Dynamic Pricing Trading Market for Resources Sharing in IIU Federated Cloud

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Abstract

Internet Innovation Union (IIU) is a union composed of universities and scientific research institutions aim to realize resource sharing. The composition and usage characteristics of the shared resources in IIU were analyzed. By introducing market mechanism in resources sharing process, the dynamic pricing strategy for resources sharing was studied and a trading market comprises of federation members and market agent was proposed. The market agent adjusts the profit rate of resources dynamically according to the statistical data of the supply-demand relationship, thus to achieve dynamic change of resource prices along with the supply-demand relationship. The market is easy to implement in IIU federated cloud, and the experimental results indicated that it can further open sharing of resources and improve resource utilization.

Keywords: *federated cloud, resource sharing, dynamic pricing, resource market*

1. Introduction

Since the beginning of the Internet, it has gone through 40 years of glorious course of development, the Internet is also facing a lot of problems needed to resolve. Today, a new round of the global wave of Internet innovation is sweeping across the world, the next generation Internet is not only the foundation platform of science and technology innovation, but also a strategic point of global science and technology competition. The United States and the European Union have expanded the strategic contention in the aspects of Internet technological innovation through Internet technology experiment platform project GENI [1] and the FIRE respectively. Although China Next Generation Internet research development and platform construction has made remarkable achievements, but the phenomenon of the resources for education and scientific research is not balanced and the cooperation in Internet technology innovation team is not fully is relatively serious, it is urgent need to promote the integration sharing of the Internet science and technology innovation resources and collaboration.

In order to solve the present problem in China Internet application innovation such as Internet experiment resources distribution uneven, the cooperation in Internet technology innovation team is not fully, *etc.*, the ministry of education science and technology development center took the lead founding the Internet Innovation Union (IIU).The union is a cross-sectoral, cross-ownership nonprofit technology innovation strategic alliance, which aim to organize and promote the international and domestic universities, scientific research institutions and enterprises to develop the construction of Internet applications open innovation platform, promote the cooperation in the field of Internet experiment technology research and development, promote sharing of Internet technology experiment resources. The union is sponsored voluntary federatively by domestic colleges and universities, the Internet industry related scientific research institutions and enterprises according to the principle of "voluntary, equality and cooperation". The theme of the union is technology research and development, standardization and industrialization of the future Internet related.

Achieving effective open and sharing of Internet technology experiment resources is one of the main purposes of the union. With the development of information technology, using cloud computing architecture to promote the efficiency of the network and infrastructure of colleges and universities has been general trend of the times. Internet Innovation Union use the technical means of federated cloud to achieve integration and sharing of the Internet technology laboratory equipment resources between different experimental platforms in different areas. Using federated cloud to interconnect the experiment platform resources of each school together, which avoids the risk of the massive redundant construction and can eliminate the limitations in the space of experiment equipment, geographical location, hardware resource, software resource of various experimental institutions and promotes open sharing of information resources and equipment resources in different regions and different experimental institutions and reduces the experimental cost and improves the utilization efficiency of lab equipment and helps to reduce or even eliminate regional disparities.

Now at the preliminary stage of the union construction, the ministry of education science and technology development center offers an introductory financial support to encourage members to provide shared resources and maintain the development of the union. The resources in IIU federated cloud are invested independently by each member and maintained by themselves and voluntary cooperation. The members of the union can use all the resources in certain conditions. Though this way can provide a good environment and safeguard for sharing resources, it neglects the initiative of the subject of resource sharing, and also ignores the objective laws in the process of resources sharing. Ignoring the market mechanism in the process of resources sharing is very adverse for the development of the IIU federated resources market, it would greatly reduce the enthusiasm of other scientific research institutions to join into the federation and members to share resource.

In this paper the market mechanism is introduced into the process of resources sharing in the IIU federated cloud. Resource sharing is proceed through dynamic pricing of the experiment resources the federal cloud members shared, and thus to appeal universities, scientific research institutions join into the federation and motivate the member institutions to share more resources.

2. Related Work

Although cloud computing technology [2-3] is development rapidly, resources supply reasonably for cloud providers is still a great challenge. On the one hand the providers can provide service for most of the requests only need a limited number of resources, but this would result in refusing clients in the peak times. On the other hand, low utilization rate of resources in off-peak times leads the providers to improve the service price to maintain profit. The federation overcomes these limitations by dynamic resource sharing among the providers. One of the main challenges in the federated cloud is to define a mechanism used for resources sharing among the members. This mechanism must be fair and ensure the common benefits of all the federation members. The market mechanism is suitable for this question, because the market mechanism includes the concept of relative worth intrinsically and this concept is usually abstracting into a price or other type of exchange unit. Additionally, many economic models as the research topic of discipline of economics are well studied in recent years, making use of the main ideas of the disciplines to analyze and design the market mechanism for resources sharing in federated cloud become possible.

There are multiple ways to trade resources in the resources market, such as resources pricing, resources negotiation and resources auction. Eduardo *et al.*, [4] studied the mechanism of resource sharing based on the general equilibrium theory to calculate the equilibrium price to coordinate between providers in federated cloud, presented a trading market of resource sharing consist of user agent, cloud coordinator and cloud exchange. But the dynamic pricing strategy based on general equilibrium theory in this article needs cloud exchange send the price to the cloud coordinators and receive transaction demand sent back by cloud coordinators ceaselessly, until reach the balance between supply and demand. There may need many times price discovery in the pricing process and it's also likely can't get the equilibrium price. Marian *et al.*, [5-6] discussed the importance of dynamic pricing in the resources market of federated cloud, proposed a strategy-proof dynamic resource pricing strategy of multiple resource types based on reverse auction, based on this strategy they proposed a reverse auction framework in resources market of federated cloud. Buyya *et al.*, [7-8] designed and implemented a resources market in which cloud users trade resources by consultations and negotiations.

The studies in recent years mostly aimed at resource sharing market in the commercial federated cloud, while few research at the resources sharing mechanism in the experiment platforms which building through the federated cloud technology. Cloud providers can only determine whether need extra resources to meet user's requirements or not or whether there are idle resources can be sold because the high variability of cloud task load varies with time in the commercial federated cloud. The providers can't determine the coming resources use situation, so federation members need to check resources use situation in each round transaction to decide whether participate in trade or not. However, the resources are used by the members themselves only in IIU federated cloud. They can determine the resources use situation and predict conditions of resources idle and resources demand over a period of future time. Therefore the members of IIU federated cloud can submit idle resources and purchase required resources over a period of future time beforehand. In this paper, a dynamic pricing trading market for shared resources comprises of federation members and market agent was proposed according to the use characteristics of shared resources in IIU federated cloud and the market mechanism in the process of resource share, which aimed to promote the sustainable development of the open sharing of resources.

3. Shared Resource Market

At present the Internet lab resources are distribution unbalanced in China. Many colleges and universities, especially the 985 and 211 colleges and universities, have accumulated a large number of laboratory resources after years of investment of scientific research funds. But the rate of utilization of these resources is not enough and the equipment depreciation rate is very high, these resulting in the enormous waste of experiment resources. At the same time, the colleges and universities in some underdeveloped regions such as Tibet, Qinghai, Gansu and other regions the high quality experiment resources are very missing. In this case, achieving the continuous sharing of the resources through IIU platform is very necessary.

This paper proposes a trading market comprises of federation members and market agent for shared resources to coordinate the resources trading among members in IIU federated cloud. When a federation member puts their idle resources into the trading market, the member is a resource provider in the market. While a federation member need to access to resources from the market the member is a consumer. A federation member can be either the resources provider or resources consumer in the market. The idle times of the resources shared by federation members are the commodity in the market. The market agent is responsible for collecting the situation of idle resources and resources request submitted by the federation members, pricing the resources, processing resources trade, releasing resources price and sending to the federation members. In addition, in order to ensure the trade is completed, the member shall comply with the Resource Sharing Protocol (RSP) in the process of resource sharing. This protocol stipulates that after payment has done by the resources consumer, resources provider must offer the resources according to the idle times purchased by the consumer, or the provider would face penalties.

3.1. Idle Times of Shared Resources

The idle times of the resources shared by IIU federation members are the commodity in the trading market. The biggest difference of IIU federated cloud and commercial federated cloud compose by public clouds is the predictability of conditions of resources idle and resources demand. IIU federated cloud and federal cloud composed of a public cloud business the biggest difference is that idle resources and demand can be unexpected. The federation members can't predict the condition of resources idle and absent because the high variability of cloud task load varies with time in the commercial federated cloud. While the IIU federation members can determine the condition of resources idle and absent in advance because the experimental resources are used only by themselves and usually they would have clear plans for the use of resources.

The definitions:

Assume there are *L* members in the IIU federated cloud, use S_i to indicate i^{th} federation member, where $i \in [1, L]$;

Assume the number of resources shared by federation member S_i is m_i , use a_{ik} to indicate k^{th} resource shared by the member S_i , where $k \in [1, m_i]$;

Assume there are *n* types shared resources in the IIU federated cloud, use D_j to indicate j^{th} recourse in the federation, where $j \in [1, \mathrm{n}]$. Use n_j to indicate the number of resource D_j. Use set S_{ij} to indicate resources D_j owned by member S_i, where S_{ij} ={ a_{ik} | a_{ik} is resource D_j , $k \in [1, m_i]$ }.So that

$$n_j = \sum_{i=1}^{L} | S_{ij} | \tag{1}$$

The unit time for trading the resources idle time is 1 hour, each Shared resources have 24 units a day time. In each unit time resources can be one of the following three states: Nontradable, Tradable and Traded. Federation members themselves need to use the resources or don't want to sell due to profits of the resources below their expected, the resource is Nontradable. Resources are idle and federation members willing to participate in trade, the resources are Tradable. When the Tradable resources are purchased by other member, resources are Traded. Using array A_{ik} to indicate the status of k^{th} resource of IIU member S_i in one day, therefore

$$A_{ik}[t] = \begin{cases} 0 & \text{recourse is Nontradable in time slot } t \\ 1 & \text{recourse is Tradable in time slot } t \qquad t \in [0,23] \\ 2 & \text{recourse is Traded in time slot } t \end{cases} \tag{2}$$

The members submit the shared resources to the market agent when they join the federation, and all shared resources are Nontradable at the initial moment, i.e. $A_{ik}[t] = 0$ in any time slot. After the federation members determined the plan of resources using in one day, the date and the array A_{ik} of idle resources in that day is submitted to the market agent.

The federation members can update the value of A_{ik} after Submitted, but only 0 update to 1 or 1 to 0, *i.e.* the Nontradable resources can be revised as Tradable and Tradable resources can be revised as Nontradable before be purchased. If a federation member needs some resource at a certain time, the member could send resource type and number and date and time slot to the market agent to buy the idle time of the resource before that time coming. The market agent processes the request according to the resource price at the request received time. The resources had been sold cannot be withdrawn, and the resources providers must abide by RSP and offer the resources to the consumers according to the idle times purchased.

3.2. Dynamic Pricing of Resources

Federated cloud technology is used in IIU to achieve unified plan and unified management of the shared resources, and all shared resources are unified pricing by the market agent. Price is the value embodiment of the resources in the market, and it is an important factor affects transaction success or failure. The objective of IIU resources market is to ensure the interests of the resources providers and to promote the sharing of resources, which makes process of resources pricing should not only consider the cost of resources, but also consider what price can be accepted by the consumers.

There are two economic models can be used in the trading of shared resources, fixed pricing and dynamic pricing. A fixed price is set beforehand in the fixed pricing model which used to trade resources. Using a fixed price can simplify the transaction process, but can not reflect the supply-demand relationship of resources in the market. It is not conducive to improving the rate of resource sharing. In the dynamic pricing model, resources are priced according to the supply-demand relationship of resources in the market. All transactions are processed by the market agent in the IIU federated market, so the market agent could obtain the supply-demand relationship according to the resources transactions. Therefore, it is very easy to achieve the dynamic change of resource prices according to the supply-demand relationship in the IIU federated market. The dynamic pricing strategy presented in this article calculates resources price by cost-plus pricing method, and dynamically adjusts the profit rate of resources according to the supply-demand relationship of resources, thus to achieve the dynamic change of resource prices along with the supply-demand relationship.

Assume the cost of resource D_j need to purchase and install is B_j in the IIU federation, the depreciation rate per hour is β_j, the operating cost per hour is M_j, then the cost of resource D_j per hour is

$$C_j = \beta_j \cdot B_j + M_j . \tag{3}$$

Assume the initial profit margin of resource D_j is R_j^0, and then the initial price of resource D_j is

$$P_j^0 = (1 + R_j^0) \cdot C_j . \tag{4}$$

The initial price is the transaction price in the fixed pricing model.

The situation of resources idle would not change after each time slot has coming, so the market agent can count the transactions situation of each type of resource use the set S_{ij} and array A_{ik}. With I_{jd0}, I_{jd1}, I_{jd2} indicate respectively the number of Nontradable, Tradable, Traded of resource D_j of time slot *d* in the market after *d* has coming. Obviously, there is

$$n_j = I_{jd0} + I_{jd1} + I_{jd2} . \tag{5}$$

The consumers have learned the resources prices at current time before they submit the resources request, and only they accept the prices would they send the request. Therefore as long as there are enough idle resources the request would be satisfied, and the request cannot be satisfied only when the number of idle resources is not enough. Using E_{jd} to indicate the quantity required of resource D_j of time slot *d* received by the market agent, then when there are enough resources, we have $I_{jd2} = E_{jd}$, otherwise $I_{jd2} < E_{jd}$. Using f_{jd} to indicate the supply-demand relationship of resource D_j of time slot *d*, there is

$$f_{jd} = \frac{E_{jd}}{I_{jd1} + I_{jd2}} - 1. \tag{6}$$

When $f_{id} > 0$, resource D_j of time slot *d* is demand exceeds supply; when $f_{id} < 0$, resource D_j is oversupply; when $f_{id} = 0$, balance between supply and demand is achieved.

To reduce the influence of abnormal change of supply and demand to the price at next time slot and to avoid large fluctuations of the resources price, in this paper the resources profit rate is adjusted according to the total supply-demand relationship of time slot *d* and *l* time slots before *d*. With I_{jd1}^h and I_{jd2}^h and E_{jd}^h indicating the amount of Tradable and Traded and requested of time slot *d*-*h* respectively, the total supply-demand relationship of time slot *d* and *l* time slots before *d* is

$$f_{jd}^l = \frac{\sum_{h=0}^{l} E_{jd}^h}{\sum_{h=0}^{l} (I_{jd1}^h + I_{jd2}^h)} - 1 . \tag{7}$$

Obviously, when $f_{jd}^l > 0$, resource D_j in the market is demand exceeds supply, the profit rate of resource D_j should be improved; when $f_{jd}^l < 0$, resource D_j is oversupply, the profit rate should be reduced; when $f_{jd}^l = 0$, balance between supply and demand is achieved, the profit rate is invariant.

In order to ensure resources provider’s benefit and consider the receptivity of consumers to resources price, it is necessary to limit profit rate of shared resources. Assume the Minimum and maximum values are $R_j^{\min}$ and $R_j^{\max}$ respectively, where $0 \le R_j^{\min} \le R^0 \le R_j^{\max}$, using R_j^{d-1} to indicate resources profit rate of time slot *d*-1, profit rate R_j^d of time slot *d* is

$$R_j^d = \begin{cases} R_j^{\min} & f_{jd}^l < (R_j^{\min} / R_j^{d-1} - 1) \cdot 100 \\ R_j^{\max} & f_{jd}^l > (R_j^{\max} / R_j^{d-1} - 1) \cdot 100 \\ R_j^{d-1} \cdot (1 + f_{jd}^l / 100) & \text{others} \end{cases}. \tag{8}$$

Then the transaction value of shared resources of time slot *d* is

$$\begin{aligned} P_j^d &= (1 + R_j^d) \cdot C_j \\ &= \begin{cases} (1 + R_j^{\min}) \cdot C_j & f_{jd}^l < (R_j^{\min} / R_j^{d-1} - 1) \cdot 100 \\ (1 + R_j^{\max}) \cdot C_j & f_{jd}^l > (R_j^{\max} / R_j^{d-1} - 1) \cdot 100 \\ P_j^{d-1} + C_j \cdot R_j^{d-1} \cdot f_{jd}^l / 100 & \text{others} \end{cases}. \end{aligned} \tag{10}$$

Obviously, $(1 + R_j^{\min}) \cdot C_j$ and $(1 + R_j^{\max}) \cdot C_j$ are the Minimum and maximum values of resources price respectively. The market agent calculates the transaction price of resource D_j at the beginning of each time slot, and publishes the price in the resources market. The market agent processes all requests of resource D_j received in this time slot according to this price.

3.3. Trading Process of Shared Resources

After IIU federation member S_i determined the use plan of resource a_{ik} in some day, if there is idle time in that day and S_i is willing to sell the idle time to other members, then S_i send the date and resource idle array A_{ik} of that day to the market agent. Otherwise, nothing would be submitted, i.e. $A_{ik}[t] = 0$ and resource a_{ik} is Nontradable in that day. If a federation member needs resources, the member sends resource type and number and date and time slot to the market agent.

As the IIU federation members are in different regions and federal shared resources are distribution cross-regional, to reduce the transmission cost of experimental data, the distance nearby principle is used by the market agent to process resources requests in the process of resources trading. The market agent deal with the resources requests received in accordance with first come first served strategy, the trading process of shared resources is as follows:

1. The market agent receives resource request information sent by resource consumer S_x in time slot *d*. The request information includes required resource type D_j and required number *num* and required date *date* and required time period *T*, where *T* is composed by some continuous time slots, i.e. *T*={*t*, *t*+1, *t*+2,..., *t*+*g*,..., *t*+*m* | *m*≥0};

2. The market agent sorts ascending all other federation members $S_i (i \in [1, L], i \neq x)$ according to the distance with the member S_x;

3. The market agent traverses federation members S_i according to the sorted result, and queries all values of idle arrays $A_{ik}[t+g]$ whether is equal to 1, where g from 0 to m, until the amount of Tradable resources is equal to num or the traversal is complete;

4. If the amount of Tradable resources D_j is less than required number *num*, the market agent sends information of insufficient resources to S_x , and ask S_x accept the current number of resources or not. If S_x rejects it, the transaction would be closed;

5. The transaction is processed according to resource price P_j^d of in time slot *d*. The resources state of the required time slot will be changed to Traded;

6. The market agent sends transaction result to S_x and providers in this transaction;

7. The resources providers offer the resources to S_x to use when the time slot purchased by S_x arrival, the market agent supervises the procedure violate RSP protocol or not.

At present in IIU federated cloud, the resources shared by members is unified planning and unified management by resource management system of IIU platform. Federation members can reserve shared resources in IIU platform through the resource management system according to their actual needs, call the real equipment, software and data. Thus the only need is change the reservation process of shared resources of the resource management system to trading process of shared resources, the system could be used as market agent of IIU resource market to deal with shared resources trade among all federation members. Therefore, establishing shared resource market does not need much change of the basic structure in IIU federation, it is easy to implement.

4. Simulation Experiments

In this section, we present the experimental evaluation o f the proposed dynamic pricing strategy for shared resources, compare with the fixes pricing. Only one type resource is considered in the experiment, the specific resources providers and consumers are ignored. The experiment simulates the change of the amounts of resources supply and demand and resources price.

Assume the amounts of resource supply and demand are random values which subject to Poisson distribution, the distribution parameters denoted by A1 and A2 respectively. The distribution parameter is changing along with the price, the higher the price the more supply and the less demand, *i.e.* A1 is larger with higher prices while A2 is smaller with the higher prices. There are three situations of supply-demand relationship of resources in the market: short supply and oversupply and balanced. The three supply-demand relationships above are original states of the experiment, i.e. in initial moment A1=100 and A2=150 when short supply, A1=150 and A2=100 when oversupply, A1=120 and A2=120 when balanced. The other original parameters are the resource price *P0*=15 and profit rate *R0*=0.5 and the minimum and maximum values are *R*min=0 and *R*max=1 respective.

The experimental results are shown in Figure 1, 2 and 3. Figure 1 shows resource price of balanced condition is very similar to the fixed price when using dynamic pricing in the resources market, resource price increase and decrease when short supply and oversupply respectively to a stable value .In Figure 2, supply parameter increase while demand parameter decrease when short supply, and it is inverse when oversupply, both parameters will tend to be equal when using dynamic pricing. Figure 3 shows when using fixed pricing supply-demand relationship is fluctuate in the vicinity of the initial value slightly and the supply and demand condition will not change, while using dynamic pricing supply-demand relationship is tend to be 0, *i.e.*, develop to equilibrium state. The experiment result indicates that using dynamic pricing in the shared resources market, increase resource price when short supply to inspire the members to share more resources and decrease price when oversupply to promote resource demand, can achieve a balance between supply and demand and thus to promote Efficient sharing of resources.

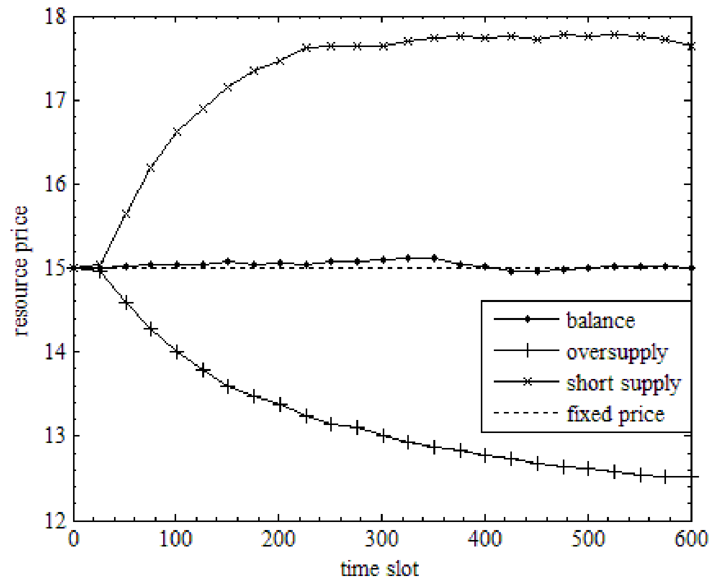

Figure 1. Resource Price

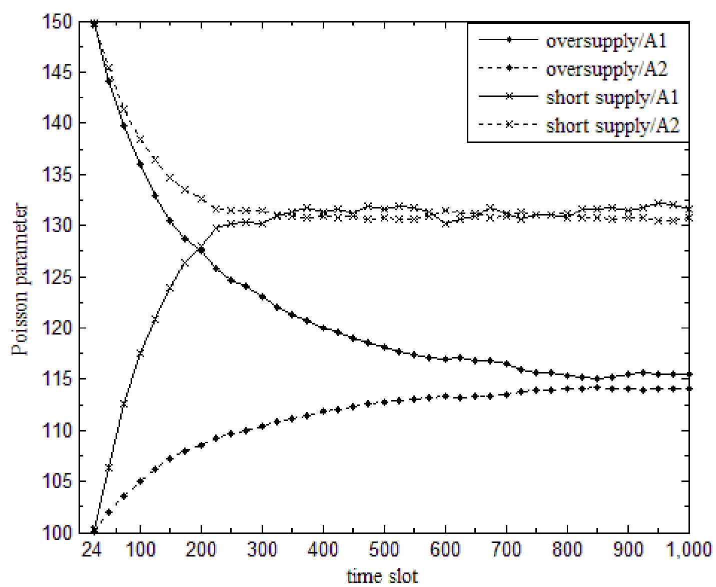

Figure 2. Distribution Parameter of Supply and Demand

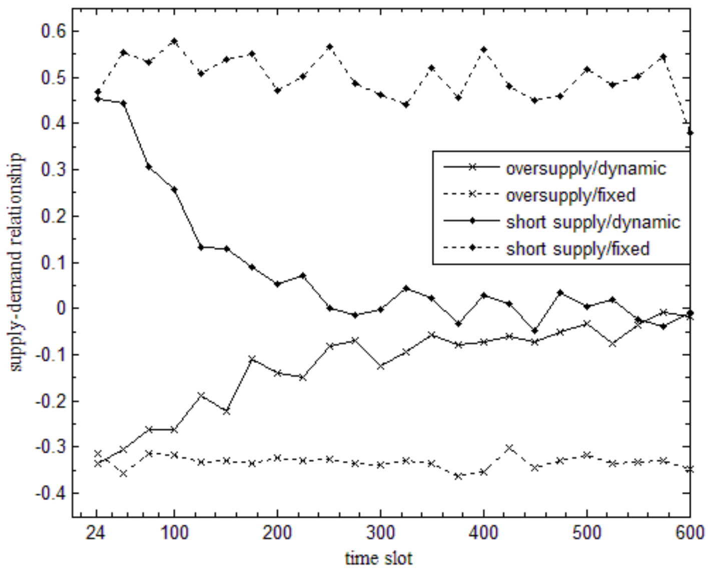

Figure 3. Supply-Demand Relationship

5. Conclusions

The resources sharing approach in IIU federated cloud ignores the market mechanism in the process of resources sharing, it is adverse to the sustainable development of resources open sharing. This article analyses the use characteristics of resources in the IIU federated cloud, federation members can predict whether the resources are idle or lacking according to the experiment plan. A dynamic pricing trading market for shared resources comprises of federation members and market agent was proposed, to achieve efficient open sharing of resources. The federation members are both resource providers and resource consumers, and the idle time of shared resources is traded commodity in the trading market. The profit rate of resources is adjusted dynamically according to the statistical data of the supply-demand relationship, so as to achieve dynamic change of resource prices along with the supply-demand relationship. The market is easy to implement in the IIU federated cloud, and it is beneficial to improve resource utilization and promote open sharing of resources. The dynamic pricing strategy proposed in this paper does not consider the cost variance of same resources and consumption level in different regional and ignores the impact of non-working time on the supply-demand relationship. The next research would consider the impact of the factors above and other factors on resource prices in the market.

Acknowledgements

This work is supported by Information Fusion and Cloud Services Network Platform project, which is a part of Internet Innovation Union (IIU).(Minister of Education, Science and Technology Development Center[2012]32). The research is also funded by Could Resource Management in Dragon-lab Project (ZH2011102).

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