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QGLG Automatic Energy Gear-Shifting Mechanism with Flexible QoS Constraint in Cyber-Physical Systems:
Designing, Analysis, and Evaluation

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ABSTRACT

This article describes how with the continuous expansion on the volume of data produced by sensors in Cyber Physical Systems, the scale of the cloud storage system has become larger. This will lead to the problems of a high energy consumption rate and a low utilization becoming a serious issue. In order to enhance the effective energy consumption, reduce the invalid energy consumption, and supply more flexible QoS for users in CPS, this article proposes an automatic energy gear-shifting mechanism with flexible QoS constraints (QGLG). The QGLG predicts system load of the follow-up period through a support vector machine model. According to the current system load, the predicted load, and the flexible QoS, QGLG automatically up-shifts and down-shifts among nodes. Substantive results from the simulation experiments done on GridSim show that the QGLG can achieve energy consumption reduction while satisfying the user's flexible QoS requirements. Compared with a similar energy-reducing mechanism, QGLG has its obvious advantage when considering the requirements of user with energy saved notwithstanding.

KEYWORDS

Cloud Storage System, Cyber-Physical Systems, Energy Management, QoS, Sensors

INTRODUCTION

Cyber-Physical Systems are the next-generation smart but complex systems, they integrate multiple techniques, including cloud computing, communication and automatic control. CPS will support variety of intelligent applications and services in many fields, such as transportation, healthcare, entertainment and city infrastructure (Liu et al., 2017). In CPS, sensors and mobile devices collect a variety of information from physical environment, which resulting in huge amount of data generated. Gartner forecast that there will be 20.4 billion sensors or devices that are connected worldwide in 2020. The large scale of data volume will be stored in Cloud Storage System, which forms more and more data centers. Data centers consume a huge amount of energy resources even with a rising trend. According to statistics, the energy consumption of Cloud Storage System accounts for 27% to 40%

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of the data center. However, the high energy consumption rate with a low storage utilization (35% approximately only). The mismatch between energy consumption and storage utilization provides a large space reduction in energy consumption in cloud storage system. Therefore, how to realize energy proportionally has received more and more attentions (Duy et al., 2010).

At present, there are many research works related to reduce the total energy consumption, various energy-saving technologies are employed in Cloud Storage System. Substantially experiment results show that compared to the cloud storage system without any energy-saving technology, the technologies employed energy-saving can reduce a lot of energy consumption certainly. There still has the space to reduce the energy consumption. Furthermore, most of the energy-saving technologies have not fully considered the flexible QoS request of the users. However, with more and more users store their data on the cloud storage system, users' requirements are ever-changing. Therefore, how to satisfy the ever-changing QoS of the users is the other demand of the cloud storage system. Aiming to reduce energy consumption and to satisfy the flexible QoS of the user, this paper proposed the automatic energy gear-shifting mechanism with flexible QoS constraint in Cloud Storage System (QGLG). The flexible QoS can be expressed by the Deadline, Budget and the Benefit Function, which can be implemented as Time Prior (TP), Cost Prior (CP), and Benefit Function based (BF). QGLG predicts the number of tasks in the follow-up period through the support vector machine prediction model. According to the flexible QoS of the user and the predicted system load of the next period, QGLG dynamically shifts different suitable gears among the storage nodes.

RELATED WORK

Cyber Physical Systems are increasingly deployed over the cloud in a wide range of applications, including smart grids, sensing, computation, storage and other operations, all of them generate a large number heterogeneous data with varying volume, velocity, variety, and value. Near recently, there are some publication discuss the research issues in Cyber-Physical Systems (Choi et al., 2017). Users need to communicate with the cloud to conduct transactions, such as selling and buying energy via a backbone architecture. Therefore, Energy management is a grand research challenges in Cyber Physical Cloud Systems, and has a direct impact on environment. How to ensure the energy is consumed intelligently in Cloud Storage Systems will be main concern both in academia and industry field.

In the past several years, energy efficient problem in Cloud Storage Systems of CPS have attracted some researchers' concern. In 2016 George et al present concept in creating a Cyber Physical System (CPS) in order to change organizations' way of consuming energy. Marcelo presented an intelligent control strategy for improving energy efficiency of a commercial building using a multi -agent system architecture (Simoes et al., 2012). On the other hand, in the past ten years, there is a mass of research work focused on energy saving while employing different techniques, such as data classification (Rini et al., 2010, Xie, 2008), data placement (Le at al, 2013, Ramana, R 2015), data replicating (Lin et al., 2013, Boru et al., 2015), combined with dynamic voltage management (Zhu et al., 2005) or scheduling techniques (Jia et al., 2016). Dynamic data aggregation algorithm for green cloud computing is proposed in literature (Yang, et al 2012). According to the data access pattern, the data and the nodes are aggregately stored dynamically. By managing the power state of the storage nodes, the energy consumption can be reduced with the consideration of QoS. Aim to reduce the energy consumption in cloud storage systems, Dr. Long designed the static and dynamic file layout, replica and data layout policies (Long, 2014). An energy consumption model is built by Wu et al (Wu et al., 2013). Virtual machine's energy consumption is estimated by the statistical method whose errors may be 3%-6%. According to the model, a virtual machine scheduling algorithm is proposed to improve the system's energy efficiency. Relationship between power consumption and infrastructure components is investigated by in (Luo et al., 2012). A resource scheduling strategy is designed according to optimization methods on energy efficiency. Jun address the energy and latency efficient access of wireless XML stream. They propose a novel distributed index structure and a clustering

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