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Task Scheduling & Energy Conservation Techniques for Multiprocessor Computing Systems

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ABSTRACT

The need for robust power-performance has enabled designers to make right direction in designing and developing the energy efficient scheduling techniques, as there is a strong need of scheduling algorithms which lowers the energy consumption and yet attain good schedules. Over the years, there has been a lot of research in scheduling the tasks for minimal schedule length and low time complexity, still little work has addressed the issues of both makespan and energy conservation together, especially for heterogeneous distributed computing system. Existing scheduling strategies for high performance computing systems provide versatile, low cost performance at the expense of huge energy consumption. This paper addresses the "state of the art" in energy aware scheduling techniques for dependent tasks in multiprocessor systems to reduce the overall makespan and reduction in energy consumption.

Keywords: Energy aware scheduling, Heterogeneous systems, Power management techniques, Task Scheduling.

1. INTRODUCTION

The heterogeneous distributed computing system (HDCS) [1] is a suite of autonomous dissimilar processors interconnected by high-speed networks, thereby promising fast processing of computationally intensive applications with diverse computing needs. High-end distributed systems use tens of thousands of power-hungry commercial components to attain powerful performance capabilities at low cost. The energy consumption of distributed computing systems has increased drastically. Increased energy consumption has created severe economic, ecological, and technical problems. As a consequence, high energy consumption leads to huge cost of electricity bill, huge generation of carbon dioxide emissions and has impact on the environmental issues. Further, high energy consumption also requires expensive packaging and cooling techniques, as insufficient cooling leads to high operating temperature that tends to exacerbate several silicon failures. Such systems consume around 0.5% of world's total power usage [4], [5] and if the current demand continues, it is projected to quadruple by 2020. Energy aware scheduling strategies is somewhat a new dimension added to the scheduling problem with the objective to minimize energy consumption with minimal performance loss. Therefore, reducing energy consumption and finding an optimal makespan together for these computing platforms is highly desirable.

The rest of the paper is structured as follows. Section 1 introduces the problem and need of proposed work. In Section 2, task scheduling problem and various scheduling heuristics approaches are discussed. In Section 3, the general scheduling model is discussed. Section 4 describes existing power management techniques. In Section 5, work related to energy conscious scheduling based on list, clustering and duplication based heuristics is presented. Section 6 concludes the paper and future scope of work.

2. TASK SCHEDULING PROBLEM & HEURISTICS

In distributed computing environment, an application is usually decomposed into several independent and/or interdependent sets of cooperating tasks and then scheduled onto a set of available processors for parallel execution. These sets of tasks are usually represented by a directed acyclic graph (DAG) to be scheduled onto the processors that can be homogenous or heterogeneous. The task scheduling problem has been proven to be NP-complete [35]. Task scheduling algorithms are typically classified as: static and dynamic scheduling. In static scheduling [14], [15], tasks are allocated to the processors in advance at compile time and allocation is done only when all the resources are available. This has the advantage of simplicity and low run-time overhead though at the cost of low resource utilization. In dynamic scheduling [31], [32] the tasks are allocated to the processors at run time as soon as the resources are available with the advantage of good CPU utilization though with increased run time overhead. As a result of which sophisticated scheduling techniques cannot be applied. Static task scheduling heuristics are broadly classified as: list, cluster and duplication based scheduling heuristics. Clustering heuristics are mainly proposed for homogeneous systems and the aim is to form cluster of tasks based on certain criteria. All tasks of same cluster are then scheduled on the same processor to get closer to the scheduling objectives. The task duplication-based algorithms duplicates the tasks onto one or more processors thereby reducing the communication cost, network overhead and potentially reducing the start times of waiting tasks. The duplication heuristics give shorter makespans but at the cost of increased complexity. Most scheduling heuristic algorithms are based on the list scheduling technique in which based upon certain priorities tasks are arranged in the form of a list and then scheduled onto the most suitable processor, satisfying the overall scheduling objectives.

Task scheduling problem for heterogeneous system is more complicated and demanding due to different processing and communication speeds among the processors. Architectural design of heterogeneous systems [24], [30] will be dominant in the future, as they allows for the inclusion of processors tailored specifically for the particular types of tasks to be assigned to the most suitable processor. Task scheduling algorithms reviewed have attributed to reduce the makespan with no or little consideration for energy conservation, a dominant issue to be addressed nowdays. Heterogeneous systems have been widely used for solving large scale and complex scientific and commercial applications and serve as a basis of obtaining powerful parallel and distributed systems. Topcuoglu et al. [7] have presented HEFT and CPOP scheduling algorithms for heterogonous processors. Luiz et al. [21] have developed lookahead-HEFT algorithm, which look ahead in the schedule to make scheduling decisions. Bansal et al. [18] have presented HLD algorithm for scheduling of precedence constrained tasks in heterogeneous computing system.

3. SCHEDULING MODEL

The task scheduling problem is the process of allocating a set N of n tasks to a set P of p processors without violating precedence constraints to minimize makespan and energy consumption as low as possible.

Makespan is defined as $M=\max\{AFT(n_{exit})\}$ after scheduling n tasks in a task graph is completed.

4. POWER MANAGEMENT TECHNIQUES

Power aware technologies have been deployed recently to improve power efficiency in large-scale distributed systems based on either hardware or software solutions. Dynamic power management [17] (DPM) techniques are applied at runtime (offline) when system is serving light workloads or idle. DPM at operating system level refers to the supply voltage and clock frequency (DVFS) adjustments. DVFS needs the hardware support. Recent advances in microelectronics have led to the development of processors that support dynamic power management strategies using dynamic voltage and speed scaling. In DVFS, linear reduction in the computation speed results in quadratic decrease of CPU energy consumption. Commercial processors that successfully implement dynamic voltage and speed scaling include Transmeta Crusoe, Intel Strong ARM and XScale processors, Rabbit Semiconductor Rabbit 2000, AMD Mobile Athlon processors, and IBM PowerPC 405LP. Static power management techniques [17] are applied at design time (off-line), targeting both hardware and software.

Virtualization [2] and green policies [3] are another mechanisms used to reduce the power consumption. Through virtualization, the consolidation of several virtual machines to a single physical machine (PM) can reduce the total number of active PMs and lower overall system power consumption; unused PMs can be switched to power-saving mode or even turned off. Green policy is heavily used in Grids and large scale data centers containing large pool of machines. Resource manager checks the overall workload and utilization of the computing infrastructure. When the resource manager detects that the overall utilization of the computing infrastructure is low, it switches redundant machines off. Later on, when there is a need for more computational power, it brings the switched off machines back to work again.

Other relevant survey pertaining to energy-aware scheduling and power reduction techniques can be found in [26]-[29].

5. RELATED WORK ON ENERGY CONSERVATION SCHEDULING

Over the past few decades, research efforts are mainly focused on the problem of task scheduling on algorithms running on homogenous [14], [33], [34] and heterogeneous [6]-[9] systems mainly with the objective of reducing the overall execution time of the job/s. It is only recent that research interest has focused towards efficient energy conservation scheduling of precedence constrained tasks in heterogeneous multiprocessor environment. Energy aware scheduling strategies is somewhat a new dimension added to the scheduling problem with the objective to minimize energy consumption. Wang et al. [20] have developed ETF scheduling algorithm and energy conservation routine for all non critical jobs using DVFS technique. Zong et al. [25] have discussed EAD and PEBD duplication based energy aware scheduling algorithms on homogeneous clusters. Ge et al. [13] have developed scheduling technique for power-aware clusters based on DVS and created a framework for application-level power measurement and optimization. Baskiyar and Abdel-Kader [19] have presented a power-aware scheduling algorithm for precedence-constrained tasks called Energy-Aware DAG Scheduling (EADAGS) based on DVFS. Apart from EADAGS, Zhang et al. [11] have proposed a two phase algorithm that formulates the scheduling problem as an Integer Programming problem. Lee et al. [16] have addressed the task scheduling problem on heterogeneous distributed computing systems and presented ECS algorithm and its extension ECS makespan with significant energy conservation and shorter schedules. Mishra et al. [12] have proposed both a dynamic and a static power-aware scheduling algorithm for a set of real-time tasks with precedence constraints. Gruian et al. [10] have proposed list based low energy scheduling algorithm for dependent tasks –LeneS. Cioara et al. [22] have proposed a power-aware dynamic resource consolidation algorithm that uses reinforcement learning to dynamically consolidate virtualized resources. Lee and Zomaya [23] have analyzed some power-aware heuristics for task consolidation.

6. CONCLUSION AND FUTURE SCOPE

This paper has discussed the energy aware scheduling techniques based on list, duplication and clustering based heuristic approaches to reduce the overall makespan and energy consumption as low as possible. Solutions based on DVFS are the most well-known solutions in the hardware assisted category. Further, various power reduction and power management techniques are also discussed to reduce the overall energy consumption of the system. As the energy aware scheduling on heterogeneous platform is still in its early stages, future work in this direction can aim at designing and developing efficient energy aware scheduling heuristics that will work fine, especially for heterogeneous systems for a set of random and regular benchmark task graphs with respect to different task graph characteristics.

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