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Research Article
Research on Workflow Optimization in Cloud Manufacturing Environment

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Abstract

Background: In order to realize the construction, implementation and management of the business process in the cloud manufacturing platform, the characteristics of the workflow in the cloud manufacturing environment are analyzed. **Materials and Methods:** According to the time of searching and binding service, the workflow is divided into 4 stages: Service model, service discovery, service binding and service invocation. **Results:** Based on the service quality requirement and service quality (QoS) attributes in the workflow abstraction model, the different service discovery strategies are chosen to make the same activity, different instances can be bound to different services and improve the flexibility and self-adaptability of cloud manufacturing workflow. **Conclusion:** In this study, according to the characteristics of cloud manufacturing workflow, authors study in the framework of building, model building and implementation process, etc.

Key words: Workflow, optimization, cloud manufacturing, quality of service

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INTRODUCTION

Cloud computing is an emerging business computing model. It will calculate the tasks distributed to a large number of computers in the pool of resources, so that all applications can access to compute power, storage space and a variety of software services[1-3]. This resource pool is called cloud. Cloud is a number of virtual computing resources that can be maintained and managed, typically for some large server clusters, including computing servers, storage servers, broadband resources and so on[4-8]. Cloud computing will focus on all the computing resources and by the software to achieve automatic management, without human participation[9-13]. This makes application providers do not need to worry about tedious details, can be more focused on their own business, is conducive to innovation and reduce costs[14].

The so-called cloud, because it has characteristics of realistic cloud in some aspects: Cloud is generally larger, the size of the cloud can dynamically scalable and its boundary is fuzzy, cloud in the air and erratic. People can't determine its exact location, but it does exist in a certain place[15-18].

Cloud computing is the development of computing parallel, distributed computing and grid computing. Cloud computing is the result of hybrid evolution of concepts such as virtualization, utility computing, IaaS (Infrastructure as a service), PaaS (platform as a service) and SaaS (software as a service)[19-22].

In general, cloud computing can be counted as a commercial evolution of grid computing. It connects the high performance computers distributed around the country with high speed networks. They are organically bonded together with a specially designed middleware software to the Web interface, which is accepted by the scientific workers from all over the world and assigned them to the appropriate nodes. The computing pool can greatly improve the service quality and utilization of resources and avoid the low efficiency and complexity caused by cross node division[23-26].

Cloud computing has the following characteristics:

- **Very large scale:** Cloud has a considerable size, Google cloud computing has about 1000000 servers, IBM, Amazon, Microsoft, Yahoo, etc., the cloud has hundreds of thousands of servers. Enterprise private cloud generally has hundreds of thousands of servers. Cloud can give users unprecedented computing power[27]
- **Virtualization:** Cloud computing supports users in any location, using a variety of terminal access applications. The requested resources come from the Cloud and not the fixed tangible entity. Applications run somewhere in the cloud, but in fact, users don not need to know, also do not worry about the location of the application running. Just a laptop or a cell phone, people can use the network service to achieve everything people need and even the supercomputing as a task[28]
- **High reliability:** Cloud using multiple copies of data, fault tolerant computing isomorphic node, such as interchangeable measures in order to ensure the service of high reliability, the use of cloud computing is more reliable than the use of the local computer[29-32]
- **Generality:** Cloud computing is not for specific applications, under the support of the cloud variety applications can be constructed, the same cloud can support different applications running at the same time
- **High extensibility:** The size of the cloud can dynamically scale, meet the needs of the application and the user scale growth[33]
- **On-demand service:** Cloud is a huge pool of resources, people can purchase on demand like water, electricity, gas and so on[34]
- **Extremely cheap:** Due to the special fault tolerance measures of cloud, people can use very cheap nodes to form a cloud. Cloud automation centralized management makes a lot of enterprises don't need to burden the high costs of data center management. The generality of cloud makes the resource utilization improved compared with the traditional system, so users can fully enjoy the cloud low cost advantage[35]

Cloud manufacturing is a product of the combination of cloud technology and manufacturing self-organization feature, which aims to provide a kind of resource sharing and collaborative environment for cross regional and across the enterprise distributed heterogeneous manufacturing resources, allows the user to submit the task to be completed in dynamic virtual organization[1]. Cloud product development problem solving in manufacturing environment is no longer just completed by a company, a new product is composed of multiple manufacturing resources of virtual organization. Geographically distributed manufacturing resources with the aid of computer, network communication and multidisciplinary team, the product development process is similar to the real world, is also a kind of orderly business activities process. However, because of the dynamic characteristics of cloud manufacturing, distribution, heterogeneity and autonomy, if use the general processing method, not only inefficient, but also cause some application

was unable to complete, need to have the corresponding service and technology to manage these applications. Therefore, cloud manufacturing workflow has been paid more attention with the development of the study of cloud manufacturing and application.

This study gives a service based workflow framework and model in the cloud manufacturing environment. Authors focus on the dynamic and complexity of the resource, binds service at workflow run time and makes the dynamic combination of the workflow and service, so as to improve the flexibility and adaptability of the cloud manufacturing workflow.

Cloud manufacturing workflow framework

Cloud manufacturing workflow features: Cloud manufacturing workflow is a workflow technology, it can be completely or partially to operate in a variety of interaction with the cloud services in the cloud environment. It is a real time interaction and data transfer between different cloud services. Cloud manufacturing has the following characteristics:

- **Work style based on virtual organization:** Virtual Organization is a temporary organization which is formed by a variety of manufacturing resources in the face of a specific manufacturing business opportunities. Before the formation of virtual organization, the distribution of manufacturing resources in internet networks can be registered to the cloud manufacturing information services loose exist as an independent behavior subject, its organization form is without boundaries. Once the business event is triggered, the event engine starts policy analyzer, carries on the business strategy computation and forms the business process. In the execution of a process, according to the event subscription information to find and call its services in the information service, generate a boundary application dynamic alliance and work together to complete each task in the process. After the completion of the task, the virtual organization will be dissolved[2]
- **Application style based on cloud services:** Before the release, any manufacturing resources in the cloud need to be encapsulated into a service object in accordance with the web service resource framework specification, thus ensuring that the manufacturing resources of the cloud can be quickly aggregated into a manufacturing service with the required manufacturing capabilities and service levels to complete the manufacturing tasks. Resource providers publish their own resources in the way of service and can effectively solve the problem of resource heterogeneity, distribution and autonomy. Compared with web service, cloud services have the following features; cloud services are dynamic and transient, can be started or shut down to change its availability, cloud services are distributed, there is no global unified trust relationship, cloud applications may contain hundreds of cloud services, these cloud services have to work effectively to complete a cloud applications, cloud applications usually have a very long life cycle and thus have a corresponding survival cycle of cloud services

In cloud manufacturing, a variety of software resources and manufacturing equipment comply with the standard of cloud services, has been packaged as a cloud manufacturing independent service node[3]. The operation of the specific physical resources in the service nodes (i.e., the implementation process) is transparent to the application description process and the resource allocation process.

- **Complexity and dynamics of manufacturing processes and resources:** In the cloud manufacturing environment, the market is global, the complexity of business process is further increased, which often includes many activities and these activities often change with the progress of time or task. As a result, it makes the static workflow that cannot meet the actual needs. Moreover, resources are often distributed around the world, which is divided into different enterprises or individuals, there are different strategies, price models and evaluation indicators. At the same time, resources are dynamically added and exited, its status is constantly changing and the discovery and selection of resources is complex

Cloud manufacturing workflow framework: This study extends the workflow reference model[4] supported by Workflow Management Coalition (WFMC) and give the framework of the cloud manufacturing workflow shown in Fig. 1. Cloud manufacturing workflow management system is divided into two stages (Construction period and operation period). During the construction of the cloud manufacturing workflow framework, users can set up the business model, the quality (quality of service, QoS) requirements are decomposed and converted into QoS constraints based on certain rules. The business model description will be converted into a format which can be recognized by the workflow engine. At runtime,

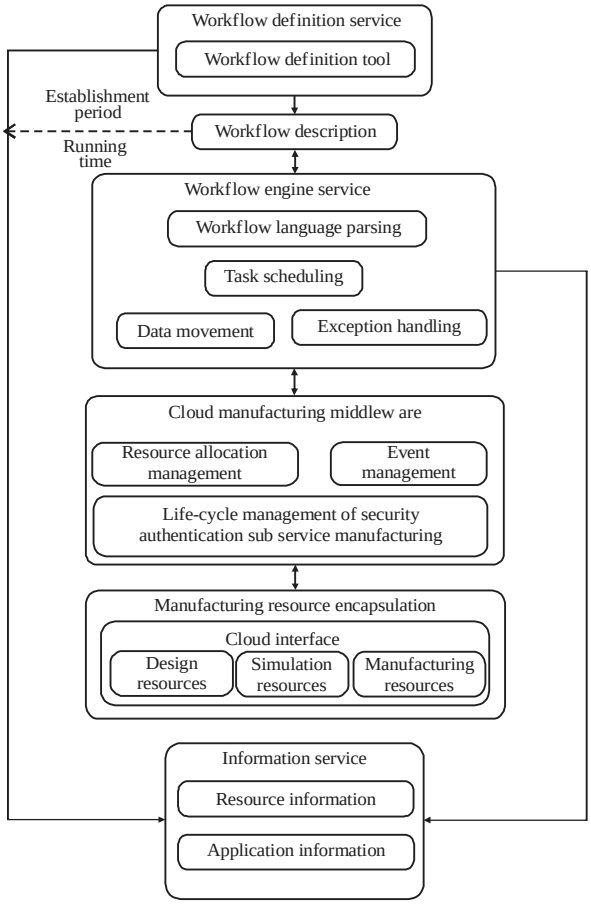

Fig. 1: Workflow framework of cloud manufacturing

workflow definition is submitted to the workflow engine service. Workflow engine service parses workflow process definition, create and implement cloud workflow instance. The main functions include task scheduling, error handling, data movement, etc. The workflow engine service is built on the cloud middleware layer, which provides an open and extensible standard and basis for the realization and interaction mechanism of the service. The most underlying manufacturing resources use cloud technology to encapsulate all kinds of independent operations. The local resources can be used as the global resource for all applications in the cloud and the heterogeneity of the cloud technology is needed.

Abstract workflow model based on service: Workflow model mainly defines the various activities in the workflow and the dependency relationship among them. Abstract workflow model refers to the time that is not bound to specific resources, but in the activities of the binding of the QoS description of resources. The definition of a service based workflow abstract model is presented here.

Definition 1: Workflow is defined as a five tuple:

$$\text{MGFlow} = \langle \text{Name, ActivitiesSet, RouteSet, ECArulesSet, MGFlow, Result} \rangle \quad (1)$$

Name represents the workflow's name; ActivitiesSet is a collection of activities; RouteSet is a collection of or, which describes the activities of the interaction and connects the activity to the end of the process instance. The ECA is a set of sequence rules. The ECArulesSet is a collection of ECA rules. Result is a set of success rules.

Definition 2: Activity is defined as the unit of the completion of the function, which is a nine tuple:

$$\text{Activity} = \langle \text{IdName, Role, InPut, OutPut, StatusSet, QoSReq, ConditionStart, ConditionEnd, ExceptionProcessing} \rangle \quad (2)$$

The IdName represents the basic properties of the activity, including the activity name, description, Role is the

action of the corresponding role, InPut/OutPut is related to the activity of the workflow related data, including input and output data, StatusSet said the activity of the state, the active state is not started, is being carried out, give up, failure, complete and be defined, etc. The QoSReq indicates that the QoS requirements of this activity, including time, quality, cost, reputation and reliability.

ConditionStart/ConditionEnd definition of the conditions for the start/end of the event instance; ExceptionProcessing for the active error handling mechanism.

In the cloud manufacturing environment, the implementation of each activity in the service workflow is the corresponding service. Service is a network of reachable, through the exchange of information to provide some of the ability of the entity, it does not rely on a specific hardware, operating system and programming environment. Service is divided into atomic services and composite services. Atomic services can be seen as a unit of service. Composite service is a new service formed by several atomic services, in order to complete a business process, in accordance with the rules of the formation of a certain rule, which itself can serve as an atomic service of other composite services. Composite services are a combination of several services that do not involve the internal structure of their own, but only through the combination of input and output activities.

On this base, this study gives the definition of service. The services here are recursively defined, that is, the individual defined services can be combined to form a complete process or a new service through their input and output. Similarly, a complete process can be considered as a service and other services to nested combinations constitute a new service.

Definition 3: Service is a six tuple:

$$\text{Service}=\langle \text{ServiceSet, DepSet, In, Out, Constraints, QoS} \rangle \quad (3)$$

ServiceSet is a collection of services, is a collection of services, DepSet is the implementation of service dependencies between services, it is from the end of a service structure to another service structure, In is the input set of services, Out is the output set of services, Constraints is the time constraint for each service in the service collection. It includes the beginning time and the end time of the output activity. The QoS determines the availability and practicality of the service.

Definitionn 4: Service quality QoS is defined as a six tuple:

$$\text{QoS}=\langle \text{Time, Quality, Cost, Fidelity, Reliability, Policy} \rangle \quad (4)$$

Time represents the time required to call the service, Quality represents the quality of the service provided, cost represents the cost of the call service, Fidelity represents the reputation of the service, Reliability represents the reliability of the service, Policy indicates that the service provider has released a policy set of services, including the reward and penalty.

Service based workflow execution process: The difference between workflow and traditional workflow is that the task of each activity in the workflow is defined, that is to say, where the task is executed, what kind of resources and what kind of running results are all in advance and in the cloud manufacturing workflow, because each activity corresponds to the service, authors use the service function description and implementation description to describe the characteristics, which only describes the service functions required by the workflow and does not bind to the specific services. Only by using appropriate discovery and mapping mechanism, can the activity map of the abstract workflow model to the suitable cloud service, realize the dynamic combination of the workflow and service.

Workflow execution process can be divided into 4 stages: Workflow creation, service discovery, service binding and service invocation, as shown in Fig. 2. On the left (workflow modeling tool, abstract workflow model, workflow engine, application) represents the traditional workflow framework and the right is the workflow extension which supports the dynamic combination of workflow and service.

Workflow created: In the workflow definition phase. First, the user is decomposed into several activities by means of cloud manufacturing portal and the type of activity is defined as the boundary conditions of the type of activity. Workflow model parser to parse workflow definition, get activity description. In order to support under the environment of cloud manufacturing service dynamic discovery and binding, in that contains, in addition to the conventional logo, description and input/output data endures, also increased the QoSReq elements, QoSReq represents the complete an activity required QoS (quality of service) constraint is the entire task put forward by the user QoS requirements in different decomposition. The QoSReq is the factor that should be considered when the service discovery.

Service discovery: Activity description specifies the activity to the quality of service requirements (QoSReq), while the description of the service also provides a description of these QoS metrics. According to the activities of the service, the current service cannot meet user needs, the current service

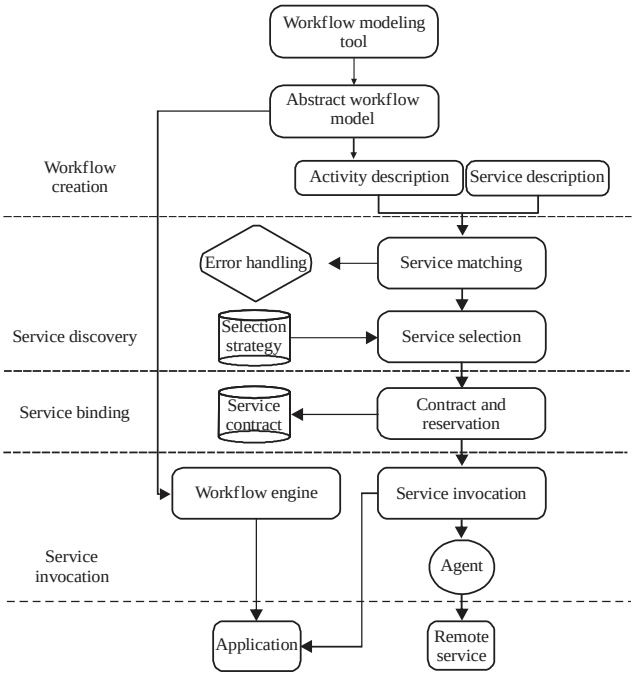

Fig. 2: Workflow execution process based on service

cannot meet user needs, the current service cannot meet the needs of users, this option is not meet the needs of users, this is a failure, the error handling module will be used to meet the requirements, or in an acceptable range, if only one service is required, the QoS service is successful service.

Service binding: When a suitable service is found, the user and the service provider are carried out between QoS negotiations to establish a service level agreements services during the call service quality, binding and reserved for the service. Different service providers can provide different SLA templates, generate SLA protocol, record the breach of service and update its QoS parameter attributes, allowing service providers to provide different service policies for different levels of users.

Service invocation: When an activity is initialized by the workflow engine, the service invocation module is bound to the active instance with the corresponding service. If the service is a local application, it can be called directly. If need to call a remote service, people can receive and send the relevant data by an agent to receive the call information.

Services description: The Web Service Resource Framework (WSRF) uses Web Services Description Language (WSDL) standard format to describe the service function, so that any implementation of the service is called in the same way. In the basic service description information, the WSRF service interface definition file defines the element tags and syntax, including input information, output information, transport protocol (or call protocol), state and life cycle management, but not including the QoS attribute description. In order to express the QoS attribute of the service, the sub tags that are integrated with a MG-QoS attributes and are used to define the elements[5].

The MG-QoS including the QoS parameters of the service, including the delivery time, price, credit and reliability, etc. In this way, the service provider can use the WSDL file to define the QoS attribute of the service and then in the cloud manufacturing information service and publish the QoS attribute of the service, to realize the service discovery based on QoS attribute. Due to the UDDI by itself provides only limited attribute query, namely; service name (service provider), key Reference (each service only) and category Bag (list all companies' category, which contains specific service) and when the service changes corresponding registration information does not automatically update. Therefore, here the use of the British University of Cardiff UDDI-UDDIe (universal description, discovery and integration extension) to support the expansion of the cloud services to support. The UDDIe allows a service to have a certain life cycle, so that services have more dynamic properties. The UDDIe can be used to create a distributed based registration center, its main role is to register the service it is maintained by a public repository of web service information.

Service discovery based on QoS: Service discovery based on QoS is based on the comparison of QoS and QoS elements in the service interface file in the activity description and the results from the UDDIe of the registered server can be a service list. The UDDIe provides service search of the API, through which it can achieve the service discovery of different QoS attributes. According to different service levels, the following different selection matching algorithm is adopted:

- **Gold search:** In strict accordance with the requirements of QoS search and matching service, the QoS attribute of the service should not be lower than the activity of the specified requirements. In UDDIe increased several search expressions, including >, <, ≥, ≤, = and < >
- **Silver search:** Activity description given a range of QoS properties, the selected value of the service should not exceed this range
- **Copper search:** Activity is specified by one or several QoS attributes, which are arranged in a certain priority order and the search of the resource has a certain flexibility

Service calls: In order to encapsulate the resource package, a service adapter is required to install a service adapter on each resource node in order to provide the service and access to the resource provider in accordance with cloud manufacturing standards and specifications and to enable them to be invoked by Soap (simple object access protocol) messages. When a suitable service provider is determined by a dynamic service binding process, the workflow engine sends a Soap message containing the service request input data to the resource service adapter and the service adapter resolve the Soap message, determine the appropriate service implementation method and create the required parameter list and service invocation. After the call is completed, the same service adapter via Soap message package feedback data and return it to the caller service. For services such as the input and output of a large number of unstructured data information (such as graphics files, etc.), the function of Soap cannot meet the requirements of automatic call service. As a supplement to the Soap message, the service request enterprise needs to upload the data and information from the E-mail or FTP to the specified service provider. At the same time, the service provider needs to transmit the image and multimedia data to the specified node in the workflow.

Application examples: In order to verify the application of cloud manufacturing workflow, this study takes a specific task in the process of testing the cloud manufacturing test bed of Ningbo Dahongying University as an example, as shown in Fig. 3.

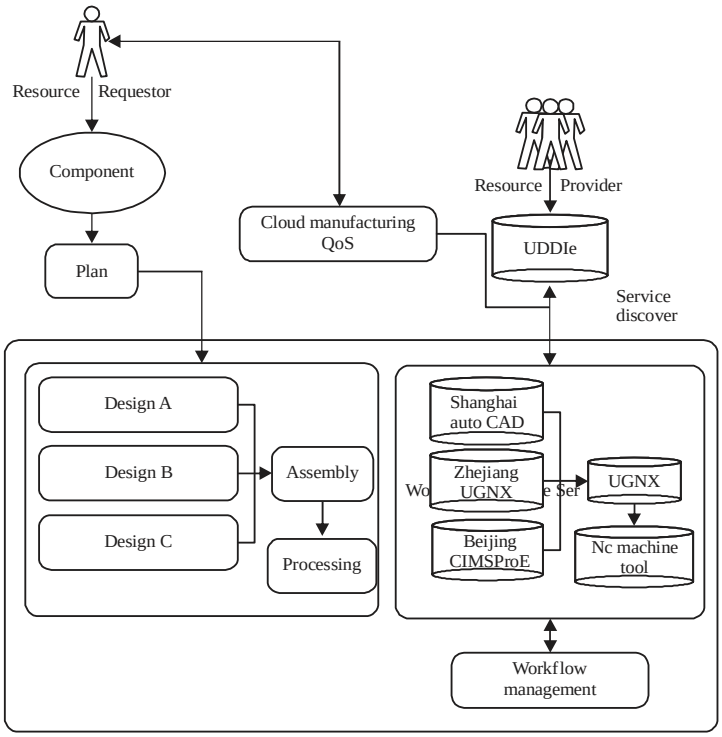

Fig. 3: Workflow frameworks of cloud manufacturing

- The user submits a request for processing the worm task and puts forward the specific requirements
- Cloud manufacturing platform to accept service requests, through the Global Process Planning (GPP) module, the the task decomposition into a series of sub tasks, including thrust ball bearing design, deep groove ball bearing design, design of the worm, worm assembly and processing
- Using the graphical process modeling tool to describe the business process and then convert it into a data structure of the XPDL (XML process definition language) format, which is in line with the WfMC standard, thus building the data model of the workflow engine
- Workflow engine service analysis XPDL document, according to the workflow definition file activity QoSReq description in UDDIe to find the required 5 services, if found to meet the QoS needs of the service, return the URL address and signed to set aside the service; it cannot find the service to meet the needs of QoS, the service quality management module and user QoS negotiation, request to reduce the QoS requirements
- The workflow engine is initialized at a predetermined time to send 3 concurrent tasks to the Shanghai machine tool factory AutoCAD resource, Baoshan UGNX resource and the ProE resource on the center CIMS
- During the execution of the workflow, the workflow management/module monitors the running status of the activity and is responsible for the execution of the workflow instance when the task is completed and when the task is completed, the task state is changed to complete

CONCLUSIONS

Cloud manufacturing workflow technology has a great significance to the development of cloud manufacturing, is an essential part of the cloud manufacturing platform. In this study, according to the characteristics of cloud manufacturing workflow, authors study in the framework of building, model building and implementation process, etc. This study has achieved good results; the following works will be conducted in the future:

- Error handling in workflow is very common in the highly distributed and heterogeneous system and there are a lot of dynamic and uncertain factors in cloud environment. In order to strengthen the robustness and reliability of the workflow system, authors provide a monitoring and error recovery mechanism
- Workflow scheduling has more difficulty and complexity, which is mainly embodied in the process of sharing limited resources. The resource in the cloud is often the task of non-cloud. Tasks in the workflow can only be carried out under the premise that the quantity, type and ability of the corresponding resources can be guaranteed, otherwise it will be stalled. Therefore, the key to ensure the normal operation of workflow is to choose the appropriate workflow scheduling rules and policies

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