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Dynamic Pricing Strategy of Shared Devices in IIU Federated Cloud

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Abstract

According to the usage features of the shared devices in IIU federated cloud, the commercialized processing of these devices is conducted. With the consideration of the price mechanism and supply-demand mechanism in sharing process, as well as the commodity remaining rate and the device usage conditions in transaction procedure, a dynamic pricing strategy of the commodities in federated cloud market is proposed. The strategy allows a small amount of commodities to be left in the market to avoid being in short supply. The device utilization rate at non-working time is increased through discount on commodities. The simulation results demonstrate that the sharing of equipment resource is improved by the proposed strategy, bring about a raise of device utilization rate.

***Keywords**: IIU, devices sharing, dynamic pricing, commercialization, discount*

1. Introduction

To solve the problem of uneven distribution of Internet experiment resources and insufficient cooperation between Internet innovation team, Internet Innovation Union (IIU) has been founded with the science and technology development center of the ministry of education in China as the leading agency [1]. One of the main purposes of IIU is achieving effective open and sharing of Internet technology experiment resources. IIU realizes the integration and sharing of the Internet technology laboratory equipment resources between different experimental platforms in different areas through federated cloud. The experiment platform resources of each school can be interconnected by federated cloud. In this way, the risk of the massive redundant construction can be avoided, and that the space limitation of the experiment equipment, geographical location, hardware resource, software resource in each unit can be eliminated. The open sharing of information resources and equipment resources in different regions and different experimental institutions can be promoted, with the cost reduced and the device utilization rate improved.

At present, the experiment devices in the IIU federated cloud can be used by IIU members for free through appointing. Although this simple way can provide a good environment and safeguard for device sharing, it neglects the initiative of the subject in device sharing, and also ignores the objective laws in device sharing. As a result, the enthusiasm of other research institutions to join into the federation and members to share devices will be reduced, which is adverse for the development of the IIU federated resources market.

Against to the above problem, we have established a trade market model for shared devices comprising of federation members and market agent and proposed a dynamic pricing devices trade mechanism in the market in [2]. However in the IIU federated platform, the types of devices owned by different federation members are different. There is even a big difference with respect to the brand and specification

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among devices of the same type. What's more, the sharing forms of different types of devices are different. For example, switch, router, testing instrument and safety equipment etc. can be shared according to the number of devices members need, the storage devices can be shared according to the storage size and the servers are shared in the form of virtual machine. Therefore, the commercialized processing for the shared devices is necessary before they are shared, making them be traded directly in the market.

Although cloud computing technology has developed rapidly, reasonable resource supply is still a great challenge for cloud providers [3-4]. Although the providers can provide service for most of the requests with only a limited number of resources, this would result in refusing clients in the peak times. On the other hand, low utilization rate of resources in off-peak times leads to a higher price for more profit. The federated cloud overcomes the above limitations by dynamic resource sharing among the providers [5-6]. 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 can meet this demand. Because the market mechanism includes the concepts of the related value, which are usually abstracted into the price or the exchange units of the other types. Additionally, many economic models have been well studied as the main research topic of economics in recent years. This makes it possible that the main disciplines of the economics can be used to analyze and design the market mechanism for resource sharing.

There are many ways used for resource trading in the resource market, such as resource pricing, resource negotiation and resource auction. Eduardo [7] studied the mechanism used for resource sharing between the federated clouds through calculating the resource price based on the general equilibrium theory. A resource sharing and trading market consists of the user agent, the cloud coordinator and the cloud exchange is proposed. Howerver, the dynamic price strategy proposed needs the cloud exchange sending the price to the cloud coordinators and receiving the transaction demand sent back by cloud coordinators ceaselessly until a supply-demand balance is achieved. During this process, the price needs to be searched repeatedly, and even the equilibrium price cannot be reached. Marian [8-9] discussed the importance of dynamic pricing in the resource market of federated cloud, and 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. In this way, the user welfare and the percentage of successful requests has been increased. Buyya [10-11] designed and implemented a resources market in which cloud users trade resources by consultations and negotiations and so the scalability performance has been imporved. Nancy Samaan [12] studied the capacity sharing problem of federated cloud, proposed a capacity sharing model of federated cloud comprise by IaaS providers which aimed to maximize the long-term profits of the cloud providers. The proposed has increased the profit and reduced the variance in the spot market virtual machine availability and prices. Fan [13] proposed the standardization and pricing mechanism of computing resources in IIU platform, but the most major shared resource in IIU platform are hardware and software resources.

The above studies mostly aimed at resource sharing market in the commercial federated cloud, while few research on the resources sharing mechanism in the experiment federated cloud built by the federated cloud technology. The resource sharing type of IIU federated cloud is different from that of the public federated cloud. In the IIU federated cloud, including the private cloud of universities and research institutions, the most primary sharing resources are various devices and industry application softwares, as well as the computing resource provided by public cloud provider. The shared computing resources can be traded directly between public clouds. While in the IIU federated cloud,

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the device trading form is diverse because of different usage mode resulted by various types of shared devices in the market.

In this paper, the commercialized processing is conducted on the shared devices in the IIU federated cloud based on their usage features. A dynamic price strategy of the commodities in federated cloud market is proposed in terms of the price mechanism and supply-demand mechanism in sharing process, along with the commodity remaining rate and the device usage conditions in transaction procedure. This strategy retains a small amount of overplus commodities to avoid short supply. On the other hand, the discount is implemented on the commodities at non-working time to improve the utilization rate.

2. The Commercialization of Devices

We have proposed a dynamic pricing trade market for shared devices coordinating the devices trading among members in IIU federated cloud. The federation member can be either the device provider or device consumer in the market. The devices shared by federation members are the commodities in the market. Assuming the unit time of commodity trading is 1 hour. The market agent is responsible for collecting the situation of idle devices, device request, device pricing and device processing request submitted by the federation members, and releasing the price and trading results of devices to both device providers and consumers. In addition, in order to ensure the trade completed smoothly, the members should obey the sharing protocol during the devices sharing process. This protocol stipulates that as long as the consumers have paid for the devices, the providers must provide the devices according to the idle time bucket paid by consumers. Otherwise, the providers would be fined, compensating for the consumers.

The usage-pattern of shared devices in different kinds is different in the IIU federated market. For example, a server can be used by multiple users at the same time in the form of virtual machines, while the testing instrument and safety equipment can only be used by a user at one time. The trade form of devices shared in different ways is different. In this paper, the shared devices in the IIU federated market are divided into three following categories according to their usage-pattern:

1. Exclusive devices, which include switches, routers, testing instruments, safety equipment, wireless devices and so on. This kind of devices can only be used by one user at one time.
2. Storage device, which can be used by multiple users according to the fixed storage capacity divided beforehand.
3. Server devices, which can be provided to users at the same time in the form of virtual machine.

The divided storage capacity and virtual machines are also used by only one user at a time. Therefore, the shared devices and storage devices are not traded directly, but in ways of storage unit and all kinds of virtual machines. As the trade patterns are different from each other, the commercialized processing and commodity cost are analyzed for exclusive devices, storage devices and server devices, respectively, in the following.

2.1 Exclusive Devices

In each time slot, the shared exclusive devices in the IIU federated market can be in one of the following three states: nontradable, tradable and traded. In some time slot, if the federation members themselves need the devices or don't want to trade due to the profits lower than their expected, the devices are nontradable. Devices are idle and the federation members are willing to participate in trade, the devices are tradable. When the tradable devices are purchased by other members, devices are traded.

Using $A_a[t]$ to indicate the status of the exclusive device a in time slot t, then

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$$A_{a}[t]=\begin{cases}-1 & a \text{ is nontradable in time slot } t\\ 1 & a \text{ is tradable in time slot } t\\ 0 & a \text{ is traded in time slot } t\end{cases} \tag{1}$$

The subsequent $A_a[t]$ values are submitted to the market agent after the usage plan being finished. After the submission, the value of $A_a[t]$ can be updated, but only from -1 to 1 or from 1 to -1. That is, the nontradable devices can be changed to tradable, and the tradable devices not sold out can be changed to nontradable.

In IIU federated market, the same type of shared exclusive devices have various brands and specifications. For example, the switches may have different port number, so that the members need to specify the minimum number of ports and support tri-layer exchange technology or not and so on when they purchase switches. The cost price of same type devices with different brands and specifications is different in IIU federated platform. So the market agent calculates the use-cost of each exclusive device per hour in the federated market.

Assuming that the cost price of exclusive device *a* is F_a, β_a is its depreciation rate per hour, and the operating cost per hour is M_a, then the use-cost per hour of device *a* is:

$$G_a = \beta_a \cdot F_a + M_a \tag{2}$$

2.2. Storage Devices

The storage devices in IIU federate cloud are provided to multiple users at one time according to the divided storage capacity. Taken *w* GB as the divided unit, USC is used to denote the storage capacity. The users can buy USC according to their requirement, i.e. the USC is the commodity in the federated market.

The transaction status of storage device in the market can be described by the tradable number of USC. Using $B_b[t]$ to indicate the supply status of storage device *b* in time slot *t*, then $B_b[t] = U_b$, where U_b is the tradable number of USC of storage device *b* in time slot *t*, i.e. the tradable number of USC of storage device *b* in time slot *t* is wU_b GB. When $B_b[t]>0$, the device b is tradable, and the number of commodities can be purchased is UCS. When $B_b[t]=0$, storage device *b* is nontradable. After the usage plan of the storage devices *b* in time slot *t* is determined, the federation member submitted $B_b[t]$ to the market agent. The federation members can update the value of $B_b[t]$.

There are various brands and specifications in IIU federated platform. Users need to specify the type, the interface type, the transmission speed and so on. As the cost of all brands and specifications is different, the federated market proposed in this paper calculates use-cost of each storage device per hour in the federated market.

Assuming that the cost price of storage device *b* is F_b, β_b is the depreciation rate per hour, the operating cost per hour is M_b, then the use-cost per hour of USC of storage device *b* is

$$G_b = w \cdot \frac{\beta_b \cdot F_b + M_b}{U} \tag{3}$$

2.3. Server Devices

The shared server devices are traded in the form of virtual machines in the IIU federated market. Multiple types of virtual machines instances are provided to users. There are differences in computing power, RAM, instance storage or network performance between different virtual machines. The users purchase virtual machine types they demand, i.e. the virtual machines are commodities in the federated market.

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Assuming that there are v types of virtual machines provided in the IIU federated market, using $V_c[t]$ to indicate the supply status of virtual machines of type c in time slot t, we have $V_c[t] = Y_c$, where $c \in [1, v]$, Y_c is the tradable number of virtual machines of type c in time slot t. When $V_c[t] > 0$, users can purchase virtual machines of type c in time slot t, When $V_c[t] = 0$, there is no virtual machines in type c of time slot t can be purchased in the market. In the IIU federated market, the running-cost of a virtual machine is decided by computing power, RAM, instance storage and network performance the virtual machines possesses.

3. Dynamic Pricing Strategy of Commodities

The commodities provided in the IIU federated market are the exclusive devices, such as switches, routers, testing instruments, safety equipment, Wireless devices and so on, commercialized USC and various kinds of virtual machines. The market agent adjusts the profit rate of each type of commodities dynamically according to its supply-demand relationship, so as to achieve dynamic change of commodities price along with the supply-demand relationship.

3.1. Dynamic Profit Rate of Commodities

After time slot t has come, the supply-demand relationship of all commodities in time slot t and before time slot t would not change, the market agent adjusts the profit rate of every type of commodities dynamically according to its supply-demand relationship. Assuming that in the market the supply number and demand number of commodity k in time slot d is I_{kd} and E_{kd}, respective, where commodity k can be one kind of exclusive devices, USC partitioned from storage devices or one type of virtual machines.

Using f_{kd} to indicate the supply-demand relationship of commodity k in time slot d, then

$$f_{kd} = \frac{E_{kd}}{I_{kd}} - 1 \tag{4}$$

When $f_{kd} > 0$, the demand of commodity k in time slot d exceeds supply, while $f_{kd} < 0$, commodity k is oversupply with $f_{kd} = 0$ representing a balance between supply and demand achieved.

In order to reduce the influence of the abnormal change of supply-demand relationship in one time slot on the price in the next time slot and to avoid large fluctuations of the commodities price, the profit rate of each type of commodities is adjusted according to the total supply-demand relationship of some successive time slots in this paper. Meanwhile, considering the randomness of the supply-demand relationship of commodities in some time slot and the utilization rate of the federated cloud resources, the supply number of commodities in the federated market should be greater than demand number in order to reduce the failed commodity purchase due to undersupply.

With I_{kd}^h and E_{kd}^h denoting the supply number and demand number of in time slot d and h, respectively, the total supply-demand relationship of commodity k in time slot d and during the l time slots before d is,

$$f_{kd}^{l} = \frac{\sum_{h=0}^{l} E_{kd}^{h}}{\sum_{h=0}^{l} I_{kd}^{h}} - 1 + \alpha \tag{5}$$

where $0 \le \alpha < 1$ represents the supply remaining rate. Obviously, when $f_{kd}^{l} > 0$, the supply number of commodity k in the market is under the desired value, and then the profit rate of commodity k should be enhanced to increase the supply. When $f_{kd}^{l} < 0$, the supply number is greater than the desired value, the profit rate should be reduced. When $f_{kd}^{l} = 0$, the supply number is equal to the desired value, the profit rate should be fixed.

The target of IIU federated platform is to promote the devices sharing and guarantee the interests of the federation members. Therefore, the pricing process should consider not only the cost but also the receptivity of the users to the commodity price. To guarantee the interests of the resource providers, as well as reconcile the receptivity of the users to the commodity price, the profit rate of commodities should be limited.

Assuming that the minimum and maximum of the profit rate of commodity k is $R_k^{\min}$ and $R_k^{\max}$, respectively, with $0 \le R_k^{\min} < R_k^{\max}$, using R_k^{d-1} to denote the profit rate of commodity k in time slot d-1, then the profit rate of commodity k in time slot d is

$$R_k^d = \begin{cases} R_k^{\min} & f_{jd} < (R_k^{\min} / R_k^{d-1} - 1) \cdot 100 \\ R_k^{\max} & f_{jd} > (R_k^{\max} / R_k^{d-1} - 1) \cdot 100 \\ R_k^{d-1} \cdot (1 + f_{kd} / 100) & \text{others} \end{cases} \tag{6}$$

3.2. Transaction Price of Commodities

The market agent calculates the price of all commodities in the IIU federated market using cost-plus-pricing method at the beginning of each time slot, and then releases the price. Considering the difference of the supply-demand relationship of commodities in the market between the working time and the non-working time, in order to reduce the supply at working time and increase the demand at non-working time, the market agent further adjusts the transaction price of commodities at non-working time by discount to maintain the stabilization of supply-demand relationship. We divide the total 24 time slots during one day into 3 stages as follows,

i. Working time- 8:00-18:00;
ii. Rest time-18:00-24:00;
iii. Night time- 0:00-8:00.

In IIU federated market, the transaction price of commodities at working time is not discounted, i.e. the price calculated by the cost-plus-pricing method is the transaction price in working time. But with respect to the transaction price of commodities at non-working time, the benefits of commodities is discounted before using the cost-plus-pricing method. Due to different demand of commodities at non-working time, the corresponding discount is different. Assuming that the discount of commodity k at rest time and night time is D_{rk} and D_{nk} , respectively, $0 \le D_{rk} \le D_{nk} < 1$ presents the discount at night time is higher than that at rest time.

The market agent calculates the transaction prices of commodities according to the usage-cost per hour, the profit rate in the current time slot and the discount. The commodities of the same type have the same benefit rate, but the different cost due to the diversity of the shared resources, so that the price is different.

Assuming that the commodity M in the market is of type k, using G_m, R_k, D_{rk} and D_{nk} denote the usage-cost per hour of M, the profit rate of commodity k in the current time slot, the discount of commodity k at rest time and night time, respectively, the transaction price of commodity M in the future time slot t is

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$$P_m(t) = \begin{cases} G_m \cdot (1+R_k) & t \text{ is working time} \\ G_m \cdot (1+R_k \cdot (1-D_{rk})) & t \text{ is rest time} \\ G_m \cdot (1+R_k \cdot (1-D_{nk})) & t \text{ is night time} \end{cases} \quad (7)$$

The market agent calculates the purchasing price of all commodities in the IIU federated market using (7) at the beginning of each time slot, and then releases it. The market agent uses the price to deal with the purchase requests received at that time slot.

4. Simulations

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In this section, we present simulations to evaluate the proposed dynamic pricing mechanism for shared resource, and compare the results with those of the fixed pricing method. The experiments simulate the purchasing process of the switches in the market, and analyze the supply-demand relationship and the changes in price, ignoring the specific resources providers and consumers, and the supply-demand relationship between the working time and non-working time.

Assuming that the specification and cost price of all switches in the market are the same, the supply number and demand number of switches obey Poisson distribution, with A_1 and A_2 the distribution parameters, respectively. The more supply and the higher price, the less demand, i.e. A_1 is becoming bigger and A_2 is becoming smaller with the growing price. There are 3 situations of the supply-demand relationship of switches in the market, that is, short supply, oversupply and balanced. Simulations start from the above 3 situations. And at the beginning, the cost of switches per hour is C=10, with the profit rate R=0.5. The maximum and the minimum of the profit rate is 0 and 1, respectively. We set A_1=1000 and A_2=1500 for the short supply. When oversupply, A_1=1500 and A_2=1000, while A_1= A_2=1000 for balance.

4.1 The Influence of Supply Remaining Rate To Supply And Demand

In the experiments, we set supply remaining rate α to be 0, 10% and 15%, respectively. We calculate the time slots with failed transaction and their average absence rate, as well as the average remaining rate in time slots with success transaction during the 1500 time slots after the stable supply-demand relationship. The supply and demand situations are shown in Table 1. From the table, we can find that the results are the same for the 3 initial situations, i.e. the short supply, oversupply and balance. When α =0, almost in half of the time slots, the supply is short of demand, leading to failed purchases. With α growing, failed purchases reduce. When α =10%, failed purchases are no more than 10, while there is no failed purchase when α =15%, with the average remaining rate approximating the supply remaining rate. The experiment results demonstrate that the supply remaining rate can reduce the failed purchase effectively.

Table 1. The Supply And Demand Situation of Switches in the Market

Initial state	Oversupply			Balanced			Short supply		
	α =0	α =10%	α =15%	α =0	α =10%	α =15%	α =0	α =10%	α =15%
Failed times	728	8	0	751	8	0	727	5	0
Lack rate	3.2	1.41	0	3.1	1.33	0	3.1	1.34	0

	4%	%		8%	%		4%	%	
Surplus rate	3.29%	9.99%	14.88%	3.17%	9.98%	14.91%	3.05%	9.99%	14.95%

4.2 The Changes of Supply-Demand Relationship and Price

There is no short of switches in the market when α =15% in 4.1, that is, there are enough switches supply in the market and no failed purchase of switches. In this section, we simulate the purchasing process when α =15%, calculate and analyze the supply-demand relationship and price fluctuations.

In Figure 1, we can find that when the initial supply-demand relationship is in balance, the switch price would grow. Due to the supply remaining rate, the supply number is greater than the demand number through growing price. The initial short supply and oversupply would increase and reduce the switch price, respectively. Whatever the initial supply-demand relationship, the market price of switches would tend to stability finally.

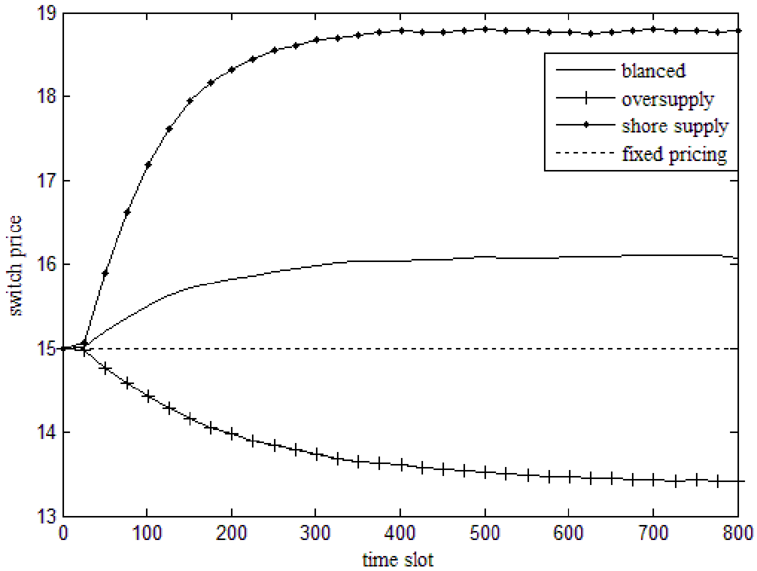

Figure 1. Switch Price Changes Over Time

Figure 2 shows the supply and demand situations when pricing dynamically. The supply and demand parameters will tend to be stable when the initial supply-demand relationship is either short supply or oversupply. In addition, the demand to supply rate is approximate 15%, while the supply and demand parameters will not change for the fixed pricing method.

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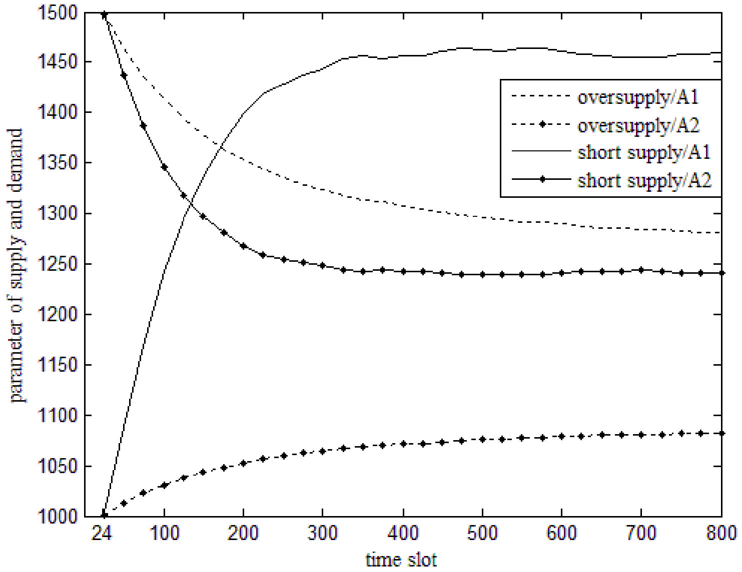

Figure 2. Parameter of Supply and Demand Changes Over Time

Figure 3 shows that the supply-demand relationship changes hardly using fixed pricing, for instance, the supply-demand status of switches would not change, while the supply-demand relationship is tend to 0 using the proposed dynamic pricing strategy. As the supply remaining rate of switches in the experiments is α =15%, so when the supply-demand relationship is equal to 0, there is 15% of supply number of switches remaining.

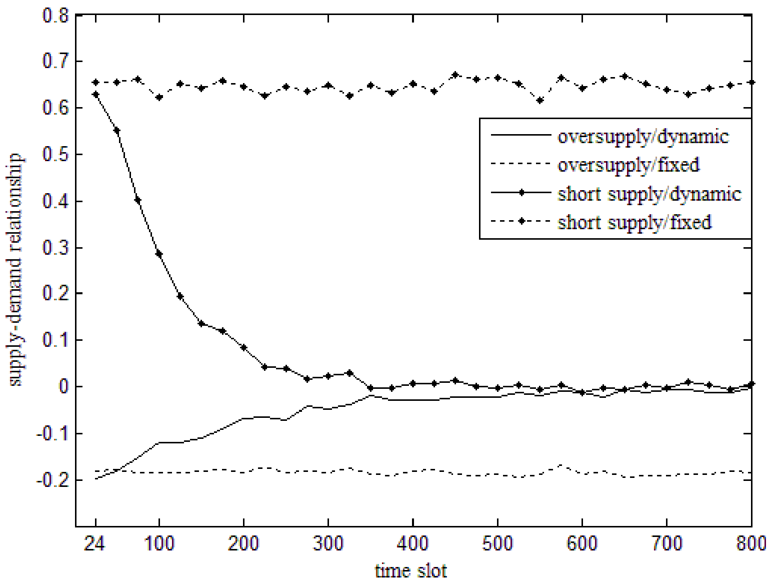

Figure 3. Supply-Demand Relationship Changes Over Time

The experiment results indicate that the proposed dynamic pricing strategy in the IIU federated market, increasing commodity price when short supply to inspire the members to share more devices and decreasing price when oversupply to promote commodities demand, can achieve a balance between supply and demand and thus promote efficient device sharing.

5. Conclusions

The present approaches for resource sharing in IIU federated cloud ignore the market mechanism, which is adverse to the open sharing of resources in the platform. In this paper, on the basis of utilization characteristics of the shared devices in IIU federated cloud, the commercialized process was conducted on the shared devices. A dynamic price strategy of the commodities in federated cloud market has been proposed to solve the problem the instability of supply-demand relationship. According to our strategy, a small account of commodities can remain in the market, and a discount is carried out on commodities at non-working time. In this way, consumers can buy idle resources in light with demand, which avoids the failed purchase caused by insufficient resources. The experiment results indicate that the proposed dynamic price strategy can reduce failed transactions effectively in the market and achieve a balance between supply and demand. So that the open sharing of device resources has been promoted, and the shared devices utilization has been improved too. The cost variance of same resources and consumption level in different regional has not been considered in this paper. In addition, the use of the supply remaining rate would lead to redundant commodities. All above problems would be studied in our future work to solve the problem of device sharing in IIU federated cloud.

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