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# The Research of Measuring Approach and Energy Efficiency for Hadoop Periodic Jobs

Yu Junyang[1,2], Hu Zhigang[*,1] and Han Yuanyuan[3]

[1]*Software School, Central South University, Changsha, Hunan 410075, P.R. China*

[2]*Software School, Henan University, Kaifeng, Henan, 475001, P.R. China*

[3]*Power Company of Kaifeng, Kaifeng, Henan, 475001, P.R. China*

**Abstract:** Current consumption of cloud computing has attracted more and more attention of scholars. The research on Hadoop as a cloud platform and its energy consumption has also received considerable attention from scholars. This paper presents a method to measure the energy consumption of jobs that run on Hadoop, and this method is used to measure the effectiveness of the implementation of periodic tasks on the platform of Hadoop. Combining with the current mainstream of energy estimate formula to conduct further analysis, this paper has reached a conclusion as how to reduce energy consumption of Hadoop by adjusting the split size or using appropriate size of workers (servers). Finally, experiments show the effectiveness of these methods as being energy-saving strategies and verify the feasibility of the methods for the measurement of periodic tasks at the same time.

**Keywords:** Energy efficiency, Energy saving, Hadoop, Measurement method.

## 1. INTRODUCTION

Since the concept of cloud computing has been promoted in 2006, it has developed rapidly and many companies have launched their own cloud computing platforms, such as Azure from Microsoft, Google Compute Engine from Google, IBM Blue Cloud Computing Platform from IBM and Dynamo from Amazon [1]. Although cloud computing technology is developing continuously, Hadoop platform is the most popular object that many scholars study. Hadoop computing platform is composed of MapReduce computing framework and HDFS file storage system, and current research regarding Hadoop [2, 3] focuses on the performance optimization but its processing efficiency is not high for small files [4, 5]. From the point of energy efficiency, this essay proposed a method to measure the effectiveness of periodic tasks that run on Hadoop platform, and it also studied as how to be energy efficient through the analysis of measurement methods.

## 2. RESEARCH STATUS

The first step to study the energy efficiency of the cloud is to have evaluation criteria. The evaluation criteria of IDC consumption normally consist of three modes, including measures of the server, the overall energy consumption of the engine room and the specific energy of the cluster.

*Address correspondence to this author at the Software School, Central South University, Changsha, Hunan 410075, P.R. China;
E-mail: zghu@mail.csu.edu.cn

### 2.1. The Energy Efficiency Standards Test of SPEC [6]

SPEC (Standard Performance Evaluation Corporation) is a global authority in application performance testing organization whose main components are world-renowned universities, research institutions and some IT companies.

The main task of the organization is to establish, maintain, and support a range of relevant benchmarks set which are used to test server and related components. Currently, testing standard for server power consumption is SPECpower_ssj 2008, and energy efficiency units are ssj-ops/watt, which refer to the number of operations regarding executive standard. Sources as shown in Equation 1:

$$\text{Performance to Power Ratio}=\sum \text{ssj\_ops} / \sum \text{power} \quad (1)$$

Performance to Power Ratio refers to the power-performance ratio, namely the energy efficiency. $\Sigma$ ssj_ops represents standard operating unit time performed by the server. $\Sigma$ power represents the power consumed by the server in a period of time. This method is often used to assess the situation on the energy efficiency of servers.

### 2.2. The Standard of Green Grid

Green Grid was founded in 2007, a third-party non-profit organization, in which utility companies, including AMD, HP, IBM and other companies, collaborate to improve the resource efficiency of data centers [7]. The study of energy conducted by the organization ranges from the location of the data center to the server architecture and the use of refrigeration equipment, *etc.*, and research results are

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published in The Green Grid Connection. As a result, the energy efficiency of data centers is more macroscopic, as expressed in formula 2 & 3:

PUE = total facility power / IT equipment power (2)

DCiE = IT equipment power consumption × 100% / total power consumption (3)

PUE means Power Usage Effectiveness. DCiE means Data Center Infrastructure Efficiency.

By estimating and comparing the PUE, enterprises can help to optimize space utilization and improve data center energy efficiency. The measurement criteria are more comprehensive and closer to the data center energy efficiency assessment of the entire project.

### 2.3. The Standard of SONG [8]

Formula 1 is a standard for the estimation of single server energy efficiency. Formulae 2 and 3 are standards for the estimation of the entire data center. A scholar named Song Jie presented a measurement based on the MapReduce Cloud. In his method, SONG defined computation processor at 1 GHz frequency 1 s completed for 1 U, his expression of energy efficiency formula is illustrated in the formula (4):

$$\eta(T)=\frac{L(T)}{E(T)},E(T)\neq 0 \quad (4)$$

Where $\eta$ represents energy efficiency, L (T) represents the time to complete the task within the T (the unit is U). E (T) represents the energy consumption of time T (the unit is Joules). According to the study of Elnozahy, when the computer CPU is running at full capacity of frequency *f*, the power is *P*, and then the power *P* and frequency *f* satisfy the equation (5):

$$P=P_{fix}+P_f f^3 \quad (5)$$

$P_{fix}$ is the power when the computer is in the idle state. As can be seen above, the study of IT equipment energy efficiency measure focused on issues such as the size of a single node, or the entire data center. The energy efficiency measure for Hadoop platform lacks research data. Hadoop platform has its own peculiarities; therefore, its energy efficiency measure has its own characteristics. The research result of SONG compensates for the energy efficiency measure about Hadoop platform to some extent. The calculation of the competency-based metrics can effectively compare different energy efficiency differences between cloud platforms.

However, in actual operation, the workers in Hadoop platform have heterogeneity. There is always a periodic task to run on (search, log analysis, *etc*.) one Hadoop platform, and the efficiency is not the same if different algorithms are used for the same problem. This essay from another angle, measuring different algorithms to solve the same problem on the same Hadoop platform, studies the energy-saving problem.

## 3. MEASURES ABOUT PERIODIC TASK ENERGY EFFICIENCY

Cloud platform is isomorphic in Song's [8] study, and his measurement can judge the efficiency of different cloud platforms. However, in practice, for programs running on the same cloud platform, it is unable to assess the programs' energy efficiency especially when the programs achieve the same goal. This essay studies measures of algorithms on the same cloud platform, the significance of which lies in how to improve the algorithm to make it more energy efficient. Hadoop platform often performs many periodic tasks, therefore, it is more meaningful to study how to be more efficient by adjusting measures.

### 3.1. The Deduction of Measure Methods

It is assumed that in unit time, Hadoop clusters electricity consumed *E*, the number of tasks completed per unit time is n, this job's energy efficiency is:

$$\mu=\frac{E}{n} \quad (6)$$

That means the efficiency of the jobs run on the Hadoop platform is the ratio of electricity consumed per unit time and the period of time to complete the number of jobs. The following is a further derivation of the formula (6):

$$\mu=\frac{E}{n}=\frac{E/t}{n/t}=\frac{P}{f} \quad (7)$$

Formula 7 represents that the job's efficiency on the Hadoop platform is the ratio of the average power of its running time and the frequency of the task. The unit of *P* is W (watts), the frequency *f* is expressed in Hz (hertz), the energy efficiency of the unit is W/Hz. W/Hz is the job efficiency on Hadoop platform. There are two reasons to use equation 6 to explain:

Firstly, Hadoop platform does not shut down after finishing the first job in practice, therefore, the idle time of job interval should be taken into account. The idle time would be more if the speed of task execution increases.

Secondly, many tasks that Hadoop platform performs, such as log analysis or searching, are cyclical, which are based on reality.

### 3.2. Correlation Analysis of Energy-Saving

The research has been conducted regarding what is related to task efficiency, how to improve algorithms' energy efficiency and reduce energy consumption by assuming that Algorithm1 and Algorithm2 can finish the same job, in the same Hadoop cluster, in less than an hour to complete the operation *n* times.

Algorithm 1 completes a task within time $t_1$ and Algorithm2 completes a task within time $t_2$. Suppose $t_1 \leq t_2$, and in this sense, Algorithm 1 is more efficient than Algorithm 2, but how can the relationship be defined between them. Assuming $P_i$ is the power consumption when Hadoop cluster is idle, $P_1$ is the average power when Algorithm1 performs tasks, and $P_2$ is the average power when Algorithm 2 performs tasks. The energy consumption of Algorithm1 and Algorithm2 within an hour is:

$$E_1 = n^* t_1^* P_1+(3600- n^* t_1)^* P_i \quad (8)$$

$$E_2 = n^* t_2^* P_2+(3600- n^* t_2)^* P_i \quad (9)$$

Here, further analysis is carried out for *E1* and *E2* to deduce energy efficiency and the relationship between energy efficiency and the average power of algorithm.

$$E_1 - E_2 = n(t_1 P_1 - t_2 P_2)+n P_i (t_2 - t_1) \quad (10)$$

According to equation (10), the comparison about algorithm efficiency can be transferred to the comparison between $(t_1 P_1- t_2 P_2)$ and $P_i (t_2- t_1)$. From the angle of physics, $(t_1 P_1- t_2 P_2)$ represents the difference between the completion of a task Algorithm1 and energy consumption of Algorithm2, $(t_1 P_1- t_2 P_2)$ represents the difference between the energy consumption in the implementation of idle time on Algorithm1 and Algorithm 2 Hadoop cluster. In other words, the idle time would be longer if the time is shortened to complete the task (such as periodic tasks, searching and sorting). Therefore, energy saving should be the difference between the task time and idle time energy consumption as a whole.

Generally, it is difficult to determine the relationship between energy consumption and time of the algorithm. The time to complete the task would be reduced because of high efficiency, but the idle time will be longer. In order to make more accurate judgment, FAN [9] model is introduced which links power *P* of the server and the utilization of CPU.

$$P_{pred} = C_0 + C_1 * U_{cpu} \quad (11)$$

$C_0$ is a constant and is the power when the server is idle, and $C_1$ is the difference between the server and the server at the power peak in the idle state. There is another linear model based on formula (11) with a calibration item. However, formula (11) is recognized as the foundation with high degree of accuracy. Formula (11) is used as a basis for research, assuming Algorithm 1 and Algorithm 2 running on a cluster that consists of *m* servers, and then the variable of formula (10) can be decomposed into formula (12-14). The job runs in some nodes, turning down the unnecessary nodes is a way to manage energy, and energy efficiency manner is necessary to refine the algorithm to each server. Comparison is carried out about the energy consumption of Algorithm 1 and Algorithm 2 per second.

$$P_i = \sum_{n=1}^{m} p_{ni} \quad (12)$$

$$P_1 = \sum_{n=1}^{m} p_{n1} \quad (13)$$

$$P_2 = \sum_{n=1}^{m} p_{n2} \quad (14)$$

For server A, the energy consumption of Algorithm1 and Algorithm2 is $E_{a1}$ and $E_{a2}$ respectively.

$$E_{a1} - E_{a2} = f(t_1 P_{a1} - t_2 P_{a2}) + fP_{ai} (t_2 - t_1) \quad (15)$$

This step is the same as equation (10), but equation (10) reflects the condition of the whole cluster. Equation (15) is specific to a server. The question about server A that processes tasks under two algorithms is whether the comparison between $(t_1 P_{a1}- t_2 P_{a2})$ and $P_{ai} (t_2- t_1)$ becomes efficient or not. From these two equations, it is evident that there is more energy efficiency when the power of server is lower and the time is shorter under the execution. Supposing that the average utilization of CPU is $\alpha$ when using Algorithm1 to process tasks and the average utilization of CPU is $\beta$ when using Algorithm2 for processing tasks. Server idle power consumption is about the energy consumption of its full load operation 70%, that is $P_{ai} = 0.7\ P_{amax}$.. Combining equation (11), there is:

$$P_{a1} = P_{ai} + \Delta P_a\ \alpha \quad (16)$$

$$P_{a2} = P_{ai} + \Delta P_a\ \beta \quad (17)$$

Bringing equation (16) & (17) into Equation (15)

$$E_{a1} - E_{a2} = f((t_1 P_{a1} - t_2 P_{a2}) + P_{ai} (t_2 - t_1)) = f\Delta P_a(\alpha\ t_1 - \beta\ t_2) \quad (18)$$

For server A, $f\Delta P_a$ is a constant, so when there is the most energy-efficiency, it is that $(\alpha\ t_1- \beta\ t_2)$. Assuming R1 (MI) and R2 (MI) are calculated when the amount of server to perform task utilizing Algorithm 1 and Algorithm 2 (When the number of nodes to perform jobs and the scheduling algorithm is not changed, when completing a job, nodes that share computational tasks barely change) $\varepsilon$ (MIPS) is computing power of CPU for server a, and then it is concluded that:

$$\alpha = \frac{R_1/t_1}{\varepsilon} \quad (19)$$

$$\beta = \frac{R_2/t_2}{\varepsilon} \quad (20)$$

Combining (18), (19) and (20)

$$E_{a1} - E_{a2} = f\triangle P_a(\frac{R_1 - R_2}{\varepsilon}) \quad (21)$$

Because *f*, $\Delta P_a$ and $\varepsilon$ are constants in equation (21), it is believed that computational algorithm directly determines its energy efficiency for servers. For Hadoop cluster, the most important way to improve energy efficiency is to reduce the amount of calculations. However, there are three ways when the number of tasks is unchanged.

(1) Maintaining appropriate node size, such as turning off unnecessary nodes.

(2) The energy consumption is the lowest when nodes are the load balancing for isomorphic server cluster.

(3) Reducing the amount of calculation by adjusting algorithm for non-isomorphic server cluster.

The first method is the most commonly used method, but the use of method 1 must be deployed by using more copies and using a special replica placement strategy. This paper focuses on the way of how to reduce the amount of calculation task in the system.

## 4. THE RESEARCH OF ENERGY EFFICIENCY

From the above derivation, the calculation of energy efficiency of different algorithms on this platform can be well estimated in Equation 2, and the most important factor for the energy efficiency of the algorithm is to complete calculation of the task. Energy-saving question then becomes as how to reduce the computational problems. There are three ways to reduce calculation by analysis of the principles regarding the Hadoop platform.

(1) Improving algorithms and optimizing them.

(2) According to Hadoop framework, optimizing processing tasks link for MapReduce

(3) Reducing the occupancy for Hadoop.

The first is commonly used, but when the algorithm cannot be optimized as when and how to be energy-efficient in computing framework -- the MapReduce framework can be analyzed.

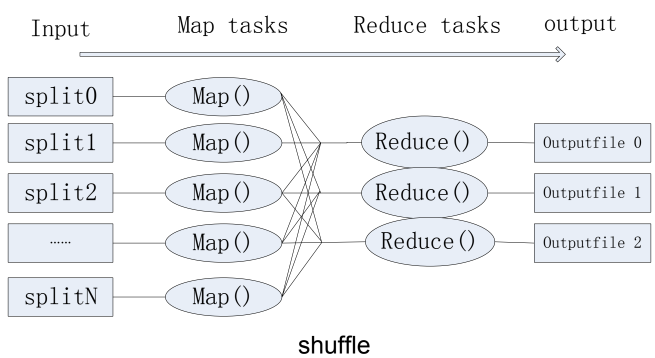


**Fig. (1)** Work flow chart of MapReduce.

When the job scheduler in MapReduce is working, it establishes a Map for each file and assigns tasks to Task Tracker. From this process, it can be seen that a file corresponds to a Map, (Each task operation of Map includes production, scheduling and end time, and a large number of Map tasks may cause some performance loss) but a Map would start a thread. The effective utilization of the resources is lower if there are more threads, because the threads occupy more resources. As a result of this, carrying out merge pretreatment for small files from the analysis about working principles of MapReduce, can reduce energy consumption and improve energy efficiency in theory. MapReduce workflow is shown in Fig. (**1**); each file corresponds to a split while Hadoop default data block size is 64 M. In reality, there are many files stored below this block size with some small files in particular. If merge processes small files, it can reduce the number of Map, reducing the number of processes in the system. In the process of reduction, the number of merger would be reduced. The efficiency and its effects can be confirmed by section 5 of the experiment.

## 5. EXPERIMENTAL COMPARISON

The experiment served two purposes. The first was to verify the effectiveness of energy efficiency metrics in section 4, and the second was to verify the data preprocessing for crushing energy savings as presented in section 5.

Experimental environment is Hadoop2.2.0, 5 sets of heterogeneous PC, hadoop0 is the node of Master, the remaining four are nodes for Slave, this cluster named Hadoop-A. Used hadoop0 as node for Master, Hadoop1 and hadoop2 are nodes for Slave, which is called cluster Hadoop-B. Table **1**.

**Table 1. Cluster configuration.**

| Hadoop-A | Hadoop-B |
|---|---|
| Switch D-link DES-3028 | Switch D-link DES-3028 |
| Hadoop0 | Hadoop0 |
| cpu: 2.00G (2) memory: 1.97G | cpu: 2.00G (2) memory: 1.97G |
| Hadoop1 | Hadoop1 |
| cpu: 2.50G (2) memory: 1.96G | cpu: 2.50G (2) memory: 1.96G |
| Hadoop2 | Hadoop2 |
| cpu: 2.50G (2) memory: 2.95G | cpu: 2.50G (2) memory: 2.95G |
| Hadoop3 | |
| cpu: 2.30G (3) memory: 1.84G | |
| Hadoop4 | |
| cpu: 1.60G (2) memory: 1.97G | |

### 5.1. Data Merge Saving

This essay used benchmark program wordcount in Hadoop as an example, randomly selecting 400 articles and then testing each article as a file (less than 2 M). Within one hour of the Hadoop-A cluster, wordcount was carried out 4 times, after which every four articles merged into one (Reduce system footprint) and still wordcount was carried out 4 times, subsequently making energy comparison.

The following Figs. (**2**, **3**) show a comparison of CPU and memory before and after the merger wordcount. CPU and MEMORY are the two most important parts in a computer:

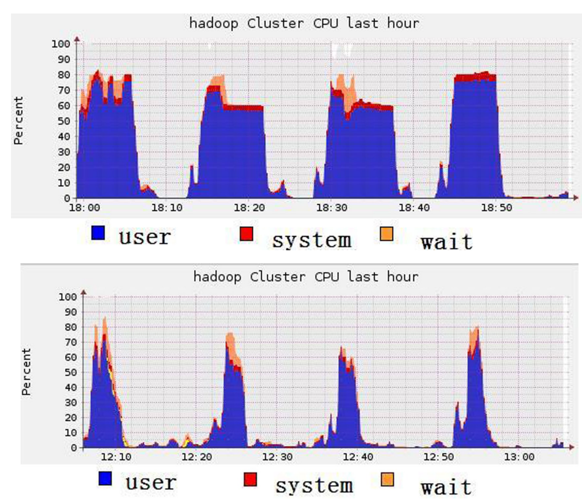


**Fig. (2).** The change of entire cluster CPU utilization.

After merging, although the CPU and Memory utilization is at peak higher than before, it is much faster to process data. As shown in Table **2**, the energy efficiency improved 14.63% after combination, which confirmed the saving method proposed in section 4.

### 5.2. Energy Efficiency Metrics

In Table **3**, energy efficiency is calculated by Equation 1 and different scale Hadoop cluster on the same batch of data before and after the merger when wordcount is carried out. Hadoop-A and Hadoop-B represent different Hadoop clusters, and Hadoop-B cluster is a small cluster consisting of three nodes. q and h represents data processing without merge and data processing with merge respectively.

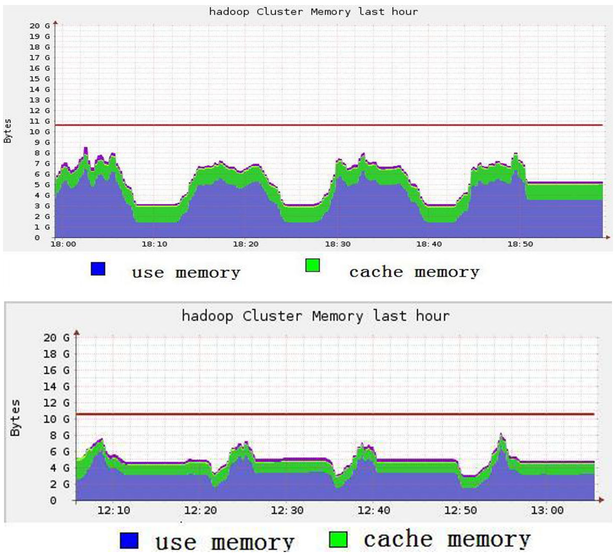


**Fig. (3).** The change of entire cluster Memory utilization.

**Table 2. The energy consumption before and after the file merger (one hour).**

| | Energy |
|---|---|
| Before files merger | 0.41 kwh |
| After files merger | 0.35 kwh |

**Table 3. Energy of different conditions.**

| | Energy Efficiency (W/Hz) |
|---|---|
| HadoopA-q | $3.69\times10^5$ |
| HadoopA-h | $3.15\times10^5$ |
| HadoopB-q | $2.34\times10^5$ |
| HadoopB-h | $1.98\times10^5$ |

As shown in equation1, different methods (algorithms) to achieve the same purpose on unified platform can be compared, and energy efficiency using the same algorithm on different Hadoop platforms can be measured.

Discrimination is quite obvious whether there are different algorithms on same platform or different platforms on same algorithm.

Therefore, equation1 can not only measure energy efficiency of a task on different Hadoop platforms, but also measure the energy efficiency of different algorithms to achieve the same goal. Formula 1 is a more reasonable way to measure.

## CONCLUSION

For cloud computing clusters, this essay proposed a very effective way to measure, which significantly distinguishes the relationship of energy efficiency in different ways to perform the same task (algorithm) on the same platform. The effective way to save energy from merger small files on Hadoop was presented which has been proven to be efficient by experiments. The next step to study is how to divide the data blocks achieving optimal energy efficiency.

## CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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