Chapter 64
Energy and Carbon Footprint-Aware Management of Geo-Distributed Cloud Data Centers: A Taxonomy, State of the Art, and Future Directions

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ABSTRACT

Cloud computing provides on-demand access to computing resources for users across the world. It offers services on a pay-as-you-go model through data center sites that are scattered across diverse geographies. However, cloud data centers consume huge amount of electricity and leave high amount of carbon footprint in the ecosystem. This makes data centers responsible for 2% of the global CO2 emission. Therefore, having energy and carbon-efficient techniques for resource management in distributed cloud data centers is inevitable. This chapter presents a taxonomy and classifies the existing research works based on their target system, objective, and the technique they use for resource management in achieving a green cloud computing environment. Finally, it discusses how each work addresses the issue of energy and carbon-efficiency and also provides an insight into future directions.

INTRODUCTION

In recent years the use of services that utilize cloud computing systems has increased greatly. The technology used in cloud is not new and its main goal is to deliver computing as a utility to users. Cloud computing consists of virtualized computing resources inter-connected through a network, including private networks and the Internet. Over the years since its formation, different definitions for cloud

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computing have been proposed. According to the definition by the National Institute of Standards and Technology (NIST) (Mell and Grance, 2011): "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models". The three service models provided by the cloud providers are Infrastructure, Platform, and Software as a Service.

Cloud computing delivers service, platform, and infrastructure services to users through virtual machines deployed on the physical servers. Virtualization technology maximizes the use of hardware infrastructure and physical resources. Hardware resources are the servers located within the data centers. Data centers are distributed across the world to provide on-demand access for different businesses. Due to the distributed nature of cloud data centers, many enterprises are able to deploy their applications, such as different services, storage, and database, in cloud environments. By the increase of demand for different services, the number of data centers increases as well; which results in significant increase in energy consumption. According to Koomey (2008) energy usage by data centers increased by 16% from the year 2000 to year 2005. Energy consumption of data centers almost doubled during these five years, 0.5% and 1% of total world energy consumption in 2000 and 2005, respectively. Hence, during the recent years there has been a great work on reducing power and energy consumption of data centers and cloud computing systems. Recently, considering data centers carbon-efficiency and techniques that investigate cloud data centers energy sources, carbon footprint rate, and energy ratings have attracted lots of attention as well. The main reasons for considering carbon-efficient techniques are increase in global CO_2 and keeping the global temperature rise below 2°C before the year 2020 (Baer, 2008).

In the rest of the chapter, the authors provide an in-depth analysis of the works on energy and carbon-efficient resource management approaches in cloud data centers, based on the taxonomy showed in Figure 1. The authors explore each category and survey the works that have been done in these areas. A summary of all the works is given in Table 1.

Figure 1. Taxonomy of energy and carbon-efficient cloud computing data centers