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A Survey on Scheduling of Parallel Programs in Heterogeneous System

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Abstract—**In this survey paper we can make use of the heterogeneous system by mapping the tasks and schedule them on different processors so that their finish time can be reduced. Total finish time is time which includes individual runtime of programs and their communication cost among programs. The optimal scheduling of parallel programs is considered as NP-complete problem. A major issue in the operation of parallel computing systems is that of scheduling, which is an important problem in other areas such as manufacturing, process control, economics and operation research .Heterogeneity in parallel systems introduces an additional degree of complexity to the scheduling problem. The complexity of the problem increase when task scheduling is to be done in a heterogeneous environment, where the processors in the network may not be identical and take different amounts of time to execute the same task. Quite a few methods have been used to solve this problem. In this paper we are studying about different scheduling techniques which help to reduce time complexity as well as the over all cost of the process and their fruitfulness.**

Keywords— **Genetic Algorithms, Program Scheduling, Heterogeneous Multiprocessor System, Total Finish Time.**

I. INTRODUCTION

Heterogeneous systems become fashionable in both client and cloud. A parallel program can incur operations on various processing resources such as CPU, GPU, and vector processor units. Scheduling a parallel program is a crucial step in inefficiently harnessing the computing power of a heterogeneous computing system. Obtaining a lowest finish time schedule for a set of precedence constrained tasks is a well known NP-complete problem. Heterogeneity in parallel systems introduces an additional degree of complexity to the scheduling problem, i.e. changeable speed of processors. Research in task scheduling algorithm is a challenging problem for high-performance computing; mainly achieving a superior make span is a key issue in design and development of heterogeneous algorithm. Optimal scheduling of parallel tasks with some precedence relationship, onto a parallel machine is known to be NP-complete. The complexity of the problem increase when task scheduling is to be done in a heterogeneous environment, where the processors in the network may not be identical and take different amounts of time to execute the same task.

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II. TASK SCEHDULING IN HETEROGENOUS SYSTEM

To exploit a heterogeneous computing (HC) environment, an application task may be decomposed into subtasks that have data dependencies. Subtask matching and scheduling consists of assigning subtasks to machines, ordering subtask execution for each machine, and ordering inter machine data transfers. The goal is to achieve the minimal completion time for the task. A heuristic approach based on a genetic algorithm is developed to do matching and scheduling in HC environments.

Many parallel applications consist of multiple computational components. While the execution of some of these components or tasks depends on the completion of other tasks, others can be executed at the same time, which increases parallelism of the problem. The task scheduling problem is the problem of assigning the tasks in the system in a manner that will optimize the overall performance of the application, while assuring the correctness of the result. The task scheduling problem can be modeled as a weighted directed acyclic graph (DAG). A vertex represents a task, and its weight the size of the task computation. An arc represents the communication among two tasks, and its weight represents the communication cost. The directed edge shows the dependency between two tasks.

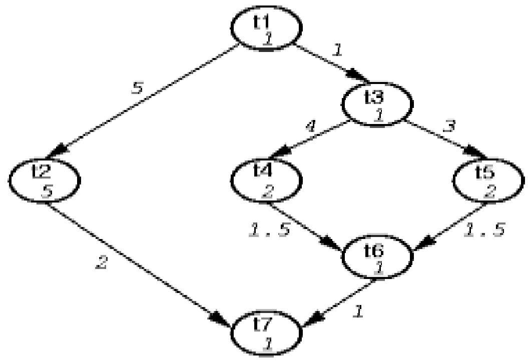

Fig. 1 Example Computation DAG

The primary goal of task scheduling is to schedule tasks on processors and minimize the make span of the schedule, i.e., the completion time of the last task relative to the start time of the first task. The output of the problem is an assignment of tasks to processors.

III. VARIOUS TASK SCHEDULING TECHNIQUES

Unfortunately, standard task scheduling is NP-complete, even for the unit task size and unit communication cost. However, various heuristic methods have been proposed that obtain suboptimal solutions (schedules) in polynomial time.

- Wave Front Method (WFM)
- Critical Path Merge (CPM)
- Heavy Edge Merge (HEM)
- Dominant Sequence Clustering (DSC)

A. *Wave Front Method*

The wave fronts of the graph are determined according to the level of the vertices in a breadth-first-search traversal of the DAG. The vertices in each wave front are independent from each other, and are all assigned to different processors. Following is an example of applying Wave Front Method.

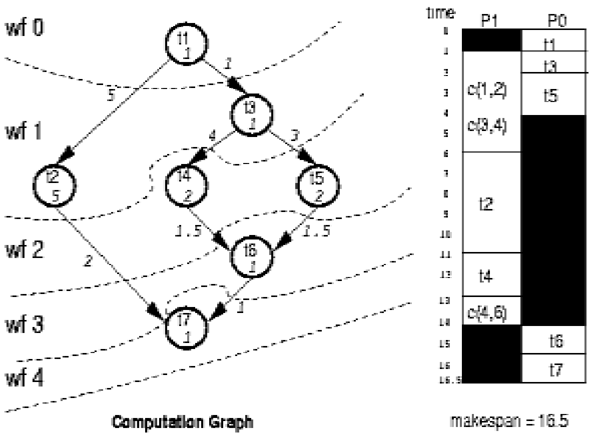

Fig. 2 Wave front method

B. *Critical Path Merge (CPM)*

A critical path in a DAG is a maximum weight root to leaf path (the path weight is the summation of all vertex and edge weights on the path). CPM computes the critical path, clusters all tasks in it, assigns them to the same processor, and removes them from the graph. This process is iterated until all tasks are scheduled.

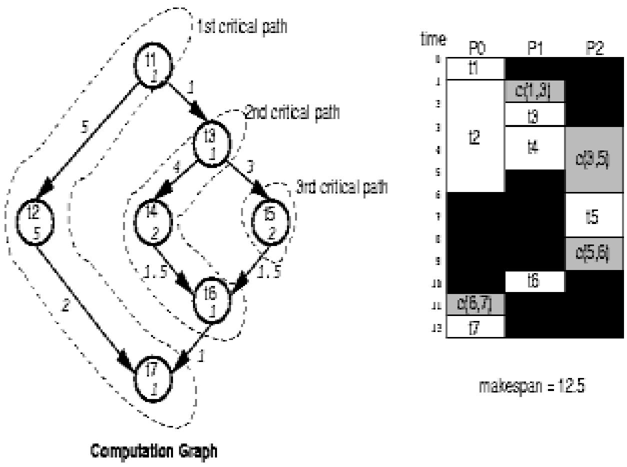

Fig.3 CPM

C. *Heavy Edge Merge (HEM)*

Heavy Edge Merge works by iteratively clustering vertices (tasks) along edges with non-increasing weights. During an initialization stage, the edges are sorted in non-increasing order by edge weight, one task is assigned to each (virtual) processor, and the make span of this assignment is computed. Then, all edges are processed in sorted order. For each edge, the makes pan resulting from merging the tasks associated with the endpoints (perhaps clusters themselves) is computed. If the make span increases, then the merge is not performed.

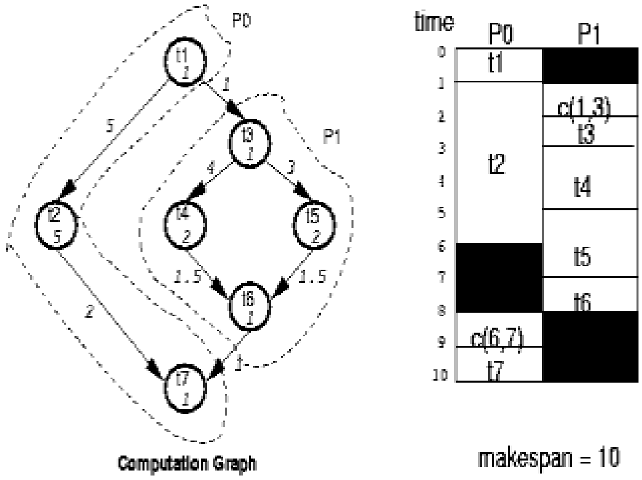

Fig. 4 HEM

D. *Dominant Sequence Clustering (DSC)*

DSC works by iteratively identifying, and scheduling, so-called dominant sequence tasks which are defined as follows. An unscheduled task is called *free* if all of its predecessors are already scheduled. A dominant sequence task is the highest priority free task.. The process is repeated until all tasks are scheduled.

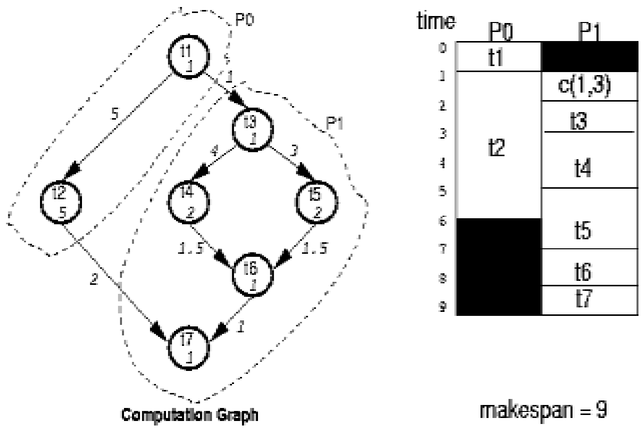

Fig.5 DSC

IV. LITERATURE SURVEY

The impressive proliferation in the use of parallel processor systems these days in a great variety of applications is the result of many breakthroughs over the last two decades. These breakthroughs span a wide range of specialties, such as device technology, computer architectures, theory, and software tools. However, there remain many problems that need to be addressed which will keep the research community busy for years to come [1].

A major issue in the operation of parallel computing systems is that of scheduling, which is an important problem in other areas such as manufacturing, process control, economics, operation research, to name a few [2,3]. To schedule is to simply allocate a set of tasks or jobs to resources such that the optimum performance is obtained. If these tasks are not interdependent the problem is known as task allocation. In a parallel processor system, one would expect a linear improvement with the increase in the number of processors used [8].

Optimal scheduling of tasks of a directed acyclic graph (DAG) onto a set of processors is a strong NP-hard problem. In this paper we present a scheduling scheme called TDS to schedule tasks of a DAG onto a heterogeneous system. This models a network of workstations, with processors of varying computing power. The primary objective of this scheme is to minimize schedule length and scheduling time itself. The existing task duplication based scheduling scheme is primarily done for totally homogeneous systems. In which he compare the performance of this algorithm with an existing scheduling scheme for heterogeneous processors called BIL. In initial simulations TDS has been observed to generate scheduling lengths shorter than that of BIL, for communication-to-computation cost ratios (CCR) of 0.2 to 1. Moreover TDS is far more superior to BIL as far as scheduling time is concerned [17].

A major issue in the operation of parallel computing systems is that of scheduling, which is an important problem in other areas such as manufacturing, process control, economics and operation research. An alternative solution was presented to the task scheduling problem. There are many methods which are currently used to schedule tasks onto parallel processor machines. A heuristic is an algorithm which is guaranteed to find a near optimal solution in less than polynomial time. It searches a path in the solution space at the expense of ignoring other possible paths. A framework for using GAs to solve scheduling problems was proposed and the results were compared with other well-known heuristics. The conditions under which a GA performs best were highlighted. It was shown that a GA performs very well when combined with heuristics that can be used to generate the initial population. GAs can be employed to design new and more generic techniques to solve scheduling problems and any advances made in this direction can be extended to other classes of problems that are NP-complete. The research community busy for years to come [1].

Efficient application scheduling is critical for achieving high performance in heterogeneous computing environments. The application scheduling problem has been shown to be NP-complete in general cases as well as in several restricted cases. Because of its key importance, this problem has been extensively studied and various algorithms have been proposed in the literatures which are mainly for systems with homogeneous processors. Although there are a few algorithms in the literature for heterogeneous processors, they usually require significantly high scheduling costs and they may not deliver good quality schedules with lower costs. In this paper, they present two novel scheduling algorithms for a bounded number of heterogeneous processors with an objective to simultaneously meet high performance and fast scheduling time, which are called the Heterogeneous Earliest-Finish-Time (HEFT) algorithm and the Critical-Path-on-a-Processor (CPOP) algorithm. The HEFT algorithm selects the task with the highest upward rank value at each step and assigns the selected task to the processor, which minimizes its earliest finish time with an insertion-based approach. On the other hand, the CPOP algorithm uses the summation of upward and downward rank values for prioritizing tasks. Another difference is in the processor selection phase, which schedules the critical tasks onto the processor that minimizes the total execution time of the critical tasks. In order to provide a robust and unbiased comparison with the related work, a parametric graph generator was designed to generate weighted directed acyclic graphs with various characteristics. The comparison study, based on both randomly generated graphs and the graphs of some real applications, shows that our scheduling algorithms significantly surpass previous approaches in terms of both quality and cost of schedules, which are mainly presented with schedule length ratio, speedup, frequency of best results, and average scheduling time metrics [19].

The node duplication (NGA) based technique for deterministic heterogeneous multiprocessor system which comprises the communication cost in precedence to minimize the total finish time and improve the throughput of system. During comparison with other algorithms our NGA performance is best with finish time. But Node duplication introduces more computation load into the parallel system in order to decrease the cost of crucial communication. The main factor here is which task should be duplicated to reduce the overall time. In future we can attempt to implement this proposed NGA method also for the problem of nondeterministic heterogeneous multiprocessor used for real time, where some benchmarks can be configured during runtime. Here we can see in the above charts for time analysis and performance analysis NGA is compared with GA, FCFS, Priority and List scheduler with start time minimization shows NGA with 64.1% and GA of 55.55% and List scheduling of 52.08 and 41.033% of FCFS and 39.033 of Priority Scheduling. The scheduling problem considered in this paper is bringing out the optimal mapping of tasks and their efficiently possible execution stream on multiprocessor system configuration. Several solutions and heuristics are proposed to solve this problem. We exhibit efficiency of Node duplication GA based technique by comparing against some of the existing deterministic scheduling techniques for minimizing inter processor traffic communication[15].

Recently (Proc. ACM Int. Conf. on Super computing, 1999), he presented two very low-cost approaches to compile-time list scheduling where the tasks' priorities are computed statically or dynamically. For homogeneous systems, these two algorithms, called FCP (Fast Critical Path) and FLB (Fast Load Balancing), respectively, have been shown to yield a performance equivalent to other much more costly algorithms, such as MCP and ETF (Earliest Task First). In this paper, we present modified versions of FCP and FLB targeted at heterogeneous systems. he show that the modified versions yield a good overall performance, which is generally comparable to algorithms specifically designed for heterogeneous systems, such as HEFT (Heterogeneous Earliest Finish Time) or ERT (which are versions of MCP and ETF, respectively, using the task's completion time as the task priority). There are a few cases, mainly for irregular problems and large processor speed variance, where FCP's and FLB's performances drop to 32% and 63%, respectively. Considering the good overall performance and their very low cost, however, FCP and FLB are interesting options for scheduling very large problems on heterogeneous systems [18].

V. CONCLUSION & FURTHER DEVELOPMENT

In this paper, we have analyzed and detail studied about how the scheduling of different parallel processes is done and as well as the total time execution of the task by the heterogeneous processor and also studied, the communication time by this processor to communicate with others. In the further development the Genetic Algorithm approach will be applying for these issues. Which will reduce the execution time of the processes as well as their communication time and also try to decreases the total cost.

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