

An Insight into Grid Scheduling Algorithms: A Survey

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Abstract – Grid scheduling is the process of mapping each and every task for the job completion with respect to the service level agreements. Grid scheduling produces effective decisions, and involves the resources from various administrative domains. The complexity of generic scheduling issue is NP-Complete. The scheduling issue is more problematic due to certain unique features of grid computations. In this paper, the recent trend in scheduling for grid computing is reviewed. It gives an account of grid scheduling mechanisms that were amended in earlier stages of grid and fruition of the same relevant to grid. It also briefs several existing metaheuristics optimization algorithm existing for grid computing and presents a comparison. The necessity for unconventional scheduling mechanism is also endorsed by focusing on issues and challenges prevailing in the current scenario.

Index Terms – Grid computing, Scheduling, Meta Heuristics.

1. INTRODUCTION

Grid technology is a promising distributed paradigm that can be used for applications that involves high performance computing and includes huge quantities of heterogeneous resources sharing. The users of grid can gain advantages as it privileges them to access the data distributed geographically across the globe in various multi-organizations. These advantages of grid technology make the user able to run enormous applications that require more than one individual resource unit[1].

The prime emphasis of the grid is to afford connectivity among heterogeneous resources at application level enabling the global sharing of the same. This goal can be achieved only by the efficient usage of grid resources. Grid Resource management system (RMS) enables this by appropriate organization of resources. Resource scheduling is the main component of this Grid RMS. Scheduling gains its importance as it appropriately matches the needs of the jobs with the available resource and this is a NP complete problem. This chapter aids to comprehend important task scheduling methods, their limitations as well as detect potential further improvements in the area.

Various Scheduling strategies are available in literature which aims at the scope of achieving optimal scheduling of resources to tasks. At initial stages of grid, conventional algorithms are used. During evolution of grid concept, many metaheuristic algorithms are developed to provide an optimal solution. This

paper intends to provide a brief survey of evolution of grid scheduling algorithms.

2. OVERVIEW OF GRID SCHEDULING

Berman [2] stated the circumstance under which Traditional scheduling algorithms are framed so that they couldn't be used for grid scheduling

- Resources are from single administrative domain.
- Centralized control of resources from scheduler
- Invariant resource pool.
- Scheduler manages contention caused by application

Predictable data staging as computation algorithm and data resides in same site but the scenario is different in grid. This necessitated the evolution of algorithms with respect to grid.

The challenges faced when designing a scheduling strategy are presented by Zhu et al. in [3]. Heterogeneity and Autonomy, Performance Dynamism and Resource Selection and Computation-Data Separation are the major challenges.

Heterogeneity of grid resources leads to many intricacies. These issues are not yet addressed completely and put forth a big challenge for grid scheduling. The heterogeneity arises as the grid resources span over multiple domains across the globe. Moreover, resources may be computational, storage, network component or any embedded instrument specific to any application. This diverse form of resources results in different capabilities of execution. Due consideration should be given to the above said factors during deriving the scheduling algorithm.

The autonomy of grid resources arises from the different resource management and access policies followed by the local resource management systems. The grid cannot violate these local policies and hence it cannot gain complete control over the resources. Thus the working of the scheduler is complicated as it has to adopt to heterogeneity and autonomy.

The feasibility of any grid scheduling algorithm relies on the performance estimation provided by the resource during selection. But in the case of grid, due to the dynamic nature performance of the resources varies continuously. For example, a resource may be interrupted by a local high priority

job and it may hinder the execution of current running grid job. This performance dynamism arises mainly due to the heterogeneity and autonomous as discussed above. This fluctuation leads to major complication in grid scheduling environment.

Another challenge faced during grid scheduling is that the data to be analyzed or stored, the application that uses the data and the resource in which the application runs are available in different site. This information is available only during the run time. Due concentration should be given to this point also while formulating a scheduling strategy.

3. CONVENTIONAL GRID SCHEDULING STRATEGIES

Even though some of the conventional algorithms tailored for grid were used during the earlier stages of grid computing and they are discussed below

The balance-constrained approach given by El-Rewini et al.[4] tries to re-balance load on every resource through periodical shifting of waiting jobs from one queue to the other. In huge systems like the Grid, this is expensive because of the significant transmission delay.

First-In-First-Out (FIFO, additionally called First-Come-First-Served) was presented by Maheswaran et al.[5]. The resource with currently minimal waiting queue is chosen for the incoming job. This principle is known as opportunistic load balancing (OLB) or myopic protocol. The primary benefit of the protocol is its simplicity however it is not an optimum method.

The random scheduling mechanism discussed by Hamscheris [6] is a non-deterministic task scheduling method wherein the subsequent task to be implemented is selected arbitrarily from tasks in the waiting queue. No task has a preference though the earliest arrived tasks have greater probability of being implemented.

Braun et al. [7] have discussed about Minimum Execution Time (MET) as well as Minimum Completion Time (MCT). MET designates every task to resources with optimal expected execution time for the task, with no consideration to whether the resource is available at the current time. The notion underlying MET is the provision of every job the optimal machine. This causes severe load unbalancing among machines.

MCT designates every job in a random order to the resource with least expected completion time for the job. This makes certain jobs designated to machines which do not possess minimal execution time for those. The notion underlying MCI is the combination of gains of opportunistic load balancing (OLB) as well as MET, while also obviating the situations wherein OLB as well as MET do not perform well.

Arora et al [8] presented an entirely decentralized, dynamic as well as sender-initiated scheduling as well as load balancing protocol for Grids. A characteristic of this protocol is that it utilizes smart search scheme for finding partner nodes wherein jobs can migrate. Further, it overlaps the decision making procedure with actual implementation of ready tasks, therein conserving valuable processor cycles.

Subramani et al.[9] propose an algorithm which does not utilize performance estimation however adopts the notion of duplication that is viable in the grid environment wherein computation resources are typically numerous but mutable.

Mateescu [10] utilizes a resource selector for finding coreservation for tasks needing numerous resources. The task queue management is done in a FIFO manner with dynamic priority correction. If co reservation is a failure for a task in scheduling cycle, the task's priority is promoted in the queue for the subsequent scheduling iteration. The resource selector ranks potential resources by the quantity of processors as well as memory sizes.

Sabin et al. [11] suggests a centralized meta-scheduler that utilizes backfill for scheduling parallel tasks in several heterogeneous sites.

Silva et al. [12] suggested a resource information free protocol known as Workqueue with Replication (WQR) for independent task scheduling in the Grid. WQR utilizes job replication for coping with heterogeneity of hosts as well as jobs and also dynamic variation in resource availability because of loads generated by other users in the Grid.

Kurowski et al. [13] proposed a scheduling policy however the aim of the re-scheduling stage in the case was not for load balancing or cost optimization, rather, it was to make running tasks release needed resources for pending tasks.

Muthuvelu et al. [14] suggested a dynamic job grouping scheduling protocol for dealing with the cases. Once a group of fine-grained jobs are received, schedulers group them as per requisites for computations as well as processing capacity that grid resources are capable of providing in a set time period. Every task in the same set is presented to one resource that can complete all of them in the specified time. Through this, overheads for scheduling as well as task launching are decreased and resource usage is improved.

Tianchi et al. [15] proposed a pM-S algorithm that expands conventional dynamic Master-Slave scheduling framework. Two queues are utilized by the master, unscheduled queue as well as ready queue. Solely jobs in the ready queue may be directly dispatched to slave nodes while jobs in unscheduled queues may solely be placed in ready queue when all parents are already dispatched.

4. META HEURISTICS BASED ALGORITHMS

4.1. Min- min based grid scheduling

Quality of service guided Min-Min proposed by [16] which schedules task requiring high bandwidth. This algorithm outperforms the classical min- min algorithm.

The algorithm proposed in [17] selects the next job based on applied heuristics. The selection is based on quality of service based Max-Min or quality of service based Min-Min algorithm. This algorithm utilizes the history information about the job execution.

Double Min-Min Algorithm based on efficient set pair analysis has been proposed in [18]. Along with reducing the makespan, this algorithm ensures system availability.

Min- Mean heuristic has been proposed in [19] which reschedules the schedule given by Min-Min. It regards the mean makespan of all resources. The performance of this protocol underperforms when the heterogeneity of the task increases.

QWMTM and QWMTS protocols are suggested in [20]. The network bandwidth is considered as variable for QOS.

A load balanced min-min algorithm has been suggested in [21]. The algorithm not only aims at reducing makespan but also aims at improving resource utilization. The second phase of this algorithm reschedules the underutilized resources.

4.2. Tabu search based algorithm

Tabu search algorithm was also used in Fayad et al. [22] for generating excellent schedules and explore robust nature of schedules during processing time differ through assessment of performance in fuzzy as well as crisp modes.

Coello et al. [23] has briefed the shortfalls of TS algorithm. TS is poor in dealing with solution search space diversity because some neighbourhood potential solutions are not necessarily created. For tackling this issue, TS is to be expanded with other heuristics which assist in the obviation of non-required neighbourhood. But the primary shortcoming of the TS expanded method is the additional computation costs created by the utilized heuristic.

Tabu search was used to provide better scheduling in Benedict & Vasudevan [24]. The objectives were maximizing job completion ratios as well as minimizing penalties of grid schedulers in selecting specific sequences. FCFS, EDF and LCFS were also compared with this method

Yusof et al. [25] proposes a TS protocol, a local search protocol that is utilized to schedule tasks in grid systems. TS utilizes a perturbation strategy for pair changing.

4.3. Ant Colony Optimization

The ACO method developed by Madadyaradeh and Bagherzadeh [26] is an updated ACO technique with biased initial ants. The goal of this scheduling method is the increase of scalability as well as adaptability of the grid system.

Xu et al. [27] suggested a simple Ant Colony Optimization method in grid simulation architectures and utilized valuation indexes in response times and resource average utilizations.

Yan et al. [28] suggested enhanced Ant Colony Optimization model that enhanced job finishing ratios. But they did not utilize the several valuation indexes to assess it

A novel method is proposed by Fidanova & Durchova [29] wherein the heuristics provide optimum solutions for huge grids. It introduced task scheduling protocol for grid computation. The protocol has its basis in ACO (a Monte Carlo technique). The work demonstrates the way to search for optimal task scheduling for grid computations.

For balancing between resources, Ruay-Shiung Chang et al. [30] suggested a Balanced Ant Colony Optimization (BACO) protocol for computation grid scheduling. The goal of BACO is the balancing of system loads as well as the reduction of makespan for submitted tasks.

A fusion of ACO as well as Max -Min scheduling methods is incorporated in the work by Ku-Mahamud & Nasir [31]. For updating resource table, the method suggested the notion of agents. The fused method functioned better than PSO as well as space-shared, time-shared scheduling method.

Ma & Wang [32] presented a task scheduling scheme on the basis of Chaotic ACO, utilizing randomness periodicity as well as regularity of chaotic motion for improving quality of ants as well as premature convergence of ACO as well as GA. For experiments, MATLAB is utilized for making simulation experiments for Chaotic ACO as well as Standard GA while the outcomes prove that job scheduling protocol effectively decreases runtime.

Mandloi & Gupta [33] suggested a controlled method of ACO with GA for job scheduling in computation grids. Performance was evaluated with regard to task completion as well as task failure. Proposed empirical evaluation revealed better performance than ANT as well as PSO scheduling methods.

Kumar et al. [34] made a study, a local search heuristic by way of multipoint mutation is introduced on the popular swarm intelligence inspired meta-heuristic, ACO. Experiments show the proposed technique improves the Makespan and converges faster than conventional ACO.

The limitations of ACO are discussed in the Selvi & Umarani [35] proves that the solution search space convergence is guaranteed in ACO. But according to Kleijnen [36] time to

convergence is uncertain. Hu & Gong [37] also states that Job scheduling on computation grids utilizing ACO yields good however sub-optimum schedules with regard to makespans as well as flowtime.

4.4. Genetic Algorithm Based Scheduling Algorithms

A sub-optimal optimization method for scheduling tasks on computation grids on the basis of GA was formulated by Hamscher et al [38]. The sub-optimal method is able to converge in simple issue. But in complicated scheduling issues, the method is not capable of convergence.

Abraham et al. [39] proposed a hybrid of three nature based methods GA, SA as well as TS for task scheduling on computation grid. The hybridized method proved better convergence as well as improved search procedure of genetic algorithm.

A Hierarchical method for task scheduling utilizing GA is suggested by Sanyal et al. [40] for computation grids for increasing scalability of the scheduling procedure.

Two frameworks, single as well as multiple services are suggested by Gao et al. [41] for estimating completion time for tasks on computation grids utilizing GAs.

For enhancing GAs even more, integration between tasks clustering utilizing fuzzy C-Mean as well as scheduling method utilizing Gas[42] was formulated by Lorpunmanee et al.

For providing excellent QoS reasonable scheduling as well as resource allotment are required when lot of jobs require grid resources. Through quantification of certain significant characteristics of Grid QoS as well as maximization of cost-performance of the system, grid resource selection optimization protocol is produced on the basis of Simulated Annealing Genetic Algorithm (SAGA): QoS-aware SAGA, as well as the flow of the protocol is presented by Ning et al. [43].

Xue et al. [44] proposed a Hybrid Clonal Selection Genetic Algorithm (HCSGA) for solving job scheduling problem. A new group of individuals is selected through clone, and then crossover/selection independently generates individuals respectively. HCSGA consists of characteristics as rapid convergence, good global search capacity.

Omara & Arafa [45] suggested critical path genetic algorithm (CPGA) as well as task duplication genetic algorithm (TDGA); both alter the typical genetic algorithm to enhance efficacy. Two greedy models are appended to genetic algorithms such that wait timings for jobs to begin and finally makespan is decreased.

The chaos-genetic algorithm by Gharonifard et al. [46] is a genetic algorithm for resolving issue of dependent jobs scheduling, to valueate QoS where chaos parameters are utilized than arbitrarily giving original population. The merging of the

benefits of genetic algorithms and chaos parameters to explore search space avoids premature convergence in algorithm and provides solutions rapidly, with quicker convergence.

Integer Genetic Algorithm (IGA) [47] is a GA to solve dependent tasks scheduling which concurrently regards three quality of service variables: time, cost as well as dependability. As the variables are conflicting, they are not capable of being concurrently optimized because enhancement in one decreases quality in the next. Weights are designated arbitrarily or by the user to every variable.

For reducing repetition of generations in Genetic Algorithm, Delavar et al. [48] suggested a novel scheduling method for attaining greater speed as well as for decreasing communications cost.

Garg et al. [49] presented a meta-broker on utility grids which schedules multiple jobs. A Linear Programming (LP)/integer programming model is presented to schedule user tasks to several resources. The capability of LP and GA was combined with LP-driven GA algorithm which aims the optimal meta-scheduling that minimizes the overall cost of every user with negligible time overhead.

Grid enables the usage of global computational infrastructure for users to use the services over the Internet. A resilient multi-objective scheduling protocol is needed for optimizing workflow grid execution. Grid scheduling's goal is the delivery of QoS to grid users as well as for raising resource usage. Three conflicting goals such as execution time, overall costs as well as reliability are taken into consideration by Radha et al. [50]. GA incorporating ACO is suggested for scheduling grids. The suggested GA with local search demonstrates its efficacy in grid scheduling.

The limitations of GA were discussed by Le et al. [51]. It has a restricted range of movement; and this decreases the probability of being forced into local optima. Nonetheless, it is also slow in finding optimal solutions because of complexity in management of population movement.

4.5. Particle Swarm Optimization Based Algorithms

A scheduling strategy using PSO algorithm which uses position and velocity vector instead of real vector was suggested by Abraham et al. [52]. The protocol aims at completing the task at minimum time span and also efficient resource utilization

Hu et al. [53] presented a protocol: Hybridized Particle Swarm Optimization Algorithm (HPSOA) for resolving dynamic web service selection with QoS global optimum in grid workflow. The core of the protocol is that the issue of dynamic web services selection with QoS global optimum is modified into a multiobjective service composition optimization with quality of service restrictions. Crossover as well as mutation operators in GA are introduced here for forming a fused protocol known

as HPSOA for solving the quality of service global optimum issue. Analyses as well as outcomes of experiments demonstrate the viability as well as efficacy of the protocol.

Zhang et al. [54] resolves task scheduling issues through the utilization of PSO alongside SPV rule taken from arbitrary key representations. SPC rules may transform continuous position values into discrete permutations in PSO. Simulations reveal that PSO outperforms GA in big scale optimizing issues.

The combination of GELS algorithm with PSO was proposed by Barzegar et al. [55] for grid scheduling. The job which cannot complete in a particular resource within dead line can be switched to another resource by using the proposed objective function. This work aims at improving QOS parameters.

Zheng et al. [56] proposed an allocation protocol on the basis of improved PSO for solving the issue of grid resource allocation for tasks. The protocol introduced crossover, mutation as well as selection operators of GA to PSO. It efficiently alleviates the issue of obtaining local optima through PSO and finds global optimal value in the search space. The procedure is simplistic and requires few variables, obviating non-required approximation of real numbers as well as increases convergence rates. After searching of particles in every sub-swarm, optimum setting for grid resource allotment was yielded. Simulations revealed the effectiveness as well as viability of the protocol and attained improved results in grid resources allotment.

A scheduling strategy using PSO algorithm which uses position and velocity vector instead of real vector was suggested in [57]. The algorithm aims at completing the task at minimum time span and also efficient resource utilization

PSO is utilized for task scheduling alongside two heuristic models: LFT as well as BPR by Chen et al. [58]. This is used for deciding task priorities in resource queues

Karimi & Motameni [59] addressed the scheduling issue of independent jobs on computation grids. A Hybridized Discrete PSO (HDPSO) as well as Min-min protocol is suggested for reducing total execution time of tasks.

Garg & Singh [60] suggested the designing as well as execution of Hierarchical Discrete PSO (H-DPSO) for dependent tasks scheduling in grids. In HDPSO, particles are ordered in dynamic hierarchies wherein good particles higher in hierarchy have greater influence on the swarm. Bi-objective variant of the issue was considered for minimizing makespan as well as overall cost concurrently as optimization conditions. HDPSO based scheduler was validated through various application job graphs. Simulations revealed that HDPSO based scheduling is extremely feasible as well as efficient in grid computations.

The limitations of PSO were discussed by Kang et al [61], and Dian et al.[62]. PSO reduces convergence speeds when they are near optimum solutions. This is due to PSO applying linear decrease of inertia weight. Application of linear decreasing inertia weight impacts search capacities at the end or run even if global search capability is required for escaping from local optima in certain situations. Moreover, PSO suffers from partial optimism. The issue impacts PSO speed as well as direction. The drawbacks of PSO impacted performance of PSO in the procedure of task scheduling in computation grids as standard PSO yields adequate however suboptimal schedules with regard to makespan.

5. OTHER OPTIMIZATION ALGORITHMS

The scheduler suggested by Izakian et al. [63] aims to decrease both makespan as well as flowtime. It focuses on concurrently minimizing makespan as well as flow time. It utilizes matrices wherein all columns represent jobs' resources allocation while all rows denote jobs allotted to resources.

The group leaders' optimization algorithm (GLOA) by Pooranian et al. [64], use the new evaluation (distributed) algorithm to resolve issue of scheduling independent jobs in grid computations. The algorithm owes its inspiration to the impact of leaders in social aggregations. Outcomes of GLOA were contrasted with GA, SA, GGA, and GSA. The comparison shows that the run time and makespan is lesser than other AI methods.

For addressing the problem of simultaneous consideration of both types of tasks, a hybridized Job Scheduling (HJS) scheme is suggested by Mansouri [65]. HJS protocol takes into consideration both data as well as computation resource availability of network as well as related requisites of all jobs for determination of a value known as W to jobs. Through this value, the significance of the two aspects for every task is defined and task is then designated to available resource. Simulations with OptorS improve that HJS considerably performs better than already present protocols in literature when quantity of tasks rises.

Selvi & Manimegalai [66] investigated on implementing Multiobjective Variable Neighborhood Search (MVNS) protocol for scheduling independent tasks on computation grid is carried out. The performance of the suggested protocol was validated with Min-Min, Simulated Annealing (SA) and Greedy Randomized Adaptive Search Procedure (GRASP) algorithm. Simulations prove that MVNS generally outperforms other metaheuristics methods.

6. CONCLUSION

As an NP complete issue, grid scheduling is hard to resolve through traditional protocols. Performance of metaheuristics for job scheduling in grid computation, owing their inspiration to nature was studied in the literature and the performance of

GA, SA, ACO as well as PSO were evaluated. This paper presented an extensive literature review about the state of art for grid scheduling strategies. It focused on conventional methods used in grid scheduling with slight modifications and their limitations. Especially Meta-heuristics task scheduling inspired from foraging nature of swarms was also reviewed.

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