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A Multi-agent Supply Chain Information Coordination Mode based on Cloud Computing

Wuxue Jiang*[1,2], Jing Zhang[1], Junhuai Li[1]
[1]School of Computer Science and Engineering, Xi'an University of Technology, Xi'an 710048, Shaanxi, China
[2]Department of Computer Engineering, Dongguan Polytechnic, Dongguan 523808, Guangdong, China
*Corresponding author, e-mail: jiangwuxue_1@163.com

Abstract

In order to improve the high efficiency and security of supply chain information coordination under cloud computing environment, this paper proposes a supply chain information coordination mode based on cloud computing. This mode has two basic statuses which are online status and offline status. At the online status, cloud computing center is responsible for coordinating the whole supply chain information. At the offline status, information exchange can be realized among different nodes by using the pre-backup supply chain information and network address of other nodes. This coordination mode coordinates the whole supply chain information through the cloud computing center at the online status and maximizes the overall benefit. Meanwhile, the offline status effectively avoids the risks to the whole supply chain brought by the overdependence of cloud computing on network and the high information concentration. The two statuses have good customers' satisfaction and higher order finished rate in supply chain. The simulation experiment based on multi-Agent verifies the effectiveness of this mode in this paper.

Keywords: *supply chain, information coordination, cloud computing, risk avoidance*

1. Introduction

With the development of information technology and network technology in the 21st century, supply chain has entered in a new era of informationization and network. In the competition between enterprises, the quality of supply chain has played an increasingly important role in terms of determining the future and destiny of the enterprise. The enterprises mastering and responding to the supply chain information rapidly are more possible to win in the fierce business competitions. The supply chain consists of supplier, manufacturer, distributor, vendor and customer and each of them consists of many entities. Moreover, each entity includes countless supply information and demand information. How to coordinate mass information from different objects in supply chain and how to maximize the overall benefit of supply chain have already become a burning issue in the current supply chain informationization process.

The market of traditional supply chain is relatively stable; however, its technical progress is slow and the product life cycle is long. Therefore, usually the previous supply chain information coordination adopted the chained information flow mode. In order to solve the problems in the chained information flow such as information distortion, long transfer cycle, low utilization rate and hard-to-share, the scholars proposed a series of information coordination modes. Mr. McCullen and Mr. Towill [1] proposed a supply chain information mode strengthening demand information. This mode added the channels feeding back customer information to supplier, manufacturer, distributor and vendor. Although such a mode has solved the problem of customer demand information distortion in the supply chain, it still does not realize information sharing of the other four nodes including supplier. R. Garcia-Flores [2] proposed a network information flow mode. At this mode, each node transfers information to the other nodes and makes decisions to the best of their own advantages. However, this mode can not maximize the overall benefit of supply chain. Mr. Hau L. Lee and Mr. Seungjin Whang proposed an integrated information flow operation mode [3] which concentrates all information in an information center for centralized processing. Such mode had the advantages of accurate

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information, fast transfer speed and sufficient information sharing, however, as all information is saved in one information center, it is easy to form information management monopoly which can cause the information asymmetry at each node in supply chain. The documents [4] and [5] propose a virtual information center scheme based on cloud computing to solve the problem of supply chain coordination. It takes the cloud computing platform as the information center at the integrated information flow mode. It has solved the problems of information management monopoly and security; however, as it adopts the centralized information management, this supply chain information flow mode will suffer a devastating blow if the cloud computing center is attacked. Some scholars implement the related studies from another perspective of information coordination. The document [6] analyzes the social risks and technical risks in the process of cloud computing supply chain information coordination in depth. Aiming at the traditional agricultural product supply modes which are highly discrete, the documents [7] and [8] implement studies to the closed agricultural product supply chain informationization platform based on computing. The document [9, 10] proposes a para-virtual enterprise logistics mode and analyzes the main logistics relationship of this logistics mode by actual cases.

Cloud computing is a new IT technology following grid computing. It has a certain risk while it brings the new opportunities for supply chain information coordination mode. Based on the cloud computing technology, this paper takes the advantages and disadvantages of its applications in supply chain information coordination into a comprehensive consideration and proposes a supply chain coordination mode which is capable of resisting the cloud computing risk.

2. Supply Chain Coordination

2.1. Definition of Supply Chain

Some Chinese scholars such as Mr. MA Shihua believe that supply chain is a functional network chain structural mode integrating supplier, manufacturer, distributor, retailer and final customer. It surrounds the core enterprises and controls the information flow, logistics flow and capital flow to produce intermediate products and finished products starting from purchasing raw materials. Finally the products are delivered to consumers through the selling network.

2.2. Supply Chain Information Coordination

Information flow reflects the process of information transferring among different nodes in supply chain. As each node belongs to different entities and each node only knows their own situation, the information of other nodes can only be mastered by information communication. In order to enhance the understanding and mastering of information of one node to the other nodes and to the whole supply chain, each node needs to transfer their own information to the other.

The function and purpose of supply chain information coordination are realizing the operation and market data sharing and exchange of different nodes and improving the response speed and quality of each node. Supply chain information coordination mainly includes the following items:

1) Interface coordination

The goal of interface coordination is realizing the coordination of each node interface and operating mode and improving the effectiveness of information exchange between the user and the whole supply chain. Interface coordination includes the similarity of information management interface of each node in supply chain and the similarity of system operating mode.

2) Data coordination

The goal of data coordination is keeping the consistency of information definition and format of each node in supply chain and realizing seamless information utilization of one node to the other nodes. Data coordination is very important to the whole system coordination. Without data coordination, different nodes can not communicate with each other, like that they are communicating with different languages. Data coordination can be measured and evaluated from three aspects: firstly, the data availability degree of different systems; secondly, the data repetition degree of different systems; thirdly, the data compatibility degree of different systems in terms of semantic limit and format.

3) Control coordination

The goal of control coordination is combining the different functions of the whole supply chain system into an organic whole and achieving the same goal together. The control coordination degree includes the availability degree of services provided by this node and the availability degree of services provided by the other nodes.

4) Program coordination

The goal of program coordination is realizing subsystems interaction to support some specific programs. The program coordination degree includes the following two levels: firstly, whether the related subsystem combination of the same program is smooth; secondly, the performance and efficiency of related subsystem collaboration.

3. Cloud Computing

3.1. Definition of Cloud Computing

Cloud computing is a new commercial computing model based on the development of distributed computing and virtualization technology. Nowadays, there is no absolutely uniform definition to cloud computing yet. Mr. LIU Peng, a cloud computing expert in China believes that cloud computing distributes the computing tasks in the resource pool consisting of a lot of computers and makes different application systems gain the computing power, storage space and different software services on demand.

3.2. Cloud Computing Risk

It does not mean that there is no risk at all by adopting cloud computing. Firstly, cloud computing is supported by high-speed network. If the user’s network connection is broken because of the low bandwidth or any emergency, the user will not gain the required services by network.

Secondly, the user must gain any service through the cloud computing center. Once the cloud computing center fails to work by attack, the supply chain will break down. If the user saves data in cloud without local backup, once the cloud platform breaks down, the user will suffer inestimable loss.

4. Supply Chain, Information Coordination, Cloud Computing, Risk Avoidance

4.1. Coordination of Online and Offline Statuses

After taking an overall consideration of advantages and risks of applying cloud computing, this paper proposes a supply chain information coordination mode which is capable of resisting cloud computing risk as shown in Figure 1 and Figure 2. This information coordination mode has two basic statuses which are online status and offline status.

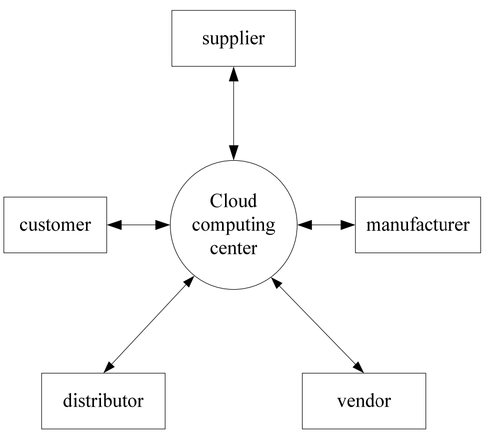

Figure 1. Online Status Coordination Mode

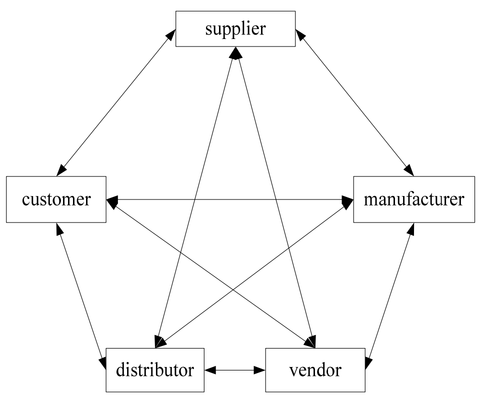

Figure 2. Offline Status Coordination Mode

At the online status, the network is smooth and the cloud computing center runs normally. At such status, each node in supply chain only exchanges information with the cloud computing center and gains the required services from the cloud computing center. The cloud computing center takes charge of coordinating the information of different nodes and realizing the optimal information integration and interest maximization of the whole supply chain. At the online status, each node can backup the supply chain information and the network address of the other nodes in real time within its own authorization range for using at the off-line status.

Once the network fails to work or the cloud computing center fails to work normally by attack, it will enter into the offline status. At the offline status, each node can exchange information with the other nodes by using the backup supply chain information and address of the other nodes completed at the online status for its own benefit maximization. This mode can guarantee the normal operation of supply chain in the case of network paralysis or cloud computing center breakdown.

4.2. Multi-agent Information Coordination Method

The last section describes the information network at the online coordination status and at the offline coordination status. As these two information networks are different, supporting two different information networks by using one coordination method is the key of the problem. This paper solves the problem by using the multi-Agent information coordination method [10]. At the online status, there are total five-layer online Agent entities in the cloud computing center including supplier, manufacturer, distributor, vendor and customer. Each layer Agent includes online Agent for order management, online Agent for material planning, online Agent for production planning, online Agent for capacity planning, online Agent for manufacturing, online Agent for inventory, online Agent for supplier management and online Agent for marketing, etc.

The functions of each online Agent are different. For example, the online Agent for order management is responsible for customer's order processing such as receiving order, checking inventory and delivering according to the information transferred by different nodes in real time; the online Agent for material planning is responsible for purchasing and managing raw materials, formulating purchase plans and providing the material available quantity information according to each node information. The cloud computing center provides services for each node by establishing the five-layer Agent entities from supplier to customer and by the mutual coordination and communication among different Agents.

There is an offline Agent corresponding to each online Agent in each node. The functions of the offline Agent are almost exactly same as those of the online Agent. When it is at the online status, the offline Agent will synchronize with the online Agent. The difference between them is that the offline Agent only works in case of network paralysis or cloud computing center breakdown; in that case, the offline Agent will communicate with each Agent distributed in the network and gain the information transferred from its upstream and downstream business Agents; based on such information, the offline Agent will provide services for the respective node.

4.3. Critical Steps Establishing the Coordination Mode

The information security performance of cloud computing center is much concerned by the user too. The cloud computing center must have good information classification and confidentiality and establish the authority management to information. According to the different confidentiality levels of enterprise information, the information can be divided into three basic levels. The information at the highest level can only be viewed by the enterprise itself and the core cooperative enterprises; in addition, such information can only be saved inside the enterprise. The information at the intermediate level is open to the whole supply chain; however, such information can only be edited by the enterprise itself. The information at the lowest level can be browsed throughout the whole network. A good information classification system is good for the information security of the whole supply chain and strengthens the trust of the user to the security of the cloud computing center.

When this coordination mode is at the offline status, the cloud computing center does not play any role any more. In this case, the offline Agent of each node which was deployed in advance shall play the role. The following items need to be noticed in the process of deploying the offline Agent: firstly, when the offline Agent is at the online status, it shall backup the information which can be browsed within the authority limit of the node from the cloud computing center. Once the network fails to work and the node enterprise fails to communicate with the cloud computing center, the node can complete the subsequent works by using the backup information which was completed in real time previously until the network recovers. Secondly, if the network works normally and the cloud computing center breaks down, the offline application shall communicate with the other nodes and gain the required information by using the backup network address of the other nodes. In this case, the coordination mode presents the network flow mode and every node can work normally. The only difference is that the goal of information coordination is transformed to benefit maximization of partial nodes from the benefit maximization of the whole supply chain.

4.4. Coordination Model

This paper presented a fair coordination model based on transaction history, it is defined as follows.

$$M_d = < N, S, V, W > \qquad (1)$$

$N : N = \{a_{1,} a_2, a_3, ..., a_n\}$ is Agent set involved in supply chain coordination, n is the number of the Agent.

$S : S = \{< s_{1,} z_1 >, < s_2, z_2 >, ..., < s_m, , z_m >\}$ is participants' proposition, including tasks, resources, etc.

$V : V = \{V_{a_1}^{S_m}, V_{a_2}^{S_m}, V_{a3}^{S_m}, ..., V_{an}^{S_m}\}$ is issue's vector-valued set which is raised by Agent.

$W : W = \{w_1^{S_m}, w_2^{S_m}, ..., w_k^{S_m}\}$ is weight value of each issue of proposition assigned by an individual agent and $\sum_{k-1}^{k} w_k = 1$.

In this paper, a satisfaction degree evaluation function based on coordination fairness was designed and it is described as follows.

$$\Phi(V,T) = \sum_{i=1}^{K} \Phi(v_i, t_i) \qquad (2)$$

In which, $\Phi(v_i, t_i)$ is satisfaction degree of x_i and it's definition is as follows.

$$\Phi(v_i, t_i) = (th + (v_i - \overline{v_i}) \times \frac{(1-th)}{v_{i0} - \overline{\overline{v_i}}}) \times w_i \times (\delta_i)^{t_i} \qquad (3)$$

Among them, th is minimum threshold for satisfaction degree, also is the retention of satisfaction. v_{i0} is initial value of issue vector x_i, while $v_i = v_{i0}$, the satisfaction degree of individual agent to the issue of a_i is 1.

5. Experimental Simulation

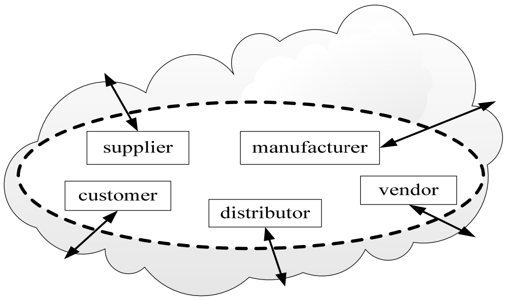

Figure 3. The Simulated Supply Chain

JACK simulation platform facing to multi-Agent implements simulation verification to the supply chain information coordination mode proposed in this paper. The simulated supply chain can be seen in Figure 3, which consists of one supplier, one manufacturer, one distributor, one vendor and one customer.

See the detailed simulation parameters in Table 1.

Table 1. Simulation Parameters

Parameter	Value
customer's order request	200
supply lead time	4
production lead time	3
mobile time span	1
finished goods inventory goal	600
raw material inventory goal	600
initial raw material inventory	200
initial number of finished goods	100
initial number of stock-out	0
initial unfulfilled order	0
initial number of raw material	100

In the process of simulation, five times tests had done, the total simulation duration is 200, Online and offline takes 100 each. According to formula (3), some result of the satisfaction of online and offline is shown as Figure 4 and Figure 5.

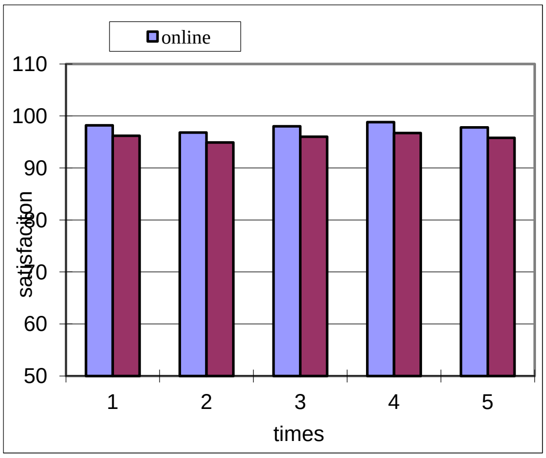

Figure 4. Satisfaction Degree between Online and Offline

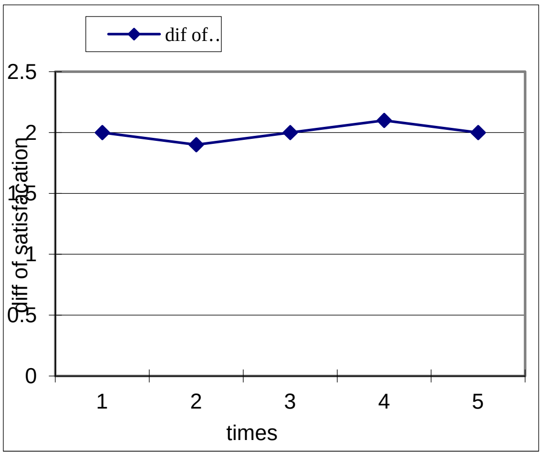

Figure 5. Difference of Satisfaction Degree between Online and Offline

From Figure 4, in the proposed coordination model, offline satisfaction is lower than the satisfaction degree of the online status, on the whole, they are very similar. In Figure 5, the difference of satisfaction between online and offline tends to be stable during the five tests, and the difference value is between 0.19 to 0.21.

Switch the supply chain to the offline status from the online status when $t = 100$. See the average order finishing rate before and after status switching in Table 2.

Table 2. Average Order Finishing Rate at the Online/Offline Status

	Average finished rate
online status	99.7%
offline status	96.8%

It can be seen from the table that the supply chain operates well when it is at the online status and the average order finishing rate is nearly 100%. It is because the cloud computing center gathers the information of all nodes and coordinates the supply chain information intensively to improve the production and transportation capability of the supply chain. When the supply chain is switched to the offline status, each node only optimizes their own status and only pursues for the benefit maximization of their own instead of pursuing for the overall benefit maximization. As a consequence, the average finishing rate falls; however, the falling range is small and the average finishing rate still reaches 96.8%. Viewed from the simulation result, the supply chain information coordination mode proposed in this paper avoids risks effectively and improves the production and transportation capability of supply chain by using the advantages of cloud computing center.

6. Conclusion

This paper analyzes the advantages and risks of cloud computing and proposes a supply chain coordination mode which can avoid the cloud computing risks. This mode has two basic statuses which are online status and offline status. At the online status, cloud computing center is responsible for coordinating the whole supply chain information; while at the offline status, information exchange can be realized among different nodes by using the pre-backup supply chain information and network address of other nodes. This coordination mode coordinates the whole supply chain information through the cloud computing center at online status and maximizes the overall benefit. Meanwhile, the offline status effectively avoids the risks to the whole supply chain brought by the overdependence of cloud computing on network and the high information concentration. The simulation result shows that when the mode is at the online status, it has very good processing capacity, including customers' satisfaction and order finished rate. When it is at the offline status, its processing capacity falls slightly; even so, its processing capacity is still excellent.

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