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Optimizing energy consumption for data centers

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ABSTRACT

Big data applications have become increasingly popular with the appearance of cloud computing and green computing. Therefore, internet service providers (ISPs) need to build data centers for data storage and data processing under the cloud service pattern. However, data centers often consume a significant amount of energy and lead to pollutant emissions. In recent years, the high energy consumption and environmental pollution of data centers have become a pressing issue. This paper reviews the progress of energy-saving technologies in high-performance computing, energy conservation technologies for computer rooms and renewable energy applications during the construction and operation of data centers. From multiple perspectives of energy consumption, cost reduction, and environment protection, a comprehensive set of strategies are proposed to maximize data centers' efficiency and minimize the environmental impact. This paper also provides energy-saving trends for data centers in the future.

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1. Introduction

1.1. Energy consumption outlook for data centers

Data centers are computer warehouses that store a large amount of data for different organizations in order to meet their daily transaction processing needs [1]. Data centers may be considered as a collection of different servers and network infrastructures, where servers are used to collect data, network infrastructures are used to utilize, keep and update servers' data and users can access the data center servers by network.

Recently, digital information has been enjoying an explosive growth and the information scope also has a vast expansion. Data centers are the core infrastructure to support such a trend. Along with the development of cloud computing and proposals for green computing, data center technologies have become the battlefield of "Information contest" for IT giants in cloud computing area. The high performance is not the only requirement for data centers deployment. People begin to pay more attention to data centers' energy consumption [2].

According to the statistics in Ref. [3], U.S. data centers consumed almost 61 billion KWH in 2006, which accounts for approximately 1.5% of the total energy consumption in the United States. The energy consumption of U.S. data centers increased to more than 100 billion KWH in 2011[4]. From a global perspective, the energy consumption of global data centers accounted for 1.1–1.5% of the total global energy consumption in 2011, which is equivalent to the average amount of energy consumption in 25,000 American households [5].

With the constant expansion of the global economy, energy consumption and carbon emissions will keep increasing in coming years. Fig.1 shows an estimate of CO_2 emissions of data centers for each information and communication technology (ICT) category from energy efficiency and low carbon enabler. According to Ref. [6], CO_2 emissions from ICT are increasing at a rate of 6% per year, and with such a growth rate, they will account for 12% of worldwide emissions by 2020.

The energy consumption of data centers may be divided into two categories: computing resources and physical resources. The statistics in Ref. [7] shows that the energy consumption of computing resources accounts for about 50% of the total energy consumption. The servers' computation takes about 40% of energy consumptions; the communication equipment' energy consumption accounts for roughly 5%, and the storage devices consume about 5%. On the other part, the energy consumption of refrigeration systems is a major part of energy consumption by physical resources, which accounts for about 40% of the total energy consumption; In addition, power supply systems and other miscellaneous factors account for about 10%, as shown in Fig. 2.

From Fig. 2, we can conclude that servers and cooling systems are the most substantial energy draining facilities in data centers. They account for a dominant portion of the total operating costs. Therefore, reducing energy consumption for servers and cooling systems is the key issue of the sustainable development of data centers.

In general, energy consumption of data centers restricts the expansion of data centers with a high electricity cost, and at the same time, the rapid growth of "carbon footprint" aggravates the damage to the environment [8]. The energy consumption issue of data centers has caused widespread concerns in both the academia and the industry.

1.2. Energy conservation framework and key contributions

From the above discussion, we can conclude that the energy consumption of data centers is concentrated in the following aspects of high-performance computing, low-power servers, energy conservation of computer rooms and renewable energy application. In this paper, we summarize a general framework of energy conservation for data centers from the main aspects, shown in Fig. 3.

Some composite energy-saving strategies are proposed maximize the efficiency of data centers and minimize the impact on environment dynamically according to user expectations and other constraints. Our key contributions are summarized as follows:

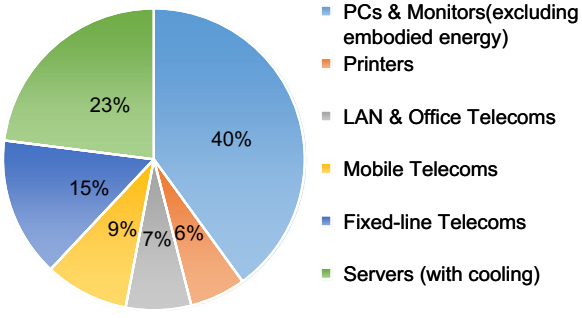

Fig. 1. Estimated ICT CO_2 emissions.

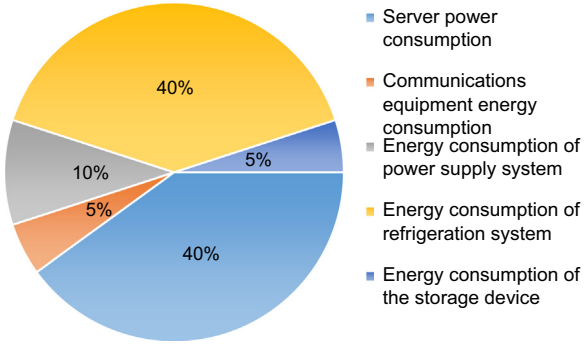

Fig. 2. Energy consumption distribution of data centers.