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Case Study

Research on Architecture and Integrated Environment of Cloud Manufacturing

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Abstract

Objective: In this study, the relationship from the abstract angle among the service oriented architecture, cloud computing and cloud manufacturing was analyzed in order to meet the urgent needs of the software architecture and development tools supporting for the manufacturing cloud and point out that cloud manufacturing inheritance and extend the former two parts. **Methodology:** In the face of manufacturing resources, the integration of Service Oriented Architecture (SOA) and cloud computing. **Results:** Cloud manufacturing service architecture was proposed and the public availability of free open source tools was selected to build a platform based on the eclipse for cloud manufacturing services integrated development environment. **Conclusion:** The case study indicates that the integrated development environment has good scalability and can promptly respond to cloud manufacturing application requirements.

Key words: Cloud manufacturing, service-oriented architecture, intergrade development environment, open source software, web service

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INTRODUCTION

At present, the overall level of the manufacturing industry needs to be further developed, the production efficiency and the product added value need to be further improved, it is facing an increasingly prominent constraints of resource and environment, so that production mode urgent need to transform. In the face of the transformation and upgrading of manufacturing industry, there is need to use the new technology, including information technology to upgrade the manufacturing industry. With the development of a new generation of information technology especially the recent rise of cloud computing service oriented manufacturing provides a new tool and opportunity, thus cloud manufacturing concept came into being. Cloud manufacturing is based on the modern information technology, including cloud computing and some cutting-edge ideas, provide high value-added, low cost and global manufacturing services in a wide range of network resources for supporting manufacturing industry. Integration type of cloud manufacturing and traditional manufacturing systems are in different ways. Traditional manufacturing systems integration technology is to solve the information silos. The face of the dynamic changes of hardware and software structure, the system adaptability is poor resulting in system maintenance and expansion costs is extremely high. Moreover, tightly coupled integration mode is lack of scalability, flexibility and not conducive to restructure and reorganize business processes of enterprise. On the other hand, web services and Service Oriented Architecture (SOA) for enterprise application integration provides a loosely coupled way. Thus, in the integrated applications of cloud manufacturing, in addition to adopting service-based technology to achieve cross-platform applications to enhance the interoperability between applications, more important is the use of SOA, through loosely coupled way to connect, to realize complex business processes based on service composition within the organization or cross-organizational, agility respond to changing business needs.

De Roure *et al.*¹ proposed a new mode of service oriented networked manufacturing and define the cloud manufacturing to solve more complex manufacturing problems and carry out more large-scale collaborative manufacturing.

McGuinness and Harmelen² described the construction process of manufacturing cloud in the cloud manufacturing system and discusses the key technologies involved in the process of building cloud manufacturing.

For more comprehensive understanding the relationship between cloud manufacturing and the existing advanced manufacturing mode, Martin *et al.*³ elaborated the relationship and difference between cloud manufacturing and these patterns in detail from the aspects of concept and application mode. This study also clear the characteristics and connotation of cloud manufacturing and pointed out that the cloud manufacturing is a new development of networked manufacturing to concrete embodiment of service-oriented manufacturing concept in order to realize the agility, intelligent service, greening as the goal.

Xue *et al.*⁴ designed the function structure of cloud manufacture services management prototype system based on whole life cycle of cloud manufacturing operation. The study also studies consistency checking, cloud service relationship, combination of cloud services, flexible, combination of network and its dynamics for the future to achieve efficient intelligent cloud manufacturing services management to provide theoretical support.

Cao and Jin⁵ proposed cloud manufacturing is a service oriented, high efficiency and low energy consumption and based on the knowledge of the network, the agile manufacturing new modes and techniques. It enriches and expands the cloud computing resource sharing content and service patterns.

Cloud manufacturing is a kind of manufacturing mode put forward only in recent years. The mainly research focus on basic definition, system structure and the key technology problem. The study on cloud manufacturing is still in initial stage, the current is lack of specific implementation techniques and related tools supporting. In this study the development of cloud manufacturing service platform was discussed especially using the Open Source Software (OSS) to build the development platform of cloud manufacturing, so that promote the development, popularization and application of cloud manufacturing.

CLOUD MANUFACTURING SERVICE ORIENTED ARCHITECTURES

Cloud Manufacturing is a new thought based on the concept of "Manufacturing as service" and the technology. Cloud computing concepts have been proposed since 2006, although Google, Amazon, Microsoft, open source organizations and other well-known companies and academia put forward some cloud computing system or platform approach⁶⁻⁷ but cloud computing platform has not yet formed a unified standard and norms constraints, application

development diversification, various cloud computing manufacturers use their own technology infrastructure to develop cloud computing applications. At the same time, these existing cloud computing platform is facing computing resources, the particularity, complexity and scalability of manufacturing resources have not been taken into account, cannot meet the needs of cloud manufacturing research and development. In addition, commercial cloud computing products are proprietary, not open to outsider researchers and cannot be free to modify and experiment. However, whether cloud computing or cloud services are service-oriented and suitable for use SOA.

The SOA is a set of software design and development specification, it connects different functional units of the application (called services) with contracts through good interface, so that the services of all kinds of system can be interactive in a way of unify and common. The services can be reused in different business process, the implementation of specific service is not dependent on specific implementation language and tools. This architecture is based on service oriented, faster response to business changes through loosely coupled, reusable, interoperable services and support services publish, query and binding/call. Cloud computing is the result of many technologies such as utility computing, distributed computing, grid computing, virtualization technology and SOA. It takes a lot of highly virtualized computing resources to form a large pool of resources. On the one hand, SOA and cloud computing have a certain similarity, both emphasize the concept of service. The basic element of SOA is the service of software, cloud computing is the extension of SOA concept in IT infrastructure. It regards all computing resources (including hardware and software) as a service to bring more efficient, more economical SOA architecture⁸. In contrast, SOA is more strategic and abstract and cloud computing is more tactical and specific. Cloud manufacturing further enrich and expand the cloud computing resource sharing content and service mode⁵. If these three are regarded as object-oriented classes

and the SOA is described as an abstract class, cloud computing can be viewed as a subclass of SOA or an architectural instance, cloud manufacturing inherited cloud computing class, as shown in Fig. 1.

Cloud computing service pattern mainly has infrastructure as a service (IaaS), software as a service (SaaS) and platform as a service (PaaS). Resources include hardware, platforms and software, etc. Cloud manufacturing besides inheriting cloud service attributes and behaviors but also has its own unique attributes and behaviors. Namely in the mode of service, in addition to the cloud services (IaaS, PaaS and SaaS), cloud manufacturing also has Design as a Service (DaaS), Fabrication as a Service (FaaS) and so on service mode. Cloud Manufacturing oriented resource is no longer simply computing resources (e.g., storage and calculation, etc.) but is a very wide range of manufacturing resources (such as computing resources, design resources, labor resources, cooperation resources, equipment resources, logistics resources and human resources, etc.) and manufacturing capacity (the demonstration, design, production, simulation, experimentation, management and integration in the process of manufacturing, etc.). Furthermore, its resources are complex, different distribution, different manufacturing resources have different functions and attributes. Manufacturing resources has exclusive, that is cannot simultaneously process two or more than two tasks. One manufacturing task is usually made by a certain sequence of processes, each process requires different manufacturing resources to complete the process. In reality, there exists the problem of entity exchange, which needs to consider the impact of the physical flow interaction on the process time and the cost of the process.

On the other hand, SOA and cloud computing are complementary. Cloud computing offers cloud services of distal end for SOA and SOA provides composition technical for cloud services to meet the needs of complex business applications. At the same time, they focus on different aspect.

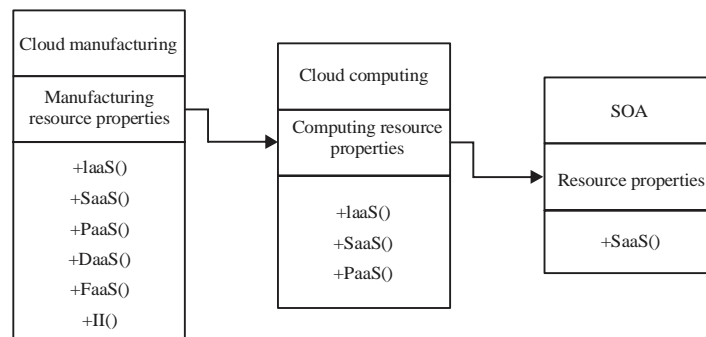


Fig. 1: Relationship among SOA, cloud computing and manufacturing

The SOA focuses on the use of service-oriented architecture for system design, how to deal with service, reusability, agility, loose coupling and so on and the cloud computing focuses on service delivery and service use, how to provide services, virtualized, on-demand dynamic expansion, resource as service and so on⁹. Faced with the manufacture of cloud computing and service-oriented demands, it is necessary to integrate the two parts. Referring to SOA¹⁰, a cloud computing architecture^{7,11} and cloud manufacturing services platform⁵, we constructed SOA4CM, service-oriented architecture for cloud manufacturing as shown in Fig. 3. The architecture reflects the integration of SOA and cloud and extends the traditional computing resources to cloud manufacturing resources. The architecture is divided into 10 layers:

- Manufacturing resources layer, includes various manufacturing resources (model resources, software resources, computing resources, storage resources, data resources, knowledge resources, manufacturing and equipment, etc.) and manufacturing capabilities, physical resources can be interconnected through Internet of Things
- Virtual resource layer, all types of manufacturing resource are virtualized through virtualization tools, virtual resource layer manage and use the manufacturing resources in centralized way and extend the resources of SOA/cloud computing to very wide range of manufacturing resources
- Service components layer, provides functions, understanding or operation for the service provider
- Service layer defines the interface of business functions or business data, provide a variety of core services, including atomic services and composite services
- Business process layer, through matching, choreography, binds process as service, allowing users to define business processes based on business needs
- Presentation layer (client layer/application layer), the user can interact with services of cloud manufacturing through different terminals, it supports user registration, authentication and description and creation of tasks requirements
- Service Integration (service bus) layer, provides intermediary, routing and transmission from the service requester to the correct service provider
- Business intelligence layer, defines business events and corresponding business rules
- Infrastructure services layer provides quality of service for services monitoring, security and quality, performance and availability services. In particular, security issue has become an obstacle to SOA/cloud computing, especially after the emergence of cloud manufacturing, security issues become more prominent
- Cloud services operating level, manages virtualization and service-oriented manufacturing resources and provides users with on-demand services, such as publication, query, binding, scheduling and deployment of services

Figure 2 shows the relationship between the left side of the three actors (service providers, service requestor and the service registered agent or service operator) and three basic operations (publish, find and bind). Cloud service provider translate manufacturing resources and manufacturing capabilities to cloud manufacturing services (cloud services or services) and publish through virtualization. Under the supports of service bus, infrastructure and cloud services operations, service provider defines a business process based on business demand to provide on-demand services through finding the required services. Compared to the previous architecture of cloud manufacturing from the perspective of the middleware, the proposed SOA4CM by this study has the following characteristics:

- The SOA4CM is developed from the fusion of SOA and cloud computing as well as the inheritance relationship between them. Figure 1 shows the same as SOA and cloud computing, the SOA4CM can be seen as a fusion of SOA and cloud computing and the result of the expansion and development of manufacturing services. On the one hand, SOA4CM implement cloud manufacturing service integration according to the SOA specification; on the other hand, according to the concept of cloud computing, SOA4CM run services with the means of unified, centralized and intelligence management and provide users with access at any time, safe and reliable, quality and cheap full life cycle service
- The SOA4CM reflects a loosely coupled architecture and makes resource objects hierarchy (related to the functional aspects of virtualization, service-oriented, business processes and interfaces, etc.) from the service provider and service consumer perspective. At the same time, the service integration, business intelligence, infrastructure and cloud service management of shared facilities are extracted common to all services to form different vertical levels
- The SOA4CM reflects the fusion of SOA, cloud computing, Internet of Thins and smart science technology. The SOA provides manufacturing services enabling technologies

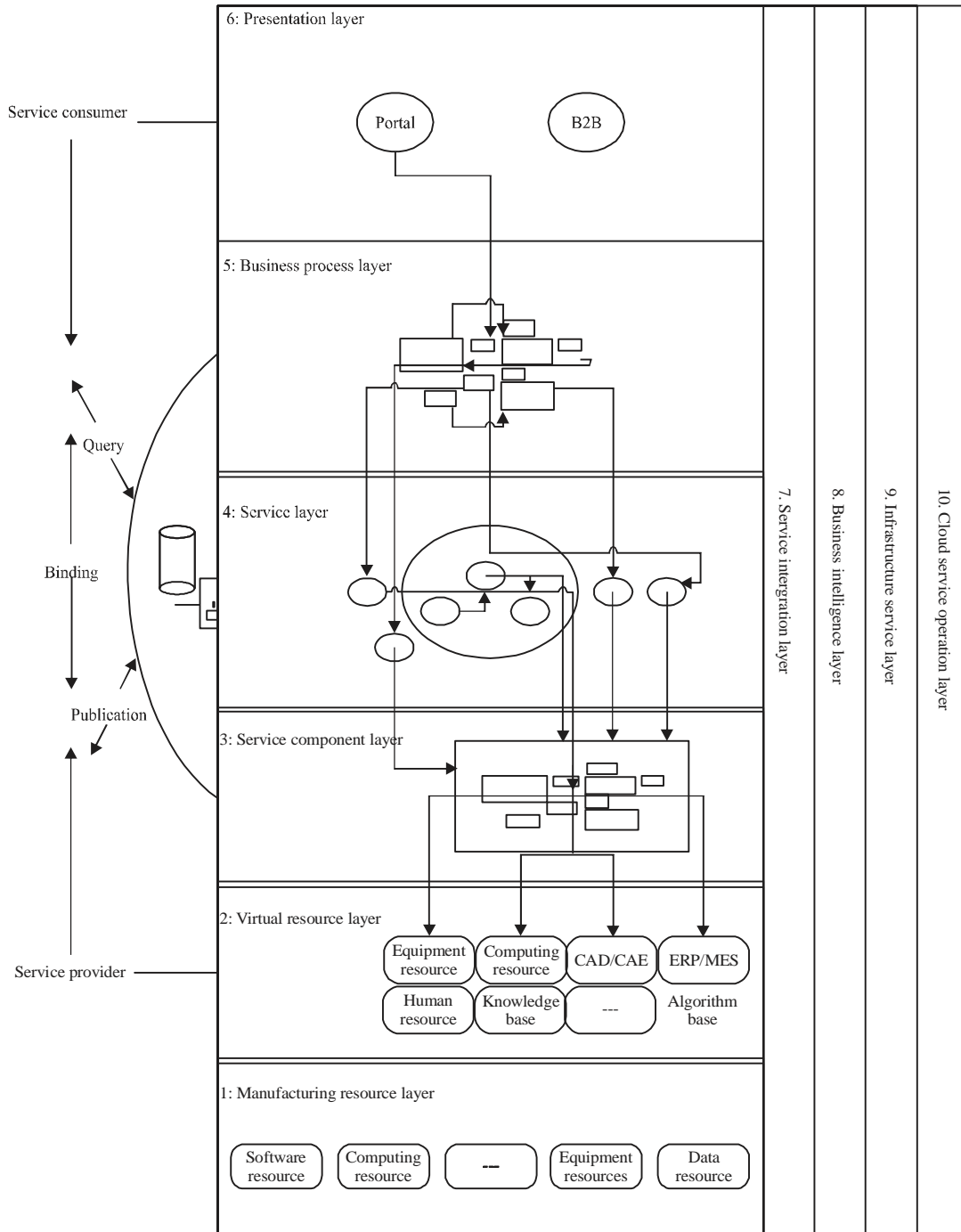


Fig. 2: Hierarchical structure for cloud manufacturing services

for quickly configured virtualized environment; cloud computing technology provide the enabling technologies for the intensive management, services on demand of manufacturing resources; Internet of Things technology provides enabling technologies and integrated development environment for the

interconnection of various types of objects and the realization of smart manufacture

- The core of SOA4CM is cloud services, it extends SOA architecture to companies in the cloud service, deploy the appropriate resources, services and applications based on business needs constantly adjust strategy with business

changes in the wide network resources area and the environment, dynamic scalability and high fault tolerance and reliability bring enterprise with lower costs and faster delivery by the virtually unlimited use of external resources

INTEGRATED DEVELOPMENT ENVIRONMENT

Cloud manufacturing services oriented architecture of the open environment includes an integrated development platform and development tools. At present, J2EE platform and Microsoft is the mainstream Web services development platform¹²⁻¹⁵. This study uses rich software products J2EE flat considering the use of open source software to build cloud manufacturing service platform.

As open source software providing free source software and saving cost, it is also faced with the problem of selecting the appropriate software to build a development platform. Here principle is:

- Lightweight can be embedded in the integrated development environment
- It is true in the sense of open source software, free of charge and provides the source code
- Priority select the develop language with the same as the Java open source software products

Integrated development platform: The SOA4MC is a kind of architecture, it illustrates a design idea and design principle, its implementation need to use the existing concrete technology in the application. The core of SOA is service, the realization of the service is no limit to the technology, can use all kinds of language to achieve, at present the SOA services mostly use web services technology. This study also uses the Web service technology to realize service in SOA4MC and begin from selecting plug in tool in service/service layer.

Web service technology uses a series of standards and protocols related functions, including the basic agreement Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description Definition and Integration (UDDI). The SOA is inspired from the web service standards, SOA early model is defined as service providers, service requesters and service registry. Those three roles are composed of a set of web architecture model¹²⁻¹⁵ as shown in Fig. 3. Service provider describe web services with WSDL, use UDDI to publish and register Web service to service registration publication agent.

In addition, for the design, management and monitoring system abnormal conditions, such as the capture completion

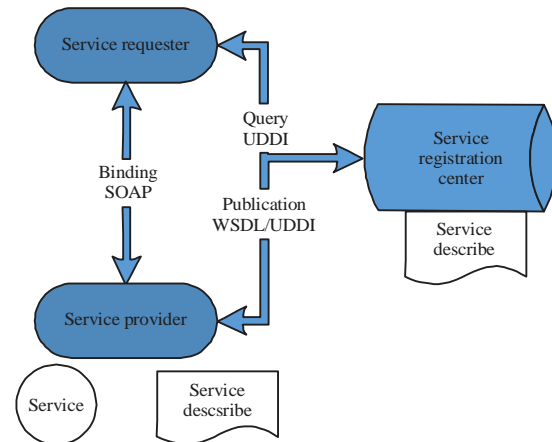


Fig. 3: SOA early model

Table 1: Selection of open source tools

Name of function layer	Open source development tools	Other open source tools
Cloud service operation layer	Hadoop	
infrastructure services layer	Synapse/eclipse	
Business intelligence layer	Drools/esper	Open rules
Service integration layer	Synapse	Service-Mix/Mule
Presentation layer	Portal/JSP/JSF/Ajax	
Business process layer	Apache ODE	jBPM
Service (component) layer	Tuscany SCA/JAX-WS	
Virtual resource layer	CloudSim	

time delay, the production process, equipment normal or abnormal trends, use open source event stream processing engine¹⁶⁻¹⁹ in order to achieve event correlation, aggregation and analysis capabilities. Synapse/SCA/ODE/Esper and other eclipse provide service monitoring, management and QoS-based services for Infrastructure services management. Cloud service operations and management select the open source Apache Hadoop²⁰⁻²³. The final selected open source plug-in tools achieve SOA4CM each functional layer as shown in Table 1 and Fig. 4.

DEVELOPMENT AND APPLICATION EXAMPLES

When using SOA4MC to develop practical business applications in addition to considering the needs of the service function but also need to consider the needs of performance of the whole system, availability, safety, reliability, fault tolerance, scalability and so on non-functional problem. Using ESB integration mode is an effective means to meet requirements of these non-functional. The selected Synapse ESB supports HTTP, SOAP, SMTP, JMS, FTP, POP3, SMTP, MTOM and other transport protocols. Many Web services specifications (WS-*) and QoS, such as WS-Addressing, WS-Reliable Messaging, WS-Security and WS-Policy etc., almost cover all of the basic features.

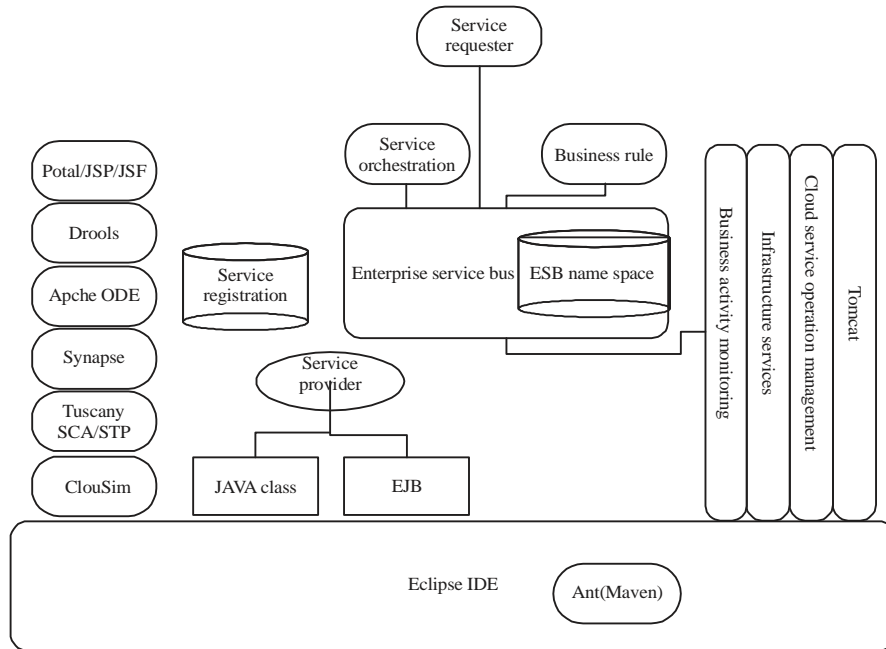


Fig. 4: SOA4CM integrated development tools

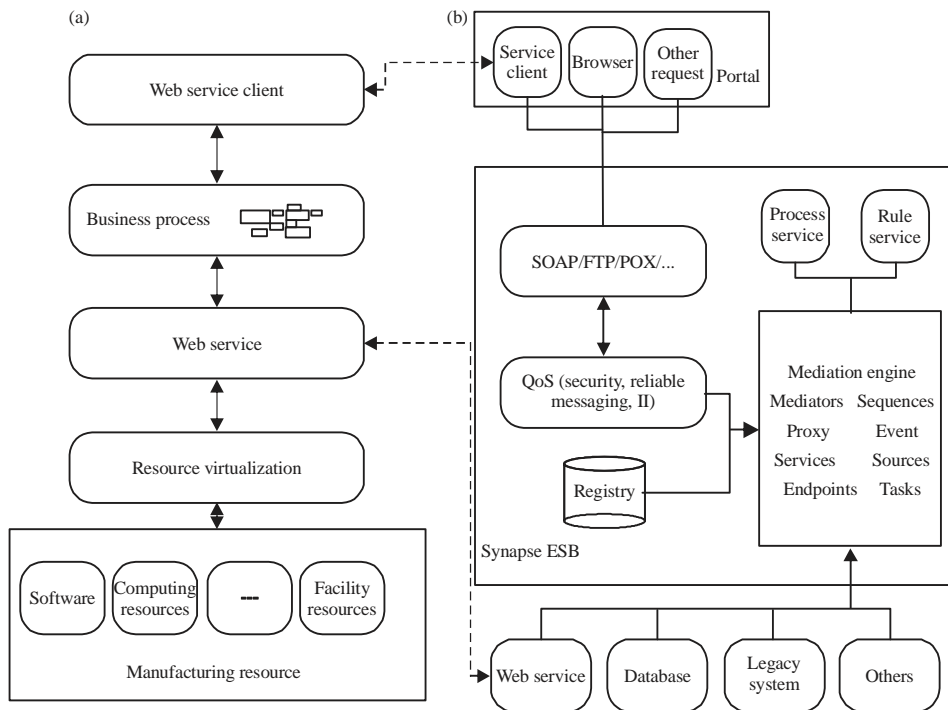


Fig. 5(a-b): Two modes of service integration, (a) Based on the process integration of service orchestration and (b) Based on the ESB integration

Figure 5a process integration model based on service orchestration and individual service direct integration is different. Figure 5b omits the manufacturing resources and the virtualization of the underlying and shows that ESB

integration mode regards the business activities, processes or the rules as a service, adopting the bus to manage and simplify integration topological structure between applications. The ESB plays connectivity and service

intermediary role also has the functions of service registration, so as to realize the protocol request of different forms (such as SOAP, SMTP, JMS and FTP, etc.) and various forms integration of services or procedures (including Web services, processes and rules for services, as well as the legacy applications and databases and so on).

CONCLUSION

This study analyzes the SOA, cloud computing and cloud-based manufacturing and proposes SOA4MC. The SOA4MC takes Eclipse as an integrated development platform, select CloudSim, Tuscany SCA/STP, Apache ODE, Apache Synapse, Drools, Esper, Hadoop and other open source plug-ins, set up SOA4MC oriented development environment and shows the different use case scenarios require different plug-ins through examples from simple to complex flexible serial processing.

The SOA4MC provides a blueprint for the integrated development environment and an integrated development environment is tool and approach to achieve SOA4CM. Such tool and approach are not the only way, this study adopts widely used web services technology and commonly used open-source software tools to achieve. The SOA4MC realizes intelligent access of physical devices through Internet of Things, extends and expands computing resources to manufacturing resources by the means of virtualization and service-oriented and meet the requirements of cloud manufacturing on-demand application through both properties SOA and cloud computing. On the one hand, according to the service principle, the construction of cloud manufacturing application is based on loosely coupled, reusable and interoperable services. On the other hand, according to the concept of cloud computing, the manufacturing resources can be reduced managed, with higher quality and lower cost.

In the development of integrated environment or application, the use of open source software not only save the software cost and accelerate the progress of development. Moreover, the research of these open source code is beneficial to inspire research ideas. In specific applications, it is not necessary to use all the development tools in the integrated environment, it may also be due to the application of the requirements to join other plug-in tools. Because the integrated development environment is open and scalable, tools can be selected according to application requirements and the complexity of problems on-demand or expand.

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