CONCEPTUAL MODEL OF MULTI-AGENT BUSINESS COLLABORATION BASED ON CLOUD WORKFLOW

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ABSTRACT

With the development of information and network technology, more and more enterprises adopt the networked manufacturing mode to improve their production, service, and operations. However, the current networked manufacturing mode can not put the centralized resources into distributed services, which leads to a lower inter-enterprise business collaboration capability. This paper firstly elaborates the cloud computing and cloud manufacturing. Then, as a new networked business process management technology, the cloud workflow is introduced into cloud manufacturing to improve the multi-agent business collaboration capability. Based on the cloud workflow, a multi-agent business collaboration process is established to realize a mapping from manufacturing requirements, manufacturing services to manufacturing resources dynamically and hierarchically. Finally, a conceptual model of multi-agent business collaboration is proposed, which includes the modeling and verification of cloud workflow, the modeling and clustering of manufacturing services, and the optimal matching of manufacturing service supplies and requirements. This conceptual model will improve the multi-agent business collaboration capability of manufacturing service demander, provider and operator, and will provide a new solution, theoretical foundation and technical support for the practical application of cloud manufacturing.

Keywords: *Cloud Workflow, Business Collaboration, Conceptual Model, Cloud Computing, Multi-agent*

1. INTRODUCTION

With the development of information and network technology, more and more enterprises adopt the networked manufacturing mode, such as agile manufacturing and manufacturing grid. They unite the distributed manufacturing resources together by network and realize the resource sharing and business collaboration of inter-enterprises [1].

However, lacking of the third-party to manage and operate the manufacturing services uniformly, the current networked manufacturing mode can not put the centralized resources into distributed services, which leads to a lower inter-enterprise business collaboration capability. Furthermore, the current networked manufacturing mode emphasizes on sharing of soft resource, such as data and information, and does not provide a satisfactory solution to intelligent access of bottom processing equipments. All of these bottleneck problems restrict the extensive application of the current networked manufacturing mode seriously [2]. How

to establish the conceptual model and improve the multi-agent business collaboration capability of manufacturing service demander, provider and operator has emerged as one of the most important issues.

2. FROM CLOUD COMPUTING TO CLOUD MANUFACTURING

Cloud computing proposed by Google and Amazon in 2006 is a super computing mode based on network [3]. The core idea of cloud computing is that the specialized computer and network corporations, called the third-party service operators, establish a computing storage and computing service center, which virtualizes a lot of computing resources, storage resources and software resources into "clouds", and forms a virtual and shared IT resources pool for remote computer users [4]. In nature, the cloud computing brings a transition of service mode, which turns computing resources into a specialized service provided by network [5]. Following by concept of cloud computing, the notion of cloud security was proposed [6,7].

Cloud computing and cloud security provide a new idea to solve the bottleneck problems of current networked manufacturing mode. Further, the development of internet of things helps to realize a flatwork, in which the various types of manufacturing resources are united together. At the same time, the progress of high performance computer provides a possibility that the more complex manufacturing problems are solved and the large-scale collaborative manufacturing is realized. Based on the these new situations, Li, a member of the Chinese Academy of Engineering, and his research team proposed a new concept of cloud manufacturing in 2009 [2].

3. CLOUD WORKFLOW

Cloud Manufacturing is a new service-oriented networked manufacturing model, and is an intersectional and mixed product of advanced information technology, manufacturing technology, cloud computing and internet of things [8]. In the cloud manufacturing mode, the manufacturing service operator uniformly manages the various types of manufacturing resources provided by manufacturing service provider and the various types of manufacturing requirements proposed by manufacturing service demander. Manufacturing resources include manufacturing equipment, computer system, software tool, knowledge data, and so on. Manufacturing requirements include product design, manufacturing, marketing, and so on.

Replacing the computing resources with the manufacturing resources, the cloud manufacturing applies cloud computing into manufacturing field, enriches the shared resource types, and expands the definition of cloud computing [9]. However, the cloud manufacturing is a strategic system engineering, which requires the self organization of manufacturing nodes, scheduling on demand and seamless collaboration from the perspective of manufacturing itself [10].

Workflow technology is a core technology to realize the modeling, analyzing, optimization, management and automation of business processes. It will play a vital role from cloud computing to cloud manufacturing, as shown in Figure 1.

The concept of cloud workflow was proposed by Yun Yang and his team in 2008 [11]. The cloud workflow integrates cloud computing and workflow, and not only has massive amounts of cloud service, but also provides a system flatwork for using cloud services. In the modeling stage of cloud workflow,

the cloud workflow model is established aiming at the every steps of product life cycle. In the instantiation of cloud workflow, the manufacturing service satisfying function requirement is found in service pool. In the executing stage of cloud workflow, an intelligent algorithm is used to select dynamically a certain manufacturing service for the special manufacturing requirement and realize the optimal matching between manufacturing services and manufacturing requirements. The final manufacturing business process is completed by multi-agent of manufacturing service demander, provider and operator. Therefore, as a new networked business process management technology, the cloud workflow can improve the multi-agent business collaboration capability under the cloud manufacturing mode.
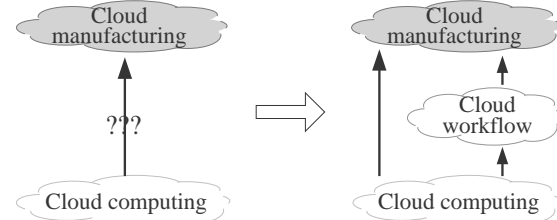

Figure 1: Relation of Cloud Computing, Cloud Workflow and Cloud Manufacturing

4. MULTI-AGENT BUSINESS COLLABORATION PROCESS

Under the cloud manufacturing mode, the multi-agent business collaboration process of manufacturing service demander, provider and operator includes three stages: collaborative business process modeling, model instantiation and model execution. Introducing cloud workflow into cloud manufacturing mode, a multi-agent business collaboration process based on the cloud workflow is established, as shown in Figure 2.

In the modeling stage of cloud workflow process, the manufacturing service demander selects an existing cloud workflow model or establishes a new cloud workflow model using a modeling tool integrating graphical and formal characteristics aiming at every step of product life cycle. The nodes of cloud workflow model are the manufacturing service requirements. The link line in any two nodes represents the logic relationships of manufacturing service requirements, such as sequence, parallel, choice and iteration.

In the instantiation stage of cloud workflow model, the manufacturing service operation platform analyzes every manufacturing service

function requirement defined by nodes of cloud workflow model, and finds a manufacturing service or service combination (private manufacturing cloud or public manufacturing cloud) from the virtualized and clustered manufacturing cloud pool

by service searching and matching mechanism to realize the logic interrelation between the manufacturing service requirements and manufacturing service supplies.
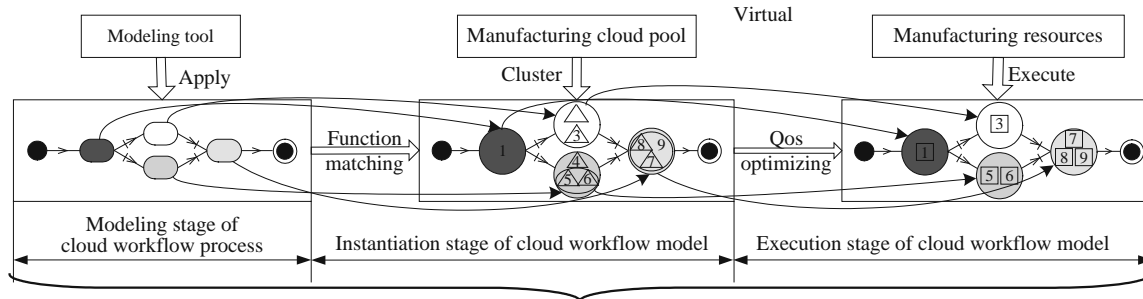

Figure 2: Multi-agent Business Collaboration Process Based on Cloud Workflow

In the executing stage of cloud workflow model, the unique manufacturing service or service combination is determined as real service. However, in most cases, several candidate services can be found, which satisfy the manufacturing service requirement and have the different quality of service (Qos). Here, based on the global Qos of cloud workflow process, an intelligent algorithm is used to select dynamically a certain manufacturing service or service combination for the special manufacturing requirement and realize the optimal matching between manufacturing services and manufacturing requirements. Because the manufacturing services are virtualized from bottom manufacturing resources, the collaborative business process including manufacturing services is convenient for mapping into the collaborative business process including manufacturing resources. The final manufacturing business process is completed by multi-agent of manufacturing service demander, provider and operator.

In summary, the total life cycle of multi-agent collaborative business process based on cloud workflow includes three stages, such as cloud workflow modeling, model instantiation and model execution, and realizes a map from manufacturing requirement, manufacturing service to manufacturing resource dynamically and hierarchically. The precondition of total life cycle of multi-agent collaborative business process is the virtual interrelation and clustering sharing of manufacturing resources. The principle of total life cycle of multi-agent collaborative business process is the internal logic of manufacturing business. The destination of total life cycle of multi-agent collaborative business process is the optimal matching between manufacturing service

requirements and manufacturing service supplies. Finally, a collaborative business process is obtained, which is composed of many manufacturing resources and can be executed by multi-agent together.

5. CONCEPTUAL MODEL OF MULTI-AGENT BUSINESS COLLABORATION

Figure 3 shows a conceptual model of multi-agent business collaboration based on cloud workflow.

5.1 Modeling and Verification of Cloud Workflow

Under the cloud manufacturing mode, the total manufacturing life cycle has several outstanding features and constraint conditions including complex business logic, various business type, large data, time constrain, space constrain and resource constrain. To response to the market personality requirement, a cloud workflow model of total manufacturing business is essential.

Polychromatic sets theory (PST) is a relatively new mathematical theory and information processing tool originally developed by the Russian scientist V.V. Pavlov [12]. PST has two important concepts: polychromatic sets and polychromatic graph. The polychromatic graph model not only describes whether the interrelation exists in any two nodes, but also represents a connected kind of interrelation existing in any two connected nodes. Using the super Boolean operation of PST and existing algorithms, the polychromatic graph model can be verified and optimized from perspective of logic structure. Therefore, the cloud workflow model based on PST is feasible in theory.
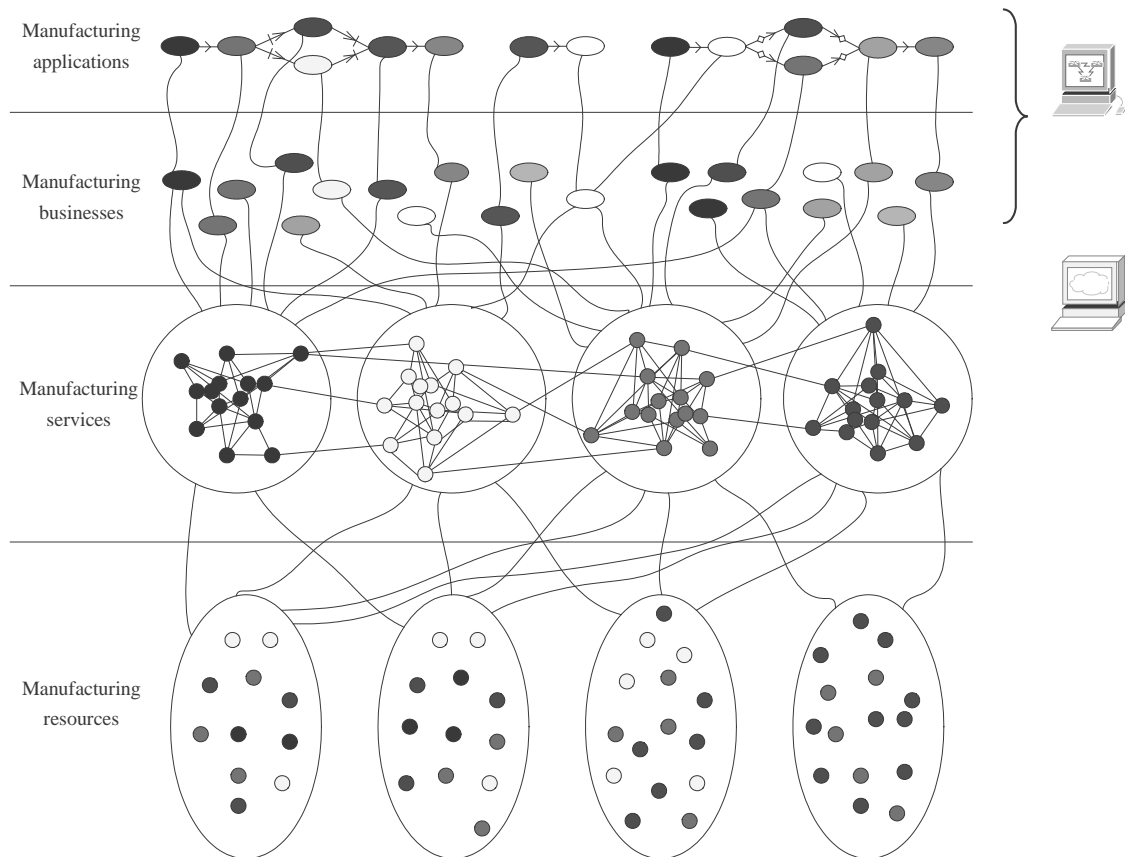
Figure 3: Conceptual Model of Multi-agent Business Collaboration Based on Cloud Workflow

5.2 Modeling and Clustering of Manufacturing Service

The manufacturing resources include hard manufacturing resources and soft manufacturing resources. Under the cloud manufacturing mode, the various manufacturing resources are serviced and clustered functionally to form a large and virtual resource cloud pool with high scalability and agile flexibility for invoking by manufacturing service requirement dynamically.

The complex network is a technology and method for researching complex system. It pays attention to the topological structure of elements in system, and is a basic approach to understand the character and function of complex system. The network cluster structure is one of most common and most important attributes of topological structure. The complex network clustering method is to reveal the real network cluster structure existing in complex network. Therefore, the network theory is used to establish the association model of manufacturing services, and the complex network clustering method is used to realize the function clustering of manufacturing services.

5.3 Optimal Matching of Manufacturing Service Supply and Requirement

Under the cloud manufacturing mode, multi-agent business collaboration is realized by sharing manufacturing resources. After the clustering analysis, the manufacturing services with similar functions in the resource cloud pool may have different quality of service (Qos). It is important that the final manufacturing service is selected according to Qos, such as cost, time and credit, to realize the optimal matching of manufacturing service requirements and supplies. Therefore, the optimal matching problem of manufacturing service requirements and supplies in term of Qos is abstracted into a global multi-objective optimal problem. The immune algorithm is suitable for solving this optimization problem.

6. CONCLUSIONS AND FUTURE RESEARCH

With the development of information and network technology, many enterprises are currently facing challenges of unprecedented and abrupt changes, including saturated market, economic globalization, and rapid IT infrastructure changes.

For maintaining competitive advantages, more and more enterprises are adopting networked manufacturing mode to improve their production, service, and operations. However, lacking of the third-party to manage and operate the manufacturing services uniformly, the current networked manufacturing mode emphasizes on the centralized utilization of distributed resources and can not put the centralized resources into distributed services, which leads to a lower inter-enterprise business collaboration capability.

Based on the cloud computing and cloud manufacturing, this paper introduces the cloud workflow into cloud manufacturing to improve the multi-agent business collaboration capability. A multi-agent business collaboration process is established to realize a mapping from manufacturing requirement, manufacturing service to manufacturing resource dynamically and hierarchically. Finally, a conceptual model of multi-agent business collaboration based on cloud workflow is proposed, which includes the modeling and verification of cloud workflow, the modeling and clustering of manufacturing service, and the optimal matching between manufacturing service supply and requirement. This conceptual model will improve the multi-agent business collaboration capability of manufacturing service demander, provider and operator, and will provide a new solution, theoretical foundation and technical support for the practical application of cloud manufacturing. In the future, we will expand the current work to the concrete and key techniques existing in the conceptual model of multi-agent business collaboration based on cloud workflow.

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