Available online at www.sciencedirect.com
SCIENCE DIRECT®
Information Sciences 176 (2006) 3105–3131
INFORMATION SCIENCES
AN INTERNATIONAL JOURNAL
www.elsevier.com/locate/ins

A multi-model algorithm for the cost-oriented design of Internet-based systems

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Received 7 April 2005; received in revised form 22 December 2005; accepted 23 December 2005

Abstract

The selection of a cost-minimizing combination of hardware and network components of Internet-based systems to satisfy organizational requirements is a complex design problem with multiple degrees of freedom. Decisions must be made on how to distribute the overall computing load onto multiple computers, where to locate computers and how to take advantage of legacy components. The corresponding optimization problem not only embeds the structure of NP-hard problems, but also represents a challenge with a well-structured heuristic approach.

A scientific approach has been rarely applied to cost minimization and a rigorous methodological support to cost issues of the design of Internet-based distributed systems is still lacking. The methodological contribution of this paper is the representation of complex design issues as a set of four intertwined cost-minimization sub-problems: two set-partitionings, a set-packing and a min k-cut with a non-linear objective function. Optimization is accomplished by sequentially solving these sub-problems with a heuristic approach and tuning their solution with a local-search approach. Results indicate that

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0020-0255/$ - see front matter
doi:10.1016/j.ins.2005.12.013

decomposition significantly reduces optimization time and solutions have also lower costs than those identified without prior decomposition (20–60%). Cost reductions considerably grow (25–70%) when methodological outputs are compared with practitioners' solutions.

Keywords: Distributed applications; Web-based services; Algorithms; Costs minimization; Combinatorial optimization; Design tool

1. Introduction

Cost minimization is a critical objective of the design of Internet-based distributed systems, as it represents the counterpart of performance maximization and the ultimate decision criterion of feasibility analyses [18,7,23]. The infrastructure of Internet-based systems is comprised of hardware and network components. Different combinations of hardware and network components can satisfy given performance requirements and, accordingly, cost minimization has multiple degrees of freedom.

From a cost perspective, the literature distinguishes between two macro-design alternatives, related to the selection of hardware and network components, respectively. The first alternative is how to distribute the overall computing load of a system onto multiple machines. The second is where to locate machines that need to exchange information in order to minimize network costs [12,18,5]. Design decisions on both alternatives are strongly inter-related and the cost-minimizing design of an Internet-based infrastructure raises a NP-hard optimization problem.

Cost issues of infrastructural design have been primarily addressed by the professional literature, which evaluates selected infrastructural choices to provide cost benchmarks and practical design rules [30]. In contrast, a scientific approach has been rarely applied to cost analyses and a rigorous methodological support to cost minimization is still lacking. In this paper, infrastructural design alternatives are organized within an overall optimization framework. Computational complexity is tackled through a sound decomposition of the overall NP-hard optimization problem into sub-problems that can be solved with operations research techniques. Four intertwined cost-minimization sub-problems are identified: two set-partitionings, a set-packing and a min k-cut with a non-linear objective function. Optimization is accomplished by sequentially solving all sub-problems with a heuristic approach and finally tuning their solution with a local-search approach.

The methodology is empirically verified with a database of costs that has also been built as part of this research. Multiple sources of cost data have been combined, including previous professional literature, vendors'