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Task Allocation for Distributed Computing Systems: From Past to Present

Anju Khandelwal
Dept. of Mathematics
S. R. M. S. College of Engg. and Tech.
Bareilly (U. P.) –INDIA
dranjukhandelwal@rediffmail.com

Abstract: The objective of this paper is to present a brief survey of research work of high quality that deal with task Allocation in different fields of engineering, Science and technology. This paper covers several important areas of task allocation in distributed computing systems, significant research efforts being made all over the world. The survey provides insight into past, present and future trends of task allocation in different fields such as Communication Technology, Grid Computing, Simulated Annealing, Distributed Database Systems etc. with applications and specific problems.

Keywords: Coherent Systems, Distributed Computing Systems, Grid Computing, Task Allocation, Reliability, CCN.

I. INTRODUCTION

The computing systems have been so complex that in order to predict their performance one finds a difficult task. Mathematical modeling plays the important role for predicting the performance of the distributed computing system. Assigning tasks to processors of a computing system is called task allocation that involves the allocation of tasks to processors in such a way that some effectiveness measures are to be optimized. The problem of task allocation arises when specifying the order of executing the system tasks is not required. In other words, system tasks might interact or communicate without imposed precedence relations. In a distributed computing system made up of several processors, the interacting tasks comprising a distributed program must be assigned to the processors so as to make use of the system resources efficiently.

The task allocation in a distributed computing system find an extensive application in the facilities where large amount of data is to be processed in relatively short period of time, or where real time computations are required. Meteorology, Cryptography, Image Analysis, Signal Processing, Solar and Radar Surveillance, Simulation of VLSI circuits and Industrial process monitoring are areas of such applications. All these applications require not only very fast computation speed but also different strategies involving distributed task allocation systems, as the quality of output is proportional to the amount of real-time computations.

II. EARLY DEVELOPMENT

In 1970s, Distributed computing systems have become more and more attractive and important in recent year due to the advancement of VLSI and computer network technologies. Distributed computing systems not only provide the facility for utilizing remote computer resources or data not existing in local computer systems but also increase the throughput by provided facilities for parallel processing. Thus, the purpose of task assignment in distributed computing system is to reduce the job turnaround time and increase the throughput. This can be done by maximizing and balancing the utilization of resources while minimizing the communication between processors.

Several approaches to task assignment in distributed computing systems have been suggested [2], [3] and [31]. They can be roughly classified into three categories, namely, graph theoretic, mathematical programming and heuristic methods .The graph-theoretic method uses as a graph to represent a task, and applies the minimal-cut algorithm to the graph to get the task assignment with minimum interprocessor communication. The mathematical programming approach formulates task assignment as an optimization problem, and the heuristic method provides fast but suboptimal algorithms for task assignment, which are useful for application where an optimal solution cannot be obtained in real time [1].

In a two processor distributed computer network, maximum flow algorithm can be used to find optimal program module to processor assignments to maximize the performance of distributed programs. Stone [2] discuss the critical load factor in two processors, where load on one processor is held fixed and the load on the other is varied. In their paper stone assume that the modules of a distributed program are free to move from processor to processor in a two processor system during the course of computation. Also he extends the network flow technique of Stone [3] to prove the existence of a critical load factor for each program module.

III. THE 1980's

Chien-Chung Shen and Wen-Hsiang Tsai [1] proposed a new task assignment model for distributed computing systems, based on a graph matching approach and a more meaningful cost function for task assignment optimization. In this paper each graph match corresponds to a specific task assignment and the Cost values are defined in terms of a single unit, time, for evaluating the effectiveness of task assignment. The Minimization of cost functions is based on a so-called minimax criterion. The model proposed by them allows easy incorporation of most system constraints encountered in applications.

In a heterogeneous computing system, the tasks of an application program must be assigned to the heterogeneous processors to utilize the computational capabilities and resources of the system efficiently. However it is a difficult problem to compute an assignment of tasks to processors for which the total cost of running the program is minimized [32], [33]. Static and dynamic algorithms can be extremely efficient in homogeneous systems. If all processors are identical then the choice "to which node should we assign in the next task?" falls on the processor with the fewest outstanding jobs [4].

The rapid progress of microprocessor technology has made the distributed computing systems economically attractive for many computer applications. Perng-Yi Richard et al [5] presents a task allocation model that allocates application tasks among processors in distributed computing systems satisfying minimum inter-processor communication cost, balanced utilization of each processor and all engineering application requirements. Author presents a task allocation model for distributed computing systems based on a zero one programming technique, the branch-and-bound method.

A flexible manufacturing systems (FMS) is a complex system consisting of many interconnected components of hardware and software, as well as many limited resources such as pallets, automated moving vehicle etc.. In an FMS, parts are automatically transported via autonomous vehicle from one workstation to another for processing under computer control. One of the main problems of an FMS is the traffic coordination which controls the movement of work pieces, raw material, and tool among the workstations. C. L. Chen et al [6] presents a graph theoretic approach to determining an optimal task or routing assignment of p autonomous vehicles among m work stations in a flexible manufacturing system to minimize the assignment completion time as well as to achieve the load balancing among the autonomous vehicle. In their paper optimization of the cost function is based on the minimax of the job execution time and the minimization of max-min of the travelling time. Then optimal task assignment problem is solved by a state-space search method.

IV. THE 1990's

The performance of heterogeneous distributed systems heavily depends on the way task composing a parallel program are allocated to processors. Significant research has been done on the task allocation problem and different models have been proposed. Y. Kopidakis et al [7], consider the problem of assigning tasks to processors in a distributed system in order to minimize the sum of interprocessor communication and task processing cost. They considered heterogeneous Processors; having different processing capabilities depending on task nature and each processor communicates with others through identical communication channels. In their paper, they transformed the initial problem of minimization of total communication and execution cost into a maximization one, where they try to determine and avoid large communication and execution penalties.

Resource distribution in Distributed computer system (DCS) is seen as a way to improve systems throughput, fault-tolerance, and availability. An important resource for distribution is the user's one of the programme that consists of a set of task .Distribution of the task set among multiple processors provides for parallel processing and helps in decrease the overall response time of the task set. Larry Dunning et al [8] discusses on optimal static assignment of a group of communicating task among a set of processors. In his paper they discuss the application of a heuristic cost estimation method that results in a speed up in solving the delay optimization problem.

Real time scheduling theory is one of the areas in which efforts must be concentrated in order to develop a science of large scale real time systems. Conventional real time systems are mainly concerned with tasks that do not change their fundamental timing parameters during execution (static tasks). They may be sporadic or periodic. J. Santos et al[9] presents a heuristic approach to the problem of assigning a set of preemptible resource-sharing and blockable real time tasks to be executed in a set of heterogeneous processors communicated through an interprocessor network. Heuristic model for task allocation in distributed computer system is also discussed by several authors [34], [35].

In distributed computing environment, a job to be executed on the distributed system consists of a set of communicating tasks which we shall refer to as a task force. Virginia Mary Lo[10] investigate the problem of static task assignment in distributed computing systems. Their work is an extension of the graph theoretic approach to the task assignment problem begins by Stone[3] in which the definition of the task force is limited to (1) the execution cost of each task on the heterogeneous processors and (2) communication costs incurred between tasks when they are assigned to different processors.

Anup Kumar et al[11] discussed a performance and reliability optimization for distributed systems under a given budget constraint using the Genetic Algorithm. They measured the overall effectiveness of a distributed system in terms of the average network throughput. They developed newly performance oriented reliability parameters such as Average Network Throughput, Average Distributed Program Throughput and Average Distributed System Throughput.

A set T of n tasks is given. The assignment problem is to map each task to a processor from the set P of m processors. Each task has a known execution cost on each of the processors. Each task in the task set may communicate with zero or more other tasks in the task set. Two communicating tasks incur an inter-process communication overhead when they are assigned to different processors. Anup Kumar et al[12] investigated a new algorithm for solving the optimal task assignment problem in their paper. They introduce two approaches one is based on genetic algorithms and other is A*, a well known tree search algorithm for solving the same problem. They use the algorithm execution time as a performance criterion for the two algorithms. In their paper they proved that the genetic algorithm techniques are more favorable than A* for larger search spaces while for smaller search spaces A* is preferred.

V. THE 2000's

Task allocation in distributed computing systems is an important research problem. In distributed computing system the computers may be homogeneous or heterogeneous, connected together for some common application execution. The advancement in new technologies in communication and information lead to the

development of distributed systems and parallel systems. Distributed computing systems such as a network of heterogeneous workstations or PCS becomes an attractive alternative to expensive, massively parallel machines, but to exploit effective parallelism or distributed system, the tasks must be properly allocated to the processors. If multiple tasks could not managed properly would lead to the degradation of overall system. Thus task allocation is an important research problem[30]. Suchita Upadhyaya et al[13] compared DCS and DDBS with reference to task allocation models, algorithms, issues and tools. They explained general models and objective function in this paper which can be treated as basic platform for research in this area of task allocation. They derived the objective function by modifying the terms present in general model, which inturn depend on characteristics of the system concerned ex. Distributed computing system, distributed database system, parallel system and microprocessors etc.

Rapid advances in communication technology and proliferation of inexpensive PCs and workstations have created a wide avenue for Distributed computing system to move into mainstream computing. A distributed computing system (DCS) consists of a number of PCs or workstation interconnected through PPP, LAN or WAN. These systems provide a higher performance, better reliability and throughput over centralized mainframe systems. Hussein et al [14] will add an important factor which is the amount of contention on communication operation. The challenge here is to make an algorithm for the allocator/scheduler of task into machines in a heterogeneous environment taking into consideration the account of network contention. Hussein et al. discusses the two main problems, first one include partitioning the application into tasks referred to" task partitioning problem" and the second one include assigning the tasks onto computer in system referred "task assignment problem".

In recent years, mathematical problems for solving real problems get complication. Such that resource allocation problems. Since it is difficult to compute on time the problem by using a single computer, there is the case in which these large-scale problems are solved by using a distributed computing system. Satoshi et al [15] proposed a network based distributed computing system and multistep task allocation method. In his paper they propose a software agent based hierarchically distributed computing method which models the complications distributed computing system.

Grid computing provides a new way to share geographically distributed diverse computing, storage resources and specific digital instruments transparently. Grid resources are distributed, heterogeneous and dynamically changing in nature, moreover, different applications have different requirements for resources, thus how to assign tasks to appropriate resources is a key and important issue in the area, which should be tackled firstly. Optimal task assignment in grid computing has been proved to be NP hard problem, so approximate optimal heuristic scheduling algorithms are practical selections in general. In hybrid heterogeneous and dynamically changing distributed grid environment, how to assign tasks to appropriate resources is one of the most challenging techniques. Fufang Li et al[16] presents a novel grid task assignment model and corresponding algorithm based on agents, small-world network model theory, and power law. With the help of agents to assign tasks, the proposed model and algorithm can exactly assign grid task to suitable resources in real time. The model and algorithm which are proposed by them are designed for applying two basic rules of complex networks, which makes the nodes of the grid system more searchable, and thus helps the task assignment agents to find needed resources for specific tasks more quickly and efficiently.

With in grid or cloud computing environments, companies or research groups can outsource their business or scientific workflow. In both cases, a workflow contains a sequence of tasks. The example of delegating workflows into grids or clouds is that these are equipped with high performance hardware shared among all customers. An optimal resource allocation is desired to increase the efficiency of systems processing business or scientific workflows. These systems includes the processing of workflows in distributed computing environments such as grid or cloud computing. Current approaches used in this system consider QoS-requirements as quality, speed or costs in the resource allocation process and just select the resources that satisfy these requirements. Stefan Spitz et al [17] presents approaches which improve the current trust models according to the problems mentioned. Thereby, the degree of automation in the trust evaluation process will be increased as well.

A distributed system is a collection of processor-memory pairs connected by communication links. The reliability of a distributed system can be expressed using the distributed program reliability, and distributed system reliability analysis. The computing reliability of a distributed system is an NP-hard problem. The reliability oriented task assignment problem, which is NP-hard, is to find a task distribution such that the program reliability or system reliability is maximized. Chin-Ching et al [18] presents a genetic algorithm based reliability oriented task assignment methodology for computing the distributed task assignment reliability problem. They proposed algorithm that uses a genetic algorithm to select a program & file assignment set that is maximal, or nearly maximal, with respect to system reliability. The technique used by them would be helpful for readers to understand the correlation between task assignment reliability, and distributed system topology.

Genetic algorithms (GA) are computerized search and optimization algorithms based on the mechanics of natural genetic and natural selection. They were first envisioned by John Holland and were subsequently developed by various researchers. Hungarian algorithm for solving the assignment model is more efficient than branch-and-bound algorithm. Anshuman Sahu et al [19] attempt the problem to solve the generalized "Assignment Problem" through genetic algorithm and simulated annealing. While solving this problem through genetic algorithm, they used a unique encoding scheme with Partially Matched Crossover (PMX). In simulation annealing (SA) method, they employ exponential cooling schedule based on Newtonian cooling process. In their paper they attempt the same model using two non-traditional techniques: Genetic Algorithm and Simulated Annealing. It is basically an experimental investigation into various parameters affecting these two algorithms and adapting them to their problem.

A system that is to be distributed around a network must be broken down into components that are allocated to physical nodes. The process of breaking the system down into components is called "partitioning". The process of allocating the components around the network is called "allocation". The allocation process usually has the goal of minimizing inter-process communication cost, minimizing execution cost, load balancing, increasing system reliability and providing scalability. Replication is difficult to use effectively but has the potential to greatly improve the performance of a distributed system. H. T. Barney et al [20] presents a new technique for allocating objects in order to improve performance in a distributed system that support replication. They compare the performance of the new technique with the performance of the existing technique in order to demonstrate both the validity and superiority of the new technique that can utilize object replication.

In the area of information technology, Fuzzy logic contributions could be in the form of approximate reasoning, where it provides decision-support and expert systems with powerful reasoning capabilities bound by a minimum number of rules. Theoretically, fuzzy logic is a method for representing analog processes, or natural phenomena that are difficult to model mathematically on a digital computer. The processes are continuous in nature, and are not easily broken down into discrete segments. Much of the power of fuzzy logic is derived from its ability to draw conclusion and generate responses based on vague, incomplete, and imprecise qualitative data. Fatma A. Omara et al [21] proposed a dynamic task scheduling model based on fuzzy logic. The main objective of the technique is to improve the fuzzy decision which is used in task scheduling on a network of processing elements by introducing new input parameters to an existing fuzzy model and, in the same time, improving the load balance on the network in the dynamic environment. The fuzzy model proposed by them is capable of processing inputs from on the fly data arises from the current state of the processor.

The task-parallel computing is a kind of many tasks computing (MTC). Its primary object is to minimize every task parallel computation's turnaround time, which mainly depends on three factors: number of utilized parallel computing resources, load-balance among the utilized resources, and computation-partitioning overhead caused by operations like resource allocations and remote file transmissions. Huashan Yu et al [22] presents a task scheduling algorithm for MTC in large scale distributed systems. The aim of the approach used is, minimizing a task parallel computation's turnaround time with as few computing resources as possible. Based on many tasks computing (MTC) model, a self optimizing task partitioning algorithm they has been devised for scheduling tasks in MTC. It separates task assignment from resource allocation; and makes a tradeoff between maximizing utilized resources, balancing workload and reducing computation-scheduling overhead.

The advent of large scale distributed computing platforms, consisting of many personal computers connected to the internet, provides researchers and practitioners a new and relatively untapped source of computing power. Many recent large-scale distributed computing applications utilize spare processor cycles of personal computers. The resulting distributed computing platforms provide computational power that previously was available only through the use of expensive supercomputers. However, distributed computations running in un-trusted or unstable environments raise a number of concerns, including the potential for disrupting computations and many security issues. It is shown that the standard techniques for managing these issues, i.e. replication and/or redundancy, till do not always resolve situations where computational integrity is threatened. Doug Szajda et al[23] presents a generalized strategy for applying redundancy in a manner that is tunable and provides several advantages. In addition, the improvement is achieved without an increase in the amount of computation required by participants and only a slight increase in task tracking overhead.

Recently, power consumption of server computers is one of the most important topics. Especially, to reduce power consumption of processors is very essential since the processor is the most power consumed part in servers. Thus in order to reduce power consumption of servers, it is effective to reduce power consumption of processors. Dynamic Voltage Scaling (DVS) is one of the technologies for reducing power consumption of processors [24]. DVS is a technology in which combinations of an operating voltage and an operating frequency of a processor can be changed dynamically at run time. Yuichiro Mori et al[25] propose a task scheduling algorithm to reduce power consumption of multiprocessor servers. In their algorithm they apply DVS to tasks of a scheduling result generated by traditional algorithms which do not take power consumption into account. The authors consider application of DVS at heavy load time as well as at idle time without increasing the make span of the task graph.

Interconnection networks can be broadly categorized as indirect networks, such as the multistage networks, or as direct networks, such as the multidimensional networks. Among the many interconnection networks that can be used to connect the processors in a parallel computer, the family of multidimensional networks has received a great deal of attention due to the large number of commercial parallel computer systems in which they are used. James R. Anderson et al[26] undertakes the study of multidimensional networks and explains why previous results appear to be at odds. They introduced an improved Stochastic analysis technique of multidimensional networks with unidirectional or bidirectional links between adjacent nodes and end-around connections which yields a simple closed form solution that is more accurate.

Task assignment is a research topic studied for many years in the literature of operations research and weapon target assignment. However, task assignment in cooperative control requires online real time solution. A single task is able to service multiple modules. Furthermore, some modules must be serviced following a specific sequence in time. Therefore, task assignment for cooperative control is fundamentally different from off-line static task assignment studied in the literature. Wei Kang et al[27] formulate the problem of multiple tour task assignment using linear programming. In their paper simulation results are shown for multiple-tour assignment with both terminal and non-terminal tasks. Then, a result on optimal task assignment using partial information is also proved. These results imply that the size of the linear programming is determined by the

number of tasks, and independent of the number of the UAV's.

Multi-robot systems have been the subject of much research. A mobile robot team can complete an assigned task rapidly and efficiently by dividing the overall task into several subtasks, assigning them to individual robots, and executing the subtasks simultaneously. Multi-robot systems have obvious advantages such as faster operation, higher efficiency, and better reliability than a single robot system. Task assignment of multi-robot systems is to control a group of mobile robots so that they move to their designated target locations, with the coordination and cooperation of each robot. Anmin Zhu et al[28] proposed a neural network approach to task assignment for a multi-robot system in dynamic environments subject to uncertainties. Their task assignment method is based on self organizing map (SOM). The method proposed by them is capable of dynamically controlling a group of mobile robots to achieve multiple tasks at different locations, so that the desired number of robots will arrive at every target location, from arbitrary initial locations.

Recently, consumers need more diverse and individual goods. In consequence, producers need to response to it and a high-mix low-volume manufacturing becomes the main stream in manufacturing industries. We can divide the control problem into two: the scheduling problem of process machines and the Task Assignment and Routing Problem (TARP) of Autonomous Transportation Systems (ATSs) such as Automated Guided Vehicle (AGV) systems. Autonomous Distributed Manufacturing Systems (ADMSs) have advantages such as improvement of fault tolerance, reduction of load, and so on, but it is difficult to achieve total optimization. How to obtain more efficient solutions is important in the framework. Yusuke Morihiro et al[29] focuses on on-line TARP for ATSs along with a schedule made by a production scheduling system. The algorithm developed by them is able to plan deadlock free routes even though the buffer capacity is small, but includes reformability at the point that computational time increases drastically as the buffer capacity lessen. The proposed initial task assignment method developed by them gives the reduced computational time on planning routes. In the proposed initial task assignment method, a task reassignment procedure, called Initial Move Task loop, is used by them and the aim is to reduce computational time for obtaining good assignments by using this procedure.

VI. CONCLUSION AND FUTURE

This paper describes the development of task allocation techniques from the early days of heuristic methods through the present day of the Autonomous Transportation System and Automated Guided Vehicle. Some of the transitions to implementing the next generation, includes

a. Formulation of the modified task allocation problem with process sequence. Also different algorithms for solving the problem that are proposed in different applications such as Grid Computing, Simulated Anneling, Fuzzy theory etc.
b. Developing some stochastic models for improving the performance of the system.
c. Improving the performance, in the case when hardware/ software redundancy used.
d. To solve some heuristic allocation techniques for the systems, in the case, in which optimization solution technique becomes computationally complex.
e. To develop some allocation techniques and algorithm for the systems, in the case of network contention which optimize the run time and balance the load on each processor evenly?

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