Proceedings of the 5th WSEAS Int. Conf. on SIMULATION, MODELING AND OPTIMIZATION, Corfu, Greece, August 17-19, 2005 (pp83-88)

The Computon in Computing Grid

Junguo Yu, Huaping Chen, Yuewen Liu
Management School
University of Science and Technology of China
Hefei, Anhui, 230026
China

Abstract: - Computon is a concept to denote the bundle of processing power, storage, and bandwidth that can be sold and consumed. In this paper, the method to form the computon is suggested, and how to set the weight which is the key factor to form the computon is also been researched. At the last part of this paper, it suggests the processes to charge the resource users and to allocate the revenue to the resource providers.

Key-Words: -computing grid; computon; computing resource;

1 Introduction

The concept of utility computing holds enormous appeal for potential service providers hoping to create the information technology equivalent of the electric industry. The vision: Access to extra processing power or storage capacity, or bandwidth will be as easy as turning a tap to fill a tub with water.

HP Senior Fellow Bernardo Huberman and his team at HP Labs are working toward an answer. It involves what they call computon [1], which is a unit of measurement for the use of computing resources. They define the computon as a bundle of processing power, storage, and bandwidth that can be sold and consumed.

Like many other economic entities, a computon's value can change constantly, automatically rising or falling based on factors such as demand for particular applications, types of computing resource, time of day and project priority.

Until now, there are many papers about how to allocate computing resource with the method of economic model. In [2, 3 and 4], the authors consider the computing resource as commodities to trade with each other based on the theory of commodity market. The change of the supply and the demand of resource influence the price. They are the pioneers to use economic theory to allocate computing resource in grid. The shortage of them is that they didn't analysis the structure of the resource market, and personally supposed that the resource market is in the state of completely competition, and they didn't consider whether they should price each kind of computing resource or price the combination of them.

In [5, 6], the authors are pricing the computing resource from the view of multiple units combination auction. They try to allocate the computing resource and price them with the method of winner determination. Though they consider the combination of computing resource, its price is randomly set by the bidders with their private cost function; it can't reflect the change of the supply and the demand of the computing resource in resource market.

The concept of computon is to solve the problem mentioned above. The transform of many kinds of computing resource to uniform virtual resource could simplify the process of pricing resource. With the economic theory, the computing resource could be traded on the base of standardized unit, and with the computon, it is beneficial to do with the settlement of the expense of usage.

After the concept was referred in 2003 by Huberman, many people and corporations only pay attention to the meaning involved in the concept and have no good result. In this paper, we'll make use of the concept of computon and try to do some job about the method of its form and the pricing method, also solve the problem of how to charge the users and allocate the revenue to resource providers. We are only doing the beginning work.

2 The Resource System in Computing Grid

In this paper, we use the computing resources allocating framework of [7], and simply it to form the system structure as figure 1.

The following are the notations to be used in the following section:

GIS is the grid information service nodes which could be logical.

GD_i denotes i th grid domain which is composed of many participants involved in the computing grid, and $i \in [1, n]$.

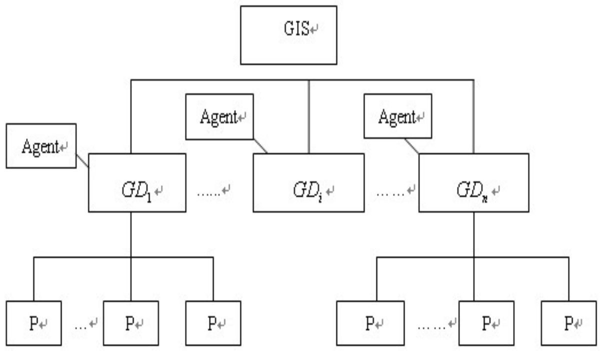

Figure 1: The Resource System in Computing Grid

P denotes the participants which could be either the resource user or resource provider.

The computing grid is constituted by n domains, and in each domain, there are so many participants who could be either the consumers of computing resource or the providers of it. We use P to denote the participants. Also an agent is set in each domain to watch the information such as to see which are the participating nodes and the distributing of computing resource and how many proportional resources the node want to provide and so on. The agent should report the information it knows to the informational service node of computing grid, which we denote as GIS, so the grid could master the distributing information of the computing resource within the whole system.

In this section we simply introduce the resource system in the computing grid. Next we'll give the method to transfer several real computing resources to a virtual resource which is called computon.

3 The Method to Form Computon

The goal of computing grid is to have the familiar attribute with the power grid. In the gird when a user needs computing power to complete his task, what he should do is only to pay the expense with the price set before according how much the computing power he has used.

To reach the goal mentioned above, the standardization of the computing resource should be considered .It is a big problem to integrate the different kinds of computing resource and the same kind but heterogeneous resource. Next we will give some clues to this problem.

3.1 Computing the Amount of Resource

Some papers [3, 9, and 9] refer that the following kinds of computing resource should be considered to charge. They are processing power, storage, bandwidth and some other computing resource. So we only have to standardize these kinds of resource.

First we set a standardized value for each kind of computing resource, for example, we define 64M as the standardized value for the memory, and set it as "1" unit of memory. If a machine holds 640M memory, it has 10 units of standardized memeory. Other computing resource is so on. Suppose that there are m kinds of computing resource.

We use j ($j \in [1, m]$) to denote the j th computing resource. Thus, we could use a vector to describe the quantity of all kinds of computing resource that belong to a participant.

It is $X_i^k = (x_{i,1}, x_{i,2}, \cdots x_{i,j}, \cdots x_{i,m})^T$,in which X_i^k means the i th participant's resource in k th domain, x_{ij} means the quantity of j th resource that X_i^k owns, and T means the transfer of a matrix.

Obviously, $X_0 = (1,1,\cdots\cdots 1)^T$ means the quantity of each kind of resource of the participant is one standardized unit, and we could look it as the standardized resource denoted by a vector.

In the description above, $k \in [1, n]$ is the number of domain in the market, $i \in [1, l]$ is the i th participant in the k th domain, and we suppose that in k th domain there are l participants.

We define e_j = （0，0，…，1，…0）as the resource combination in which the quantity of j th resource is 1 and others is 0.

We use γ_{kj} to describe the quantity of the j th resource in GD_k , then

$$\gamma_{kj} = \sum_{i=1}^{l} (0,0,\cdots,1,\cdots,0)(x_{i1}, x_{i2}, \cdots, x_{im})^T = \sum_{i=1}^{l} e_j \cdot X_i^k \quad (1)$$

We use S_j to describe the quantity of the j th resource in all the computing grid, then

$$S_j = \sum_{k=1}^{n} \gamma_{kj} = \sum_{k=1}^{n} \sum_{i=1}^{l} e_j \cdot X_i^k \quad (2)$$

3.2 Computing the Amount of Computon

Next we'll set the weight for each kind of computing resource. When the resource is used by users, the users pay the providers according the price of the resource and the quantity of the resource that had been used. The price we mean is the price of the combination of a bundle of different kinds of computing resource. Analysis the price of the combination, we could find that the contribution of each kind of resource to the price is not the same, which is varied with the supply and the demand of the resource and the importance of the resource to the running of the task that has been completed. Here we use a vector to describe the rate of contribution of the certain resource to the price of the resource combination. It is $\alpha = (\alpha_1, \alpha_2 \cdots, \alpha_j \cdots, \alpha_m)$,in which α_j is rate of the contribution of the j th resource to the price of the resource combination, also it could be considered as the weight of j th resource., which denotes the importance of the certain resource to the running of a task. Obviously $\sum_{j=1}^{m} \alpha_j = 1$. In fact, when a task is submitted to run, lack of any kind of resource will lead to its failure. Each kind of resource is necessary, so α is only used to compare the relative importance of each other.

We have that

$$q_0 = \alpha \cdot X_0 = \sum_{j=1}^{m} \alpha_j = 1 \tag{3}$$

$$q_i^K = \alpha \cdot X_i^k = \sum_{j=1}^{m} \alpha_j x_{ij} \tag{4}$$

From the equation of (3) and (4), we could know that with α , m kinds of resource could be transferred to a resource combination, which we use "computon" [1] to mean it. The concept of computon is mentioned above. X_0 is the unit of it. To a participant who has the quantity of real resource is X_i^k , the computon he has is $q_i^k = \sum_{j=1}^{m} \alpha_j x_{ij}$. Though the rate of contribution to price, different resource could be integrated to a virtual resource of computon, and in computing grid, the supply and the demand of the computon could be counted. According the principle of equilibrium price in the market, we could first compute the equilibrium price of the computon based on the law of supply and demand, then with the rate of contribution to the price, the real price of m kinds of real resource could get. It means that if we know the price of computon is P , the price of j th resource is

$$P_j = \alpha_j \cdot P \tag{5}$$

Here the meaning of computon is similar to the watt to the power system. With the rate of contribution to price, each kind of real resource is transferred to the computon; it is the normal computing power.

Thus the quantity of computon in a node is

$$q_i^K = \sum_{j=1}^{m} \alpha_j x_{ij} \tag{6}$$

And the quantity of computon in a domain is

$$q^K = \sum_{i=1}^{n} q_i^K = \sum_{i=1}^{n} \sum_{j=1}^{m} \alpha_j x_{ij} \tag{7}$$

The quantity of computon in all the market is

$$q = \sum_{K=1}^{l} q^K = \sum_{K=1}^{l} \sum_{i=1}^{n} \sum_{j=1}^{m} \alpha_j x_{ij} \tag{8}$$

When a resource user submits his task, the agent could analysis the performance of time and space it needs and value the probable quantity of each kind of real resource, then through the transform with α , the agent could probably estimate the quantity of the computon that the task needs.

Thus all the supply and the demand of the resource in the system could be expressed with computon, it providers the convenience when we compute the price of the resource in the grid system.

Because the participants in the computing grid is free to join or leave, the amount of the resource may change much in a moment, and that leads the price to vary much. In order to master the information of the spot price in grid, we could use the theory of statistics to monitor the state of the demand and the supply. It is periodic and long term work to do the statistic. The period of time can be adjusted according the overall resource information in system. If the demand and the supply are stable, the period of statistic can be relatively long; otherwise if the demand and the supply are changing much, the period of statistic should be short and we should enhance the statistical frequency.

4 Pricing the Computon

Someone may think that it is not reasonable to use the uniform price of the computon on all the users because of the multiformity of them. But if we over-emphasize the individual difference and use different price for different resource-exchange case, it will be very complicated and nonsense. With a good charge system and the profit-allocating system, the participants could get what they want with the uniform price.

So how should we price the computon? We mentioned above that computing power of one unit of computon is the power that one unit of each kind of computing resource cooperate to complete a task. In computing grid, the expense of the exchange uses the electronic currency instead of the currency. Thus, we could set the price of one unit of computon be p unit of electronic currency.

How to set the value of p ? The computon is combined by several kinds of computing resource, and there is cost for each one. Also the value that a kind of standardized computing resource creates in different period is varying, so it isn't a simple process to set the value of p . It is related with the cost of the resource, the demand and the supply of it, the time, and other factors. Simply we could use a function to set the value of p .That is $p = P(S,D,C,T,O)$,in which, S denotes the supply of resource, D denotes the demand of resource, C denotes the cost of each standardized resource, T denotes time, and O denotes other factors. In the following research, we will consider the detail of the process to set the value of p , and use the numerical value to demonstrate it.

Is the value of p fixed? In the computing grid, the demand and the supply are changing all the time. When the supply exceeds the demand, the price will be lower; otherwise when the demand exceeds the supply, the price will be higher. But to an individual case, especially when the task is submitted and is running, whether the change of supply and demand in outside grid influences its price? We think that the value of p is fixed in a period of time. After a period of time, the system releases new value of p according current demand and supply. Because it's too difficult to predict the change, a result may be that when the tasking is running after the price has been set, the demand and supply change much after the exchange, the price of the resource changes too at the current time. Thus if the new price is much higher than before, the provider will endure potential loss; if the new price is much lower than before, the user in the exchange will pay more. In order to minimize the potential loss to each other, the system could take the average price of a period of time as the price to be reported out according the trend of the change of the resource. For example, if the system reports the price at a period time of h , the price reported at time t is $p(t) = [\alpha(t) + \alpha'(t+h)]/2$, in which, $\alpha(t)$ is the price computed through the equilibrium of demand and supply at time t , and $\alpha'(t+h)$ is the predicted price for time $t+h$.

5 Computing the Value of α

In the 3rd section, with the method of standardization and the rate of contribution to price, all real resource could be transferred to computon, it gives convenience to do research.

To pricing the computon, it is important of the rate of contribution to price. After we get the price of the computon in system, only with the rate of contribution to price, the real price of each kind of real resource could be computed reversely. This section we'll use the theory of statistics to compute the value of α .

From the section above, we know that after each period of some time, the GIS need to count the quantity of the supply and the demand of computon, also with the real exchange case. Generally we suppose that in the period of $[t_{i-1}, t_i]$, among the real exchange cases, we randomly select a set of exchange cases, it is $T = \{T_1, T_2, \cdots T_i \cdots\}$, in which $T_i = \{(x_{i1}, x_{i2}, \cdots x_{im}), t_i, c_i\}$. It is a integrated vector, and T_i is the i th case selected, the combination of $(x_{i1}, x_{i2}, \cdots x_{im})$ is the corresponding quantity of each kind of resource in T_i , t_i means the time lasted in the case, also it could be considered as the runtime of the task , and c_i is the trade expense the user should pay.

Because the real exchange is different from the task's computing complexity and its other characteristics such as the data intensity or computing intensity, so the quantity and the kinds of real resource used to run the task is much different. To solve this problem, we could classify the set of exchange cases T to several subset based on the characteristic of the task. The tasks which have similar characteristics can be classified to a subset. In the section above, we suppose that there are m kinds of resource. Now with the method of clustering analysis, we divide the set of T to m subsets according the difference of the quantity of the m kinds of resource that the task used. We suppose those subset are s_1 , s_2 , …, s_m .

In the subset s_k , after the period of cutting down the abnormal samples, we select l cases among it. Suppose the resource matrix of the l cases is

$$X_k = \begin{pmatrix} x_{11}, x_{12}, \cdots\cdots x_{1m} \\ x_{21}, x_{22}, \cdots\cdots x_{2m} \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ x_{l1}, x_{l2}, \cdots\cdots x_{lm} \end{pmatrix}.$$

Another method to express X_k is : $X_k = (X_1^k, X_2^k, \cdots, X_m^k)$, in which X_j^k is the j th column of X_k.

Thus in s_k, the average quantity of j th resource that the l cases have used is

$$EX_j^k = \frac{1}{l}\sum_{i=1}^{l} x_{ij} \qquad (9)$$

And the average quantity of computon that the l cases have used is:

$$EX_1^k \cdot \alpha_1 + EX_2^k \cdot \alpha_2 + ... + EX_m^k \cdot \alpha_m = \sum_{j=1}^{m} EX_j^k \cdot \alpha_j \qquad (10)$$

The average cost to use the resource is:

$$Ec_i = \frac{1}{l}\sum_{i=1}^{l} c_i \qquad (11)$$

And the expected average price to computon is:

$$P_k = E\frac{c_i}{t_i} \qquad (12)$$

According the equation of quantity multiply the price equates the overall cost, we have the equation:

$$[\sum_{j=1}^{m} EX_j^k \cdot \alpha_j] \cdot P_k = Ec_i \qquad (13)$$

And

$$\sum_{j=1}^{m} EX_j^k \cdot \alpha_j = Ec_i / E\frac{c_i}{t_i} \qquad (14)$$

In the equation of (14) ,because we could get EX_j^k and $Ec_i / E\frac{c_i}{t_i}$ through computing with the information data in the real exchange cases, there are only m unknown factors in α. Also we know that to each subset s_1, s_2, …, s_m, equation (14) is true, so there are m equations. Solving the m equations, we could get the value of the m unknown factors in α.

6 Processes to Charge the Users and Allocate the Revenue to Providers

6.1 Charges to Resource Users

After the user submits the task and when it is running, the agent of the domain that the user is belonging to monitors the resource used in local domain and computes how much computing resource the user has used. Because the resource that the users used may distribute in many domains, the GIS node should collect the information of all the resource that is used after the task is completed. According the price set before and the quantity of the resource be used, GIS computes the expense that the user should pay.

6.2 Allocation Revenue to Resource Providers

After the GIS node collects the entire expense that all the nodes which used the resource should pay in a period of time, it will allocate the revenue among the nodes that provide the resource. We mentioned above that the price is based on computon, and not the price of real resource. Maybe some nodes only provide few kinds of resource and not all kinds. Also the quantity of each node provided is not the same. So how to specify the revenue that should be allocated to each node is a problem that should be considered.

Here we use a simple example to explain how to allocate the revenue to each node involved.

Supposed that the task T submitted by user U is scheduled to 4 nodes, the id number of the four nodes is 1,2,3,4. The node of number 1 and 2 is in domain 1; the node of number 3 is in domain 2; the node of number 4 is in domain 3. All together T has used 500 units of resource, 700 units of resource B, 200 units of resource C, 400 units of resource D, and 100 units of resource E. At the moment of scheduling, the weight of each resource is respectively $0.3, 0.1, 0.2, 0.25, 0.15$. After T is completed, node 1 provides 300 units of resource A, 200 units of resource B and 300 units of resource E; node 2 provides 200 units of resource A and 400 units of resource D; node 3 provides 500 units of resource B and 300 units of resource D; node 4 provides 200 units of resource C.

First GIS gathers the information collected by each agent about the resource used by T and gets the result of the quantity that U has used. It is $q = 500\times0.3+700\times0.1+200\times0.2+400\times0.25+100\times0.15=375$. If the price set before is p, the expense that the user should pay is $375p$.

Then GIS allocates the revenue according the real resource that each node provided.

For node 1, the revenue is:

$R_1 = (300\times0.3+200\times0.1+0\times0.2+0\times0.25+100\times0.15)\text{p}=125\text{p}$

For node 2, the revenue is:

$R_2 = (200\times0.3+0\times0.1+0\times0.2+100\times0.25+0\times0.15)\text{p}=85\text{p}$.

For node 3, the revenue is:

$R_3 = (0\times 0.3+500\times 0.1+0\times 0.2+300\times 0.25+0\times 0.15)\text{p=125p}$.

For node 4, the revenue is:

$R_4 = (0\times 0.3+0\times 0.1+200\times 0.2+0\times 0.25+0\times 0.15)\text{p=40p}$.

So the revenue of each node is respectively $125p, 85p, 125p, 40p$, we could see that the sum of the revenue of each node is equating with the fee that user U paid.

By this example, we could see that the revenue of a provider is relative with the quantity of the computons he provides.

7 Conclusions and Future work

In this paper, we simply give the method to form the computon which is a bundle of processing power, storage, and bandwidth that can be sold and consumed. Also we discussed how to set the weight for each real computing resource which is used to form the computon and reflect the relative importance when they are coordinated to run a task. The method about how to compute the value of weight vector is suggested. At the 6^{th} section, we suggested the processes of how to charge the resource users and how to allocate the revenue to the resource providers.

The contribution of this paper involves the next three aspects.

(1) It gives the method of how to form the computon. Because the completeness of a task need the coordination of many kinds of computing resource, the multiformity of the computing resource makes the process to pricing them and to confirm the amount of usage complex and difficult. With the computon, a uniform unit of virtual resource, the problem above could be easily solved.

(2) It gives a function to pricing the computon. Because computon is combinatorial resource, the process to pricing it should consider many factors, such as the cost of each kind of real resource and the supply and the demand of them. This paper gives a simple function, which involves each related factors and gives the direction of how to pricing computon.

(3) It gives a simple example of settlement. Because of the space limitation of the paper, we don't introduce the details of the settle, and only with a simple example to clearly indicate the process.

Because we haven't set up a perfect model to simulate the computing grid, we can't get reasonable result about computon. We are only focus on the research of theory.

In the following work, we'll gradually make use of the conclusion above in the test model to validate its validity and efficiency and improve them to get much better result.

Preference:

[1] Hewlett-Packard corporation, An Economy of IT: Allocating Resources in the Computing Utility,*http://www.hpl.hp.com/news/2003/oct_dec/computons.html*, 2003.

[2] R. Buyya, D. Abramson, and J. Giddy:An Economy Driven Resource Management Architecture for Global Computational Power Grids. *Proceedings of the 2000 International Conference on Parallel and Distributed Processing Techniques and Applications* (PDPTA 2000).

[3] Rajkumar Buyya: Economic-based Distributed Resource Management and Scheduling for Grid Computing. A thesis submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy, School of Computer Science and Software Engineering Monash University, Melbourne, Australia. April 12, 2002.

[4] R. Buyya, J. Giddy, and D. Abramson: An Evaluation of Economy-based Resource Trading and Scheduling on Computational Power Grids for Parameter Sweep Applications. *Proceedings of the 2nd International Workshop on Active Middleware Services* （ACM 2000）.

[5] C. Chen, M. Maheswaran, and M. Toulouse: Supporting co-allocation in an auctioning-based resource allocator for Grid systems. *1th IEEE Heterogeneous Computing Workshop* (HCW 2002).

[6] T. Sandholm: An Algorithm for Optimal Winner Determination in Combinatorial Auctions. *International Joint Conference on Artificial Intelligence* (IJCAI),1999, pp. 542-547.

[7] Jun-yan Zhang, Fan Min, and Guo-wei Yang: Integrating New Cost Model into HMA-based Grid Resource Scheduling. GCC2003

[8] Foster, I., Kesselman, C., Tuecke, and S.: The Anatomy of the Grid: Enabling Scalable Virtual Organizations. International J. Supercomputer Applications, 15(3), 2001.

[9] K. Krauter, R. Buyya, and M. Maheswaran: A taxonomy and survey of Grid resource management systems. *Software Practice and Experience*, Feb 2002,Vol. 32, No. 2.