

Chapter 17

Computational Engineering in the Cloud: Benefits and Challenges

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ABSTRACT

Cloud computing services, which allow users to lease time on remote computer systems, must be particularly attractive to smaller engineering organizations that use engineering simulation software. Such organizations have occasional need for substantial computing power but may lack the budget and in-house expertise to purchase and maintain such resources locally. The case study presented in this paper examines the potential benefits and practical challenges that a medium-sized manufacturing firm faced when attempting to leverage computing resources in a cloud computing environment to do model-based simulation. Results show substantial reductions in execution time for the problem of interest, but several socio-technical barriers exist that may hinder more widespread adoption of cloud computing within engineering.

INTRODUCTION

Cloud computing has recently emerged as a service model where users obtain short-term access to large-scale computational resources, potentially at lower cost than purchasing and administering computing hardware (Armbrust et al., 2009). Most of the initial drive and interest in cloud

computing has been in the IT community. More recently, there has been growing interest on using cloud computing as a platform for computational science and engineering (Shainer et al., 2010)

The term *computational science* refers to the application of computers for solving scientific problems, particularly the use of computer simulations to predict physical phenomena (Post

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& Votta, 2005). The term *computational engineering*, analogously, refers to the application of computers in solving engineering problems (Post, 2009). While there are many similarities between computational science and computational engineering, important differences also exist. Computational engineers use computers to do *virtual prototyping*, analyzing the behavior and failure modes of proposed designs through model-based simulations. Virtual prototyping has the potential to reduce both engineering development time and cost by reducing the amount of physical prototyping required to do a design validation, as well as opening up possibilities for design optimizations. Commercially available engineering packages put these simulation techniques within reach of the end-user engineer, although a high degree of domain expertise is required to set up and interpret the results of such simulations.

Engineering simulations are extremely computationally intensive, with simulations taking anywhere from hours to days or weeks, depending on the type of simulation required. Many of these commercial engineering packages have support for running on high-performance computing (HPC) systems, and a survey of larger engineering firms indicates that such firms take advantage of HPC (Joseph et al., 2004). However, such systems are expensive to maintain and require additional IT expertise, rendering them inaccessible to many smaller engineering firms.

In this paper, we describe a feasibility study undertaken by the authors to help determine whether the use of remote HPC resources for modeling-based simulation would have a positive return on investment for a small-to-medium-sized manufacturing company. This paper describes our experiences, including the benefits of reduced processing time, as well as practical challenges that we faced while supporting computational engineers in using remote HPC resources.

RELATED WORK

Armbrust et al. (2009) provide a broad overview of the costs, benefits, and challenges of cloud computing. Although they do not focus specifically on scientific and engineering applications, they discuss several issues that appear in this study, such as batch processing of parallel processing applications, compute-intensive desktop applications, data transfer bottlenecks, and data licensing issues.

Cloud computing for computational science and engineering is a very young but increasingly active area, as evidenced by new workshops emerging in 2010 such as the first Workshop on Science Cloud Computing (ScienceCloud) (<http://dsl.cs.uchicago.edu/ScienceCloud2010/>) and Cloud Futures 2010: Advancing Research with Cloud Computing Workshop (Faculty Connection, 2007). Some early experience reports have begun to emerge. Hoffa et al. (2008) explored the use of cloud computing for executing a scientific workflow in the field of astronomy. Lauret and Keahy used cloud computing resources to quickly perform a preliminary analysis of a nuclear physics experiment in time to submit a conference paper (Heavy, 2009).

The MapReduce programming model has dominated much of the early interest in cloud computing applications. Dean and Ghemawat (2004) introduced the MapReduce model of processing datasets on large clusters, which has been implemented by the open-source Hadoop project (Bialecki et al., 2007). Much of the current cloud computing research focuses on data-intensive applications that map well to this model, such as indexing of spatial databases (Cary et al., 2009), processing very large graphs (Zhao et al., 2009; Cohen, 2009), and indexing of very large text corpora for information retrieval (Callan & Kulkarni, 2009).

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