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A Comprehensive Study of Various Metaheuristic Based Parallel Job Scheduling Techniques With Different Constraints.

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Abstract— Scheduling techniques play a prominent role in parallel computing environment to reduce the waiting time of users. Parallel computing provides an incredible amount of resources for user's on-demand. Therefore, it has become more challenging to schedule the resources in an efficient manner. It has been observed that scheduling is NP-Hard in nature so in order to solve this, meta-heuristic techniques are used for optimal solution. This paper has exhibited a comprehensive review on different scheduling algorithms in the perspective of scheduling metrics such as Execution cost, response time, Makespan, Energy Consumption, Resource utilization are presented. Additionally, classification of meta-heuristic techniques such as GA, PSO, ACO, DA etc. and various constraints designed for parallel computing environment have also been discussed.

***Keywords*—**ParallelComputing,Scheduling,Meta-heuristics,Deadline,ReliabilityConstraint.

I. INTRODUCTION

A. Parallel computing

Parallel computing is a form of computation in which many calculations or executions of processes are carried out simultaneously. Parallel computing is one of the most promising approaches for meeting the increased computational requirements that have introduced a number of problems. the term parallel computing refers to the simultaneous use of multiple resources to solve computational problems in order to reduce completion time [1]. Larger problems are often divided into smaller parts which then solved concurrently. The parallel processing is the ability to take out multiple operations or task simultaneously.

B. Jobs:

The job refers to a parallel program composed of several threads, give in to the system for its execution. Each job is consisting of two parts: its length defines execution time of a job and size denotes the number of threads.

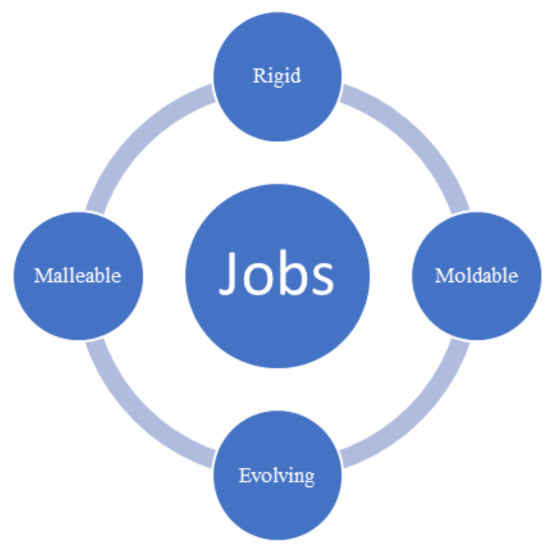

Figure 1. Types of job

1. **Rigid** - The user specified the number of processors made available to the job and is external to the scheduler.
2. **Moldable** - The scheduler determined the number of processors assigned to the job but within certain constraints.
3. **Evolving** - In evolving type of job, the number of processors is different in different phases. The processor assigned to the job may change during execution in response to job requesting.

4. **Malleable -** The number of processors allocated to the job may change during execution at the discretion of the scheduler.

The rest of the paper is organized as follows, Section I contains the introduction of parallel computing and different types of parallel jobs, Section II describes the basic concept of scheduling in the parallel environment, Section III contain Metaheuristic techniques for job scheduling, Section IV contain Scheduling Parameters and the comparative analysis of scheduling techniques with different constraints section V explain the conclusion of the paper.

II. BASIC SCHEDULING IN PARALLEL ENVIRONMENT

Scheduling plays a significant role in the parallel computing environment to assign resources to end users. Scheduling examines which jobs could be processed through which machines in what order within a certain time period [3]. Scheduling is considered as a process to schedule all the tasks on the given number of available processors without violating precedence constraints so as to achieve a desired quality of service. The objective of scheduling in parallel systems is to maximize the efficiency, maximizing system throughput, balance the load of resources, minimize execution time i.e. completion time, minimizing cost on the user side.

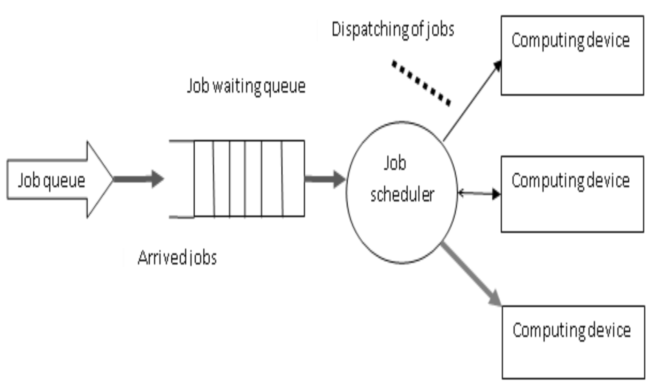

Figure 2. Scheduling model

In the fig 2, the user submitted the jobs into a system where job scheduler assigns the job which is placed in waiting queue to a computing device. A good scheduling technique is designed to schedule the jobs in order to achieve minimum execution time with Quality-of-Service requirements of the user. Most of the existing heuristics focused on minimizing the response time, optimal span and completion time of tasks without considering other constraints such as reliability, Deadline or budget. System reliability is more important than other performance metrics. Furthermore, energy consumption and system reliability are two conflicting objectives early and reliable execution of jobs is another essential factor from user's point of view, but it incurs more cost.

III. METAHEURISTIC TECHNIQUES FOR JOB SCHEDULING

Metaheuristics are the approximate methods that use search procedure for preserving the global view of the solution space and are flexible in handling different types of constraints and objectives. They provide an efficient way of moving quickly towards an optimal or near optimal solution. Metaheuristics are of various types based on search strategy single solution based, nature inspired. some of them are as follows:

A. Genetic Algorithm(GA)

A Genetic algorithm is an optimization technique introduced by Johan Henry Holland in 1962 based on Darwin's theory of survival of the fittest. Genetic algorithm (GA) is used to produce high -quality solutions for search and optimize the problems using the concepts of mutation, crossover, and selection [4]. In GA, initially a set of candidate solutions is taken and iteration is done to refine them by alternating and selecting the good solution for next generation. The selection of candidate solution is done on the basis of the fitness function to evaluate quality. The five phases of the genetic algorithm are initial population, fitness function, selection, crossover, and mutation.

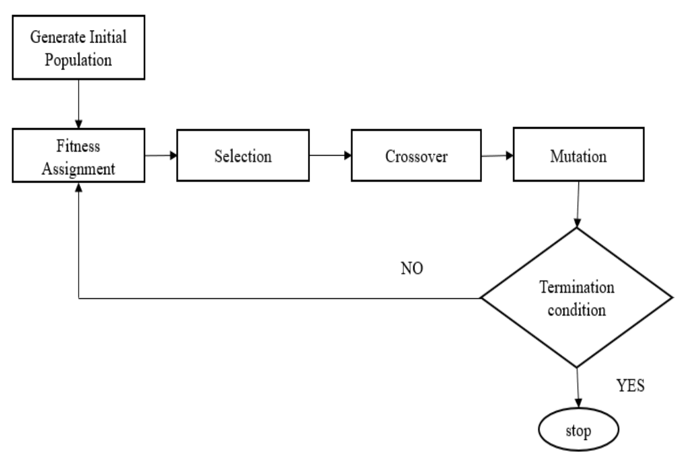

Figure 3. Flowchart of Genetic Algorithm

B. Particle Swarm Optimization(PSO)

Particle swarm optimization is an optimization technique introduced by Kennedy and Dr Eberhart in (1995) used for solving various nonlinear functions. It is inspired by social behaviour of animals such as schools of fish, a flock of birds etc. It moves solutions through search space. PSO is very simple and easy to implement and computationally efficient.

In PSO, a population of random solutions known as particles is Initialized. Each particle must keep track of its coordinates in search space for the best solution. Each particle is updated by following two "best" values i.e. best position p_{best} and velocity value in every iteration. p_{best} defines the personnel best position of a particle having its co-ordinate in the solution space with the best solution achieved by the particle [5]. Velocity value indicates how much the value has changed. PSO keeps track of three global variables namely target value, global best position g_{best} and the stopping value indicating when the algorithm should terminate. g_{best} is the global best value obtained so far by any particle in the neighborhood of that particle.

C. Ant Colony Optimization

In ACO, several artificial ants' help in building solution for optimization problems and by using a communication scheme, they exchange the information. They find the shortest paths as the moving ants lay pheromone on the ground so that when another ant encounters it, it can detect it and decide to follow the trail. As a result, the emerged collective behavior is an indication that if a number of ants choose a particular path, then the probability of other ants following the same path increases [35].

Procedure ACO Metaheuristic
Start

- Construct Ants Solutions
- Calculate the fitness function for every ant.
- For each ant, determine the best position.
- Determine the best global ant.
- Update Pheromones.

End

Figure 4. Pseudocode for ACO [7].

D. Cuckoo Search(CS)

Cuckoo search is a heuristic search algorithm proposed by Yang in 2009 for solving the continuous optimization problems algorithm. The algorithm is inspired from the breeding process of cuckoo species which lay their eggs in the nest of other host birds. In this algorithm, female cuckoos imitate the colors and patterns of eggs of a few chosen host species [6]. Host birds either throw their eggs away or destroy their nests if they find that eggs do not belong to them.

The detailed steps are listed as follows: -

a) Initialization Cuckoo with a set of eggs.

b) Lay eggs in different nests.

c) Some of the eggs are defected and killed.

d) If population generated is significantly less than the threshold value then checks for the survival of eggs in a nest and obtain profit values.

e) Otherwise,in worst area kill cuckoo.

f) if stop condition is satisfied then obtain maximize solution otherwise go to step 2.

E. Dragonfly Algorithm

Dragonfly algorithm is a multi-objective optimization technique inspired by the natural behavior of dragonflies, mainly depends upon exploitation and exploration. For navigating, food searching and survival from enemies the dragonflies creates sub-warms which are useful for convergence towards Pareto-optimal solutions. The Dragonfly algorithm is used to solve various single objective, bi-objective and multi-objective optimization techniques. Furthermore, this optimization algorithm is well suited for designing, modeling or generating optimal solutions [8].

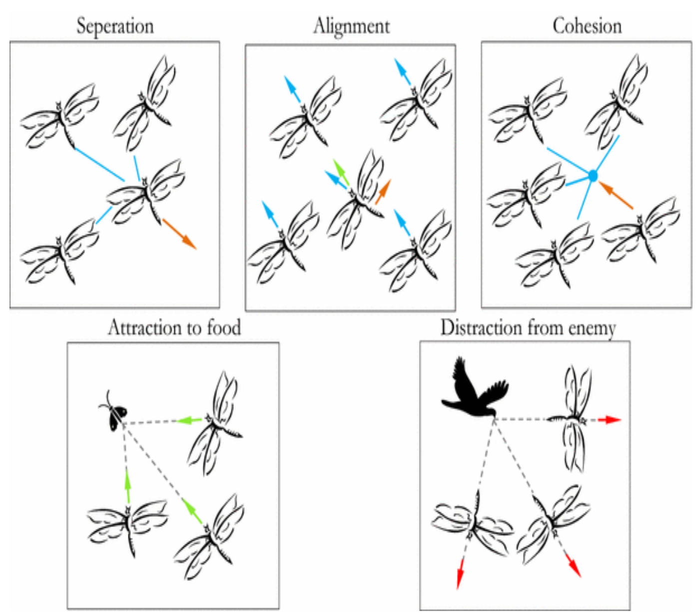

Figure 5. Behaviours' of individual in swarms [8]

IV. SCHEDULING PARAMETERS

Constraints are the restrictions imposed by the specific characteristics of the environment as well as available resources. These restraints must be fulfilled in order to obtain a certainly acceptable solution. Generally, these constraints describe dependencies among parameters(constants)and decision variables involved in the problem. Following are the various types of constraints: -

A. Deadline constraint: - Deadline of a job refers to an instant of time through which a job must be completed. When a job completes before or at the given time, it means the deadline is satisfied

B. Reliability constraint
Reliability measures the Probability that the system or its subparts will work. Generally, the reliability of a parallel system is comparatively higher than single system component as a single system will continue to work as long as at least one component works.

C. Budget constraint: -A budget is the maximum expanse of economic resource a user's wish to pay to perform their work.

The abbreviations used in the Table 1 are
D=Deadline**, R**=Reliability**, E**=Energy**, B**=Budget.

Table1. A comparative analysis of scheduling Techniques with different constraints.

Serial No	Year	Technique	Metric(s)	Objective	Constraints				Job type	Environment
					D	*R*	*E*	*B*		
[1]	2017	Cost Effective Deadline Aware [9]	Execution time and cost	Single objective	√	×	×	×	Dependent tasks	Workflow
[2]	2017	Maximizing reliability energy constraint algorithm [10]	Frequency and energy value	Bi-objective	×	√	√	×	Independent jobs	Heterogeneous distributed systems
[3]	2017	Reliability aware power management algorithm [11]	Frequency, slack time	Multi-objective	√	√	√	×	Real-time Jobs	————
[4]	2017	M/D/1 queue. [12]	Response time, Service level agreement, Mean latency	Single objective	√	×	×	×	Rigid jobs	Heterogeneous cluster
[5]	2017	Mixed-integer linear programming [13]	Make span and Feasibility	Bi-objective	√	√	×	×	Independent jobs	Heterogeneous multi-core
[6]	2017	Algorithm Energy-Efficient Replication [14]	Coverage factor, resource utilization.	Single-objective	×	√	×	×	Real-time tasks	Multi-core system
[7]	2017	Hybrid Particle Swarm Optimization [15]	Makespan and cost	Bi-objective	√	×	×	√	Dependent tasks	Cloud environment
[8]	2017	Pseudo-polynomial time dynamic programming, MILP Branch and bound [16]	Feasibility	Single-objective	√	×	×	×	————	——

[9]	2017	Coevolutionary genetic algorithm [17]	Execution cost and Makespan	Single-objective	√	×	×	×	Dependent tasks	Cloud environment
[10]	2017	Deadline-Budget Workflow Scheduling [18]	Makespan, cost	Bi-objective	√	×	×	√	Independent jobs	Cloud environment
[11]	2017	Replication-based scheduling for Maximizing System Reliability [19]	Reliability threshold	Single-objective	×	√	×	×	Workflow jobs	Heterogeneous Computing Systems
[12]	2017	Enough replication for redundancy minimization algorithm and Heuristic replication for redundancy minimization [20]	Redundancy	Single-objective	×	√	×	×	Parallel jobs	Heterogeneous service-oriented
[13]	2017	Bi-objective genetic algorithm [21]	Schedule length	Bi-objective	×	√	√	×	————	Heterogeneous Systems
[14]	2017	cluster combining algorithm [22]	Execution cost, Makespan and resource utilization	Single objective	√	×	×	×	cluster	multicore IaaS cloud
[15]	2017	Pro Lis and L-ACO algorithm [23]	Execution cost	Single objective	√	×	×	×	Dependent tasks	Cloud environment
[16]	2017	Hybrid genetic algorithm [24]	Execution time	Single objective	√	×	×	×	Workflow jobs	Cloud environment
[17]	2017	Energy-efficient fault-tolerant scheduling with a reliability goal algorithm(EFSRG)[25]	Energy consumption	Bi-objective	×	√	√	×	Parallel jobs	heterogeneous distributed embedded system.
[18]	2017	Augmented Shuffled Frog Leaping Algorithm [26]	Execution time Execution cost, Makespan Resource utilization	Single objective	√	×	×	×	Dependent tasks	Workflow
[19]	2016	subtask partition algorithm and Subtask Allocation algorithm. [27]	Completion time	Single objective	√	×	×	×	Sequential dependent jobs	Cloud Environment
[20]	2016	WRF model [28]	Execution time, system load, assigned resources	Single objective	√	×	×	×	Parallel jobs	Meteorological cloud
[21]	2016	Bat algorithm [29]	Execution time and cost	Bi-objective	×	√	×	√	Workflow tasks	Cloud environment
[22]	2016	Elastic resource provisioning and task scheduling mechanism [30]	Execution time and task failure rate	Bi-objective	√	×	×	√	Workflow jobs	Cloud environment
[23]	2016		Execution cost and		√	×	√	×	Independent	Cloud environment

		Green Cloud Scheduling Model [31]	energy efficiency	Bi-objective					tasks	
[24]	2015	Reliability maximizing energy constrained [32]	Energy Consumption Ratio, Makespan,	Bi-objective	×	√	√	×	Independent jobs	Heterogeneous cluster
[25]	2015	Constrained Workflow **S**cheduling algorithm. [33]	Make span and Execution cost	Multi-objective	√	√	×	√	Independent jobs	Grid environment
[26]	2015	Bi-Criteria Priority based Particle Swarm Optimization [34]	Execution cost	Bi-objective	√	×	×	√	Dependent tasks	Cloud environment
[27]	2015	Improved Ant colony optimization [35]	Makespan and Execution cost,	Single-objective	√	×	×	×	Independent jobs	Cloud environment
[28]	2015	Tabu search [36]	Schedule length	Single-objective	×	√	×	×	_________	Distributed Environment
[29]	2014	Reliability optimized resource scheduling algorithm [37]	Cost, Resource Utilization,	multi-objective	√	√	×	√	Independent jobs	Grid environment
[30]	2014	Heuristic-based Genetic Algorithms [38]	Execution cost, Time interval	Single-objective	√	×	×	×	Independent jobs	Cloud Environment

V. CONCLUSION

In this paper, various meta-heuristics techniques are discussed for job scheduling in parallel environment. A detailed review of existing constraints with comparison of scheduling techniques for different parameters and ratio of quality of service (QoS) parameters have been presented. Review of existing techniques has proven that multiple constraints based parallel job scheduling techniques can improve the computational speed of meta-heuristic-based job scheduling techniques. However, it is not easy to evaluate the best meta-heuristic-based job scheduling technique without considering the various constraints.

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