuristic for Computation Grids," *Journal of Central South University of Technology* Vol. 18, Issue 2, pp. 465-472,2011.

[24] X. Wang, C. Shin, J. Su and R. Buyya, "Optimizing the makespan and reliability for workflow applications with reputation and a look-ahead genetic algorithm," *Future Generation Computer Systems* 27, no. 8, pp. 1124-1134,2011.

[25] El. kenawy, El. Desoky F. Al-rahamawy, "Extended Max-MIn Scheduling using Petri Net and Load Balancing," *International Journal of Soft Computing and Engineering* 2, no. 4, 2012.

[26] H. Fard, R. Prodan, J. Barrionuevo, and T. Fahringer, "A multi-objective approach for workflow scheduling in heterogeneous environments," In *Proceedings of the 12th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (ccgrid 2012)*, pp. 300-309. IEEE Computer Society, 2012.

[27] D. Amalarethinam and F. Selvi, "A minimum makespan grid workflow scheduling algorithm," In *International Conference on Computer Communication and Informatics (ICCCI),* pp. 1-6, IEEE, 2012.

[28] S. Ghanbari and M. Othman, "A priority based job scheduling algorithm in cloud computing," *Proceeding In International Conference on Advances Science and Contemporary Engineering 2012 (ICASCE 2012),* pp. 778-785, 2012.

[29] A. Delavar, M. Javanmard, M. Shabestari and M. Talebi, "RSDC (RELIABLE SCHEDULING DISTRIBUTED IN CLOUD COMPUTING)," *International Journal of Computer Science, Engineering & Applications* 2, no. 3, 2012.

[30] J. Durillo, H. Fard and R. Prodan, "MOHEFT: A multi-objective list-based method for workflow scheduling," In *4th International Conference on Cloud Computing Technology and Science (CloudCom), 2012*, pp. 185-192. IEEE, 2012.

[31] S. Kianpisheh and N. Charkari, "A genetic based workflow scheduling considering data transmission time," In *Sixth International Symposium on Telecommunications (IST),* pp. 571-576, IEEE, 2012.

[32] Z. Wu, X. Liu, Z. Ni, D. Yuan and Y. Yang, "A Market Oriented Hierarchical Scheduling Strategy in Cloud Workflow Systems," *The Journal of Super Computing*, Vol. 63, Issue 1, pp. 256-293, Springer US.

[33] Y. Yang and X. Peng, "Trust-Based Scheduling Strategy for Workflow Applications in Cloud Environment," In *Eighth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC),* pp. 316-320. IEEE, 2013.

[34] D. Kang, C. Youn and M. Chen, "Cost adaptive workflow scheduling in cloud computing," In *Proceedings of the 8th International Conference on Ubiquitous Information Management and Communication*, pp. 65, ACM, 2014.

[35] H. Arabnejad and J. Barbosa, "A Budget Constrained Scheduling Algorithm for Workflow Applications," *Journal of Grid Computing*, pp. 1-15, 2014.

[36] J. Yu, M. Kirley and R. Buyya, "Multi-objective planning for workflow execution on grids," In *Proceedings of the 8th IEEE/ACM International Conference on Grid Computing*, GRID '07, IEEE Computer Society, pages 10–17,Washington, DC, USA, 2007.

