Chapter 2
Paving the Path to a Sustainable Digital Future With Green Cloud Computing

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ABSTRACT

Amidst an era marked by a relentless surge in digital data and computational demands, the imperative for eco-conscious and sustainable computing solutions has reached unprecedented significance. This study delves into the emerging realm of green cloud computing (GCC), a pivotal catalyst in cultivating a greener digital tomorrow. To nurture a sustainable digital frontier, this research investigates various GCC strategies encompassing efficient data center designs, resource optimization techniques, and innovative virtualization practices. Additionally, the authors scrutinize real-world instances of industry leaders embracing sustainable energy sources. Furthermore, they shed light on the obstacles within eco-friendly cloud computing while illuminating forthcoming trends for the triumphant integration of sustainable and eco-friendly technologies. This study offers profound insights for researchers, students, and stakeholders alike.

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INTRODUCTION

The dawn of the 21st century ushered in an unprecedented digital transformation era. The Internet seamlessly integrated into our daily lives, business operations, and scientific endeavors, resulting in an insatiable demand for data storage, computational power, and connectivity (Alouffi et al., 2021; Kalinaki, Thilakarathne, et al., 2023; Katal et al., 2023; Shafik & Kalinaki, 2023). Traditional computing infrastructures struggled to keep pace with this ever-escalating demand, leading to a paradigm shift in the provisioning and utilization of computing resources. From this upheaval emerged cloud computing, a technological revolution that would reshape the IT industry by offering scalable, on-demand access to computational resources via the World Wide Web (Golightly et al., 2022; Kalinaki, Namuwaya, et al., 2023). Cloud computing, characterized by its ability to deliver a diverse array of services, including infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS), hosts these services in colossal data centers housing thousands of servers and networking equipment (Ullah Khan et al., 2022). This transformative approach enables users and organizations to access these services remotely, obviating the necessity for extensive on-premises infrastructure.

As the embrace of cloud computing surged, data centers multiplied to support the burgeoning demand for computational resources. These data centers are the linchpin of cloud infrastructure, serving as the tangible facilities that house servers, storage devices, and networking equipment (Tiwari et al., 2022). They are indispensable for the seamless delivery of cloud services, enabling the storage and processing of vast volumes of data and applications. However, this proliferation of data centers has precipitated profound environmental concerns. The exponential growth in the number and size of data centers has correspondingly driven up energy consumption. For instance, Google commands a legion of servers exceeding a million in number, while Microsoft's Chicago data center boasts over three hundred thousand servers. These digital juggernauts consume a staggering 23.5% of the electrical energy grid, drawing its power from the depths of American coal-fired generators (Bharany et al., 2022). Moreover, according to the International Energy Agency (IEA), in 2022, data centers accounted for approximately 1% of global electricity consumption, with projections indicating a significant increase in the years to come (International Energy Agency, 2022). This upsurge in energy usage contributes to escalating operational costs for cloud service providers and leaves a substantial carbon footprint, further compounding the challenges of climate change.

The energy consumption of data centers is a weighty concern from both environmental sustainability and economic viability perspectives. These facilities demand prodigious amounts of electricity to power servers, cooling systems, and other infrastructure components (Ahmad et al., 2023). Notably, cooling systems constitute a substantial portion of the total energy consumption, as maintaining optimal operating temperatures is crucial to prevent hardware failures and preserve data integrity (Shao et al., 2022). The ramifications of this energy usage are multifaceted. First and foremost, it places an onerous burden on power grids, which may struggle to meet the surging demands from data centers, potentially leading to energy shortages and grid instability. Second, the carbon emissions from electricity generation for data centers are substantial, contributing to greenhouse gas emissions and the broader issue of climate change (Ortar et al., 2023). These concerns have garnered the attention of policymakers, environmental advocates, and the general public.

In this context, the necessity for sustainability within cloud computing becomes abundantly clear. While cloud computing offers unparalleled flexibility, scalability, and cost-effectiveness, it is imperative to address the environmental consequences it poses. The imperative lies in finding innovative and