Energy-Efficiency in Cloud Computing Environments:
Towards Energy Savings without Performance Degradation

Ismael Solis Moreno, University of Leeds, UK

Jie Xu, University of Leeds, UK

ABSTRACT

Due to all the pollutants generated during its production and the steady increases in its rates, energy consumption is causing serious environmental and economic problems. In this context, the growing use and adoption of ICTs is being highlighted not only as one as the principal problem sources but also as one of the principal areas that could help in the problem's reduction. Cloud computing is an emerging model for distributed utility computing and is being considered as an attractive opportunity for saving energy through central management of computational resources. To be successful, the design of energy-efficient mechanisms must start playing a mayor role. This paper argues the importance of energy-efficient mechanisms within cloud data centers and remarks on the significance of the "energy-performance" relationship in boosting the adoption of these mechanisms in real scenarios. It provides an analysis of the current approaches and the outline of key opportunities that need to be addressed to improve the "energy-performance" relationship in this promising model.

Keywords: *Cloud Computing, Cloud Computing Challenges, Energy-Aware, Energy-Efficiency, Energy-Performance, Green Computing*

INTRODUCTION

Many people today are devoted to a widespread adoption of Information and Communications Technologies (ICTs). However, due to the priorities of both providers and consumers, this has been focused principally on aspects such as processing speed, bandwidth, transfer rate, storage and memory capacity just to mention only a few, the environmental impact of their use has been relegated until recent years, when changing climate patterns and pollution problems have become high priority in the world's nations' agendas.

The increasing accumulation of greenhouse gases is changing the world's climate, creating serious problems such as droughts, floods and higher temperatures. In order to stop the accumulation of these gases in the atmosphere, it is necessary to stop the global growth of emissions, in which the generation of electricity plays a major role not only because of the carbon dioxide which results from the coal

DOI: 10.4018/ijcac.2011010102

and oil used in this process, but also because it releases sulphurs and other pollutants into the atmosphere.

Additionally to the ICTs environmental repercussions, the worldwide economy is also being affected by the steady increases in electricity rates. The number of "*smart*" devices, peripherals, computers, data centers and the amount of communications are rapidly growing along with the electricity cost required to feed them. This problem is more perceptible within the industries and enterprises which have to support large amounts of computing infrastructure normally represented by enormous data centers provided with powerful cooling systems that also require great amounts of energy to work.

In this context, cloud computing an emerging model for distributed utility computing which is normally represented by large and power-consuming data centers designed to support the elasticity and scalability required by its customers. Cloud computing is becoming commercially attractive and its use is growing since it promises reducing the maintenance and management costs in comparison with traditional data centers. However, and despite that one of cloud computing commercial credentials is the reduction of energy consumption for customers, it still represents a serious problem for providers who have to deal with increasing demand and performance expectations. This creates the need for mechanisms to improve the energy-efficiency of cloud computing data centers while preserving desired levels of operation.

Green IT emerges as a new perspective for designing, developing and managing computing infrastructure aiming for more efficient processes and mechanisms to avoid waste of resources and considering the environmental implications of its use and disposal. Regarding with energy efficiency, a branch of Green IT named Energy-aware computing which is normally applied in embedded systems where strong energy constraints exist, has came forward to change the high-level computing systems point of view from "*performance-mainly*" to "*performance-energy*" balanced systems reducing the cost by an improved use of resources and the impact to the environment by diminishing the energy consumed while QoS is maintained.

Currently, some approaches have arisen to contribute to energy-efficiency improvement for data centers. Specifically, cloud computing approaches are exploiting the advantages of virtualization technology to maximize the use of underlying physical resources, dynamically resizing computing power in proportion to the customers' requirements. However these approaches do not consider some variables that in real cloud computing scenarios could lead to performance degradations or failures. These variables represent challenges that should be addressed to boost the adoption of these mechanisms in real scenarios where customer satisfaction has priority.

This paper argues about the importance of energy-efficient mechanisms within cloud data centers and remarks the "energy-performance" relationship significance. First, it describes how ICTs are negatively impacting the environment. Then green and cloud computing are introduced. Finally, the importance of energy-efficient mechanisms in cloud computing, the analysis of current approaches and the identified opportunities in this area are presented.

ICT´S ENVIROMENTAL IMPACT

It is probably not a perceptible problem for most users, but ICTs affect the environment in different ways. According to Murugesan (2008), each of the stages of a computer's life, from its production, use and disposal produces environmental problems. Among these problems, the excessive electrical power consumption by hardware such as servers, networks, monitors and cooling systems appears to be the most critical since it results in increased greenhouse gas emissions. However, the pollution produced during the manufacturing of computing equipment and all the e-waste generated during its disposal should be taken in consideration in order to mitigate where possible the environ-