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The research of Measuring Approach and energy efficiency for Hadoop periodic jobs

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Abstract: Current consumption of cloud computing has attracted more and more attention of scholars. Hadoop as a cloud platform, the research about its energy consumption has also received considerable attentions 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 Hadoop platform. Combining with the current mainstream about energy estimate formula to conduct further analysis, this paper has reached a conclusion about 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 of energy-saving and verify the feasibility of the method for measurement of periodic tasks at the same time.

Keywords: Hadoop, energy efficiency, measurement method, energy saving.

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 platform, 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 develops 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 about Hadoop[2][3] focuses on performance optimization but it's 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 how to be energy efficiency though 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.

2.1The 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.

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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 standards for server power consumption is SPECpower_ssj2008, and energy efficiency units are ssj-ops/watt, which means the number of operations about executive standard. Sources as shown in Equation 1:

$$\text{Performance to Power Ratio}=\sum ssj\_ops \,/\, \sum power \tag{1}$$

Performance to Power Ratio means the power-performance ratio, namely energy efficiency. Σ ssj_ops represent standard operating unit time performed by the server. Σ 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[7]

Green Grid was founded in 2007, a third-party non-profit organization, which utility companies, including AMD, HP, IBM and other companies, collaborate to improve the resource efficiency of data centers. 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 published in The Green Grid Connection. As a result, the energy efficiency of data centers is more macroscopic, as formula 2,3:

$$PUE = \text{total facility power} \,/\, \text{IT equipment power} \tag{2}$$

$$DCiE = \text{IT equipment power consumption} \times 100\% \,/\, \text{total power consumption} \tag{3}$$

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

By the estimate and compare 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.

1.3 The standard of SONG [8]

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

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

η 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 satisfies the equation(5)

$$P = P_{fix} + P_f f^3 \tag{5}$$

P_{fix} is the power when the computer is in the idle state. As can be seen from the 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. Hadoop platform has its own peculiarities; therefore, its energy efficiency measure has its own characteristics. The research result of SONG compensate for the energy efficiency measure about Hadoop platform to some extent. To calculate 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 will always be periodic task to run on (search, log analysis, etc.) on one Hadoop platform, and the efficiency is not the same by using different algorithms to 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 measure can judge the efficiency of different cloud platform. However, in practice, for programs run 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 lies in how to improve the algorithm to make it more energy efficiency. Hadoop platform often perform many periodic tasks, therefore, it is more meaningful to study how to be more efficiency by adjusting measures.

3.1 The deduction of measure methods

We assume 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:

$$\mu = \frac{E}{n} \tag{6}$$

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)

$$\mu = \frac{E}{n} = \frac{E/t}{n/t} = \frac{P}{f} \tag{7}$$

Formula 7 means 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 about what is related to task efficiency, how to improve algorithms energy efficiency and reduce energy consumption. Assuming that Algorithm1 and Algorithm2 can finish the same job, in the same Hadoop cluster in less than an hour to complete these operation n times.

Algorithm1 complete a task within time t_1 and Algorithm2 complete a task within time t_2. Suppose $t_1 \leq t_2$, from this sense, Algorithm1 is more efficient than Algorithm2, but how to define the relationship between them? Assuming P_i is the power consumption when Hadoop cluster is idle, P_1 is the average power when Algorithm1 perform tasks, P_2 is the average power when Algorithm2 perform tasks. The energy consumption of Algorithm1 and Algorithm2 within an hour is:

$$E_1 = n * t_1 * P_1 + (3600 - n * t_1) * P_i \tag{8}$$

$$E_2 = n * t_2 * P_2 + (3600 - n * t_2) * P_i \tag{9}$$

Here is further analysis about $E1$ and $E2$ to deduce energy efficiency and the relationship between energy efficiency and the average power of algorithm.

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

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 Algorithm2 Hadoop cluster. In other word, the idle time would be longer if shortening the time 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 continue 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, we introduce FAN [9] model, which will link 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 power in the idle state. There is another linear model based on (11) with a calibration item. However, formula (11) is recognized as the foundation with high degree of accuracy. We use formula (11) as a basis for research, assuming Algorithm1 and Algorithm2 running on cluster that consist of m servers, and then the variable of formula (10) can be decompose 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. We have comparison about the energy consumption of Algorithm1 和 Algorithm2 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 efficient or not becomes the comparison between ($t_1 P_{a1}$- $t_2 P_{a2}$) and P_{ai} (t_2- t_1). From these two equations, it is more energy efficiency when the power of server is lower and the time is shorter under the execution. Suppose, the average utilization of CPU is α when using Algorithm1 processing tasks, and the average utilization of CPU is β when using Algorithm2 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

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

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

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

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

For server A, $f\triangle P_a$ is a constant,so when is the most energy-efficient is that(α t_1- β t_2).Assuming R1 (MI) and R2 (MI) are calculated when the amount of server to perform task utilizing Algorithm1 and Algorithm2 (When the number of nodes to perform jobs and the scheduling algorithm is not change, when complete a job, nodes that share computational tasks barely changed) ε (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) and (19)(20)

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

Because f, $\triangle P_a$ and ε are constants in equation(21), that 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 load balancing for isomorphic server cluster.

(3) Reducing the amount of calculation by adjusting algorithm for nonisomorphic server cluster.

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

4.THE RESEARCH OF ENERGY EFFICIENCY

From the above derivation, the energy efficiency of different algorithms on this platform can be well performed in equation2, and the most important factor about the energy efficiency of the algorithm is to complete calculation of the task. Energy-saving question then becomes to reduce the computational problems. There are three ways to reduce calculation by analysis of the principles about Hadoop platform.

(1) Improving algorithms and optimizing it.

(2) According to Hadoop framework, optimizing processing tasks link for MapReduce and reduce the occupancy for Hadoop.

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

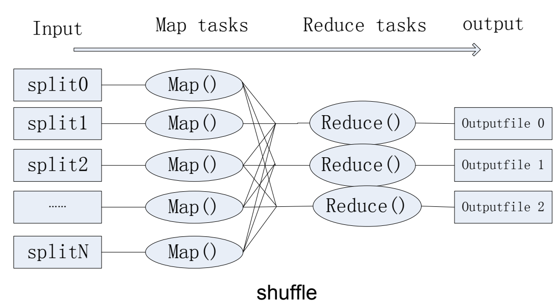


Fig.(1) Work flow chart of MapReduce

When the job scheduler in MapReduce is working, it will establish a Map for each file and assign 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 a large number of Map tasks will 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 will occupy more resources. As a result of it, doing merge pretreatment for small files from the analysis about working principles of MapReduce, and it can reduce energy consumption and improve energy efficiency in theory. MapReduce workflow has been shown in Figure 1; Each file corresponds to a split while Hadoop default data block size is 64M. In reality, there are many files stored below this block size, some small files in particular. If merge processing 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. We can confirm the efficiency and its effects by Section 5 of the experiment.

5.EXPERIMENTAL COMPARISON

The experiment has two purposes, the first is to verify the effectiveness of energy efficiency metrics in section 4, and the second is to verify the data preprocessing for crushing energy savings are correct 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.

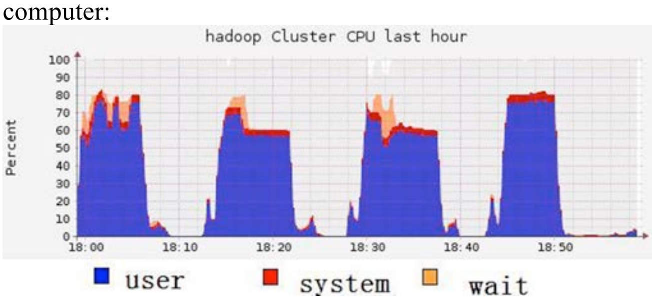
Hadoop-A	**Hadoop-B**
Switch D-link DES-3028	Switch D-link DES-3028
Hadoop0	Hadoop0
cpu: 2.00G (2) memory: 1.97G	cpu: 2.00G (2) memory: 1.97G
Hadoop1	Hadoop1
cpu: 2.50G (2) memory: 1.96G	cpu: 2.50G (2) memory: 1.96G
Hadoop2	Hadoop2
cpu: 2.50G (2) memory: 2.95G	cpu: 2.50G (2) memory: 2.95G
Hadoop3	
cpu: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

Table1. Cluster Configuration

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 2M). Within one hour of the Hadoop-A cluster do wordcount 4 times, after that every four articles merge into one(Reduce system footprint) and still do wordcount 4 times, and then making energy comparison.

The following Figures 2 and 3 is is a comparison of CPU and memory before and after the merger do wordcount, CPU and MEMORY are the two most important parts in a computer:



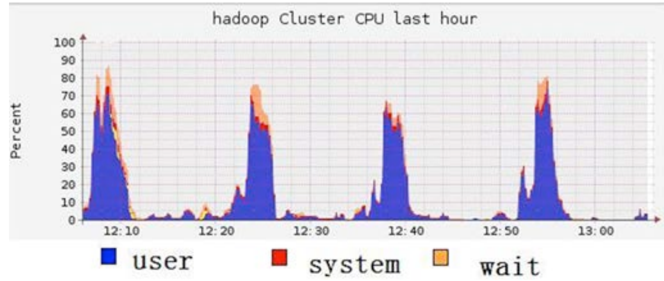


Fig.(2) the change of entire cluster CPU utilization

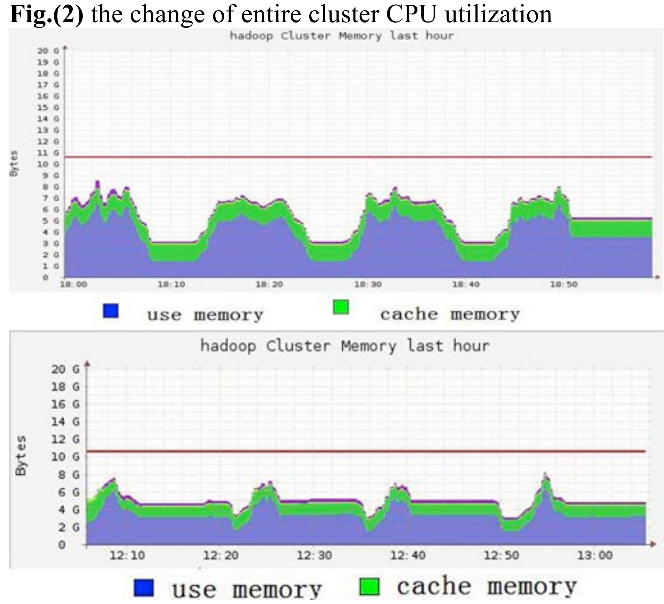


Fig.(3) the change of entire cluster Memory utilization

Table2. the energy consumption before and after the file merger (one hour)

	Energy
Before files merger	0.41kwh
After files merger	0.35kwh

After merging, although the CPU and Memory utilization at peak higher than the before, it is much faster to process data. As shown in Table2, the energy efficiency improved 14.63% after combination, which confirmed the saving method proposed in Section 4

5.2 Energy Efficiency Metrics

In Table3, 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. Hadoop-A and Hadoop-B represent different Hadoop clusters, and Hadoop-B cluster is a small cluster consists of three nodes. q And h represents data processing without merge and data processing with merge respectively.

Table3. Energy of different conditions

	Energy efficiency(W/Hz)
HadoopA-q	3.69×10^5
HadoopA-h	3.15×10^5
HadoopB-q	2.34×10^5
HadoopB-h	1.98×10^5

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 platform can be measured.

Discrimination is quite obvious whether it is 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 platform, but also measure the energy efficiency of different algorithms to achieve the same goal. Formula 1 is a more reasonable way to measure.

6. 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 those merger small files on Hadoop and this method has been proved to be efficient by experiments. The next step to study is how to divide the data blocks achieve optimal energy efficiency.

CONFLICT OF INTEREST

The author confirms that this article content has no conflict of interest.

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