Analysis on Cloud Data Service Platform for Digital Oilfields

ZHUI Zheng-Ping*, PAN Ren-Fang1, CHEN Zhe2, LI Gong-Quan1, ZHENG Guo-Sheng3
1College of Earth Science Digital Oilfield Research Center, Yangtze University, Wuhan, 430100, China
2Information Center of Petrochina Dagang Oilfield Company, Tianjing, 300280, China
3Department of Engineering Sciences, NEUT, Yong-in, Kyunggi-do 907, Korea
*Corresponding Author, email: zzp2015@yangtzeu.edu.cn

ABSTRACT: Digital oilfields are highly complicated information systems, and their size increases as the enterprise scale expands. Cloud computing as a new service model has been gradually extended from the traditional IT industry to traditional industrial domains, but research on and the application of the digital oilfield cloud platform remain lacking. By introducing the reference frame of the integrated platform of oil enterprises at home and abroad, we adopt the design method of the integrated architecture of enterprises and the metadata-based object-oriented development model based on the design concept of cloud computing to identify efficient and inexpensive information platform solutions. Research is conducted on a cloud data service management system for digital oilfields. The overall structure of the cloud platform for digital oilfields is divided into five layers of infrastructure, data resources, functional services, applications, and terminal access and into two support subsystems, namely, cloud information specifications and standards and cloud service management platform. The cloud data service platform is generalized as an architecture with “a center, three layers, two buses, and two sub-functional systems.” Results show that the cloud data management system performs the four core functions of model, data bus, data service bus, and data quality control management. Furthermore, integrating cloud computing into the transformation and upgrading of traditional industries is feasible and applicable to other related fields.

Subject Categories and Descriptors
I.2.10 [Cloud Technology]; Cloud Data Analysis; I.4.10 [Cloud Data]

General Terms
Digital oilfields, Cloud Platform

Keywords: Cloud computing, Exploration and production, Central main database, Data bus, Data service

Received: 8 July 2016, Revised: 28 August 2016, Accepted: 10 September 2016

1. Introduction

Digital oilfields (DOFs) originated from Digital Earth; they constitute the most important branch of Digital Earth and the advanced stage of information-based development of oilfields. With the development of information technology, advanced information technologies, such as cloud computing and service-oriented architecture (SOA) [1,2], have gradually emerged. Given their advanced design characteristics of being “loosely coupled” and “ready to use,” these technologies can provide information resources to users in the form of services. These technologies have penetrated into the construction of information systems in different industries because they can effectively cope with the ever-expanding system size. Meanwhile, the cloud platform has also been gradually extended to various
industrial fields from the traditional IT industry.

To increase their competitiveness, oilfield companies constantly search for highly efficient exploration techniques and methods. They attempt to perform dynamic monitoring, analysis, and decision making during the processes of drilling, reservoir evaluation, and oil and gas production to improve the success rate of oil and gas exploration and reduce the operating costs of such an exploration. Information management plays a critical role in achieving efficient data management.

China’s oil enterprises have achieved useful results in the construction of an integrated information platform; however, compared with those in foreign countries, these enterprises are relatively backward and still immature with regard to the application of new technologies and industrialization practices. Therefore, we propose an overall solution for the cloud data service platform for digital oilfields according to the developmental status of China by analyzing the basic theory of cloud computing and by referring to the information integration platform at home and abroad. The objective is to enhance the level of data management and application of China’s oilfield enterprise and further improve the utilization of digital oilfields.

2. State of The Art

The concept of cloud computing is widely recognized and has become a popular topic in the IT industry and other industries. The concept is widely applied in many domains, such as land resource management [3], machinery manufacturing [4], agricultural and rural information management [5], and railway information sharing platforms [6].

The oil industry is one of the industries characterized by the most intensive applications of information technology. With the rapid development of information technology, digital oilfields have elicited attention from global petroleum companies, such as British Petroleum (BP), Shell, Chevron, Schlumberger, and Halliburton [11]. These new technologies have been integrated into the oil industry. Nevertheless, the application of the latest information technology in the oil industry lags behind that in the IT field. For example, in the oil industry, cloud computing remains in its infancy stage. Existing research results on combined cloud computing and petroleum technology remain scarce.

Robert from the University of Queensland in Australia [12] adopted the deployment model of private cloud or the Hybrid Cloud to meet the challenges faced by the upstream business of oil and gas. These challenges include data security and big data analysis. Robert stressed that additional applications based on cloud computing should be provided to the oil industry by other industries. With regard to the serious challenge posed by the large amounts of data generated by integrated automation and communication, Oladele et al. of Baker Hughes [13] proposed a complete cloud data management system and described the development status and trends of several available cloud data management techniques.

In China, Peng Ying et al. [14] proposed a data storage and service platform for distributed oilfield geophysical prospecting. The platform is based on cloud computing and aims to solve the problem of information sharing and reuse difficulties that are prevalent in the hardware and software platforms of oil exploration units. Li Songtao in 2013 [15] proposed four stages for oil group enterprises to implement cloud computing. The four stages are infrastructure as service, software as service, platform as service and service infusion. Songtao pointed out the objectives and tasks of each stage. In the same year, Hou Xiaofeng [16] proposed the basic model for the structure design of cloud computing suitable for large-scale state-owned enterprises, and he takes the planning and structure design of cloud computing of CNOOC for example, and establishes the basis for the standards of cloud computing of CNOOC and communication models and universal language for cloud computing using the reference frame of cloud computing.

These studies have shown that regardless of location, the application of cloud computing in the oil industry remains in the theoretical research stage. No scholar has conducted in-depth research on this subject. To this end, we propose a theoretical framework for digital oilfields by referring to the actual development status of China’s oil enterprises and by incorporating advanced applications abroad. We investigated the data integration platform to exert certain pioneering effects on the construction of cloud computing in the area of digital oilfields.

The rest of this paper is organized as follows. Section 3 presents the investigation and survey on the architecture of digital oilfields at home and abroad, the architecture design of the cloud platform for digital oilfields, and the architecture of the service platform of cloud data for digital oilfields. Section 4 presents the design and realization of the service management system of cloud data. Section 5 provides the conclusions.

3. Methodology

3.1 Analysis of the architecture of digital oilfields

To design an information integration platform for digital oilfields that fits the development of China’s oilfield enterprise and is in par with advanced foreign technology, we investigated and generalized the typical architectures of information integration platforms at home and abroad. The information-based construction of foreign oilfield enterprises relies mainly on several large oilfield service companies, whereas China’s oilfield enterprise mainly adopts independent information-based construction. We selected two typical application examples, namely, Halliburton and Xinjiang Oilfield Company of China Petroleum.
3.1.1 Examples of architecture
Halliburton believes that the direction of information-based development is toward “digital assets,” that is, a real-time collaboration environment that models, observes, and maximizes the benefits of assets. Based on the original application software product developed for different professions, they designed and constructed a new DecisionSpace enterprise-level information platform (see Figure 1) by integrating advanced cloud computing and SOA. The platform contains four layers: data management (data source layer), integration (data integration and service), application (function integration), and information ecosystem.

Xinjiang Oilfield leads the information trend among oilfield enterprises at home. Since 1993, it has been conducting large-scale data collection and sorting. In 2002, Xinjiang Oilfield formally proposed the standards of “digital oilfield.” In 2008, it realized desktop-based documents and data, desktop-based business and work, and desktop-based oilfields in Xinjiang, with the applications of information system covering all aspects of oilfield exploration and development. In 2009, the “Digital Xinjiang Oilfield Website” was established. On this basis, Xinjiang Oilfield designed the overall planning and system architecture (Figure 2) for the development of digital oilfields. The system architecture can be summarized as having three layers, two platforms, and one specification.

3.1.2 Comparative analysis of architecture
With regard to the architecture of digital oilfields, although experts and related institutions at home and abroad have provided different solutions, the overall technical ideas are basically similar and can be generalized into the following two aspects.

(1) The data layer is the core layer of the entire platform. The data layers always serve as the core and foundation layer of platforms, and they include at least two layers of data source and data integration. The layer of data source is mainly responsible for on-site data collection, storage, and management, and the layer of data integration transfers the data to the upper application system in a unified form.

(2) A platform has a three-layer attribute. Through development, software systems have evolved into a three-element system and structure that includes database, function, and application layers from the traditional two-element structure. A digital oilfield is also an application system to a certain extent, and it is a very large application system that involves many fields.

Comparison of the architectures of digital oilfields at home and abroad indicates that the difference mainly lies in the following two aspects.

(1) Application of new technologies. Foreign oil service companies are superior to Chinese oil companies in terms of application of new technologies. Halliburton Company mainly uses the technical concept of SOA, and they incorporate technical ideas of cloud computing in the delivery and use of application software. Moreover, they took the lead and put forward the concept of “ecological software system” in the oil industry. For information-based construction, China’s oilfield enterprise mainly uses traditional information technologies.

(2) Focus and level of research. Foreign oil companies have formed a very complete information integration platform ranging from data acquisition, storage, and integration to management, and they are heading toward a higher level development, that is, enterprise information integration. Meanwhile, China’s oilfield enterprise is constrained by its management system and mainly adopts the model of independent construction in the domain of digital oilfields. Currently, studies focus on database and multi-source heterogeneous data integration in an attempt
to build a truly integrated data platform.

3.2 Architecture of the cloud platform of digital oilfields
After investigating the main problems in the construction of digital oilfields in China’s oilfield enterprise and typical architecture references, we created a structural diagram of a cloud digital oilfield (Figure 3).

The architecture can be divided into infrastructure, data resource, functional service, application, and terminal access layers and into two support subsystems for digital oilfields, that is, cloud information specifications and standards and cloud service management platform.

(1) Infrastructure layer. This layer is mainly composed of two parts. One part comprises the necessary hardware infrastructures that support the operation of a digital oilfield, such as computing servers, storage, and networking.

The other part is the virtual resource pool, which is mainly composed of the operating system, virtual machines, and virtualization tools. It aims to integrate the distributed hardware for deployment management into a unified pool of resources and output them in the form of service. Such a system effectively separates applications and physical resources and thoroughly eliminates the complexity and independence of underlying physical resources. Thus, resource utilization efficiency is improved.

(2) Data resource layer. This layer is responsible for data storage and management and provides high-performance and high-quality data resource services. To further improve the supporting effect of data on the application system and increase data efficiency, we developed a three-layer structure according to the above architecture investigation. The structure is composed of data source, central main database, and data application layers.

(3) Functional service layer. This is the connection layer
of the cloud platform. For the lower layers, it is responsible for managing the infrastructure resource pool and data resources. For the higher layers, it supports various software and modules of upper applications, which mainly include public infrastructure, professional application, data service interface, and access function components of the infrastructure layer. It also provides supporting service, an operation management environment, and functional components to the upper application system.

(4) Application layer. It directly faces end users and provides a high-quality software operating environment and experience to researchers. Users merely need to log on the Internet network and submit an application to the management center of the cloud platform. Afterward, they can obtain all available application software services without needing to purchase, deploy, or manage these applications. According to the research needs for digital oilfields and the deployment pattern for existing software, the application system mainly includes an auxiliary decision-making system, a production and running management system, and a collaborative research environment.

(5) Terminal access layer. This layer is the closest to the user. It contains the method and tools with which users visit and obtain cloud platform resources. It mainly includes portals, mobile terminals, desktop applications, and virtual desktops.

(6) Cloud service management platform. It guarantees the availability, reliability, and security of platform operation, and it mainly includes service quality control, security management, and service process management.

![Figure 3. Framework of the cloud platform of a digital oilfield](image-url)
3.3 Architecture of the cloud data service platform of digital oilfields

With data as the main research objective and main line, the cloud data service platform for digital oilfields is a sub-platform of digital oilfield cloud platform and an example of a cloud data oilfield. For the design process, based on the cloud platform for digital oilfields, we focused on the specific refinement processes of the data resource and functional component layers to realize the design of the service platform of cloud data for digital oilfields (also known as cloud data service platform, Figure 4).

3.3.1 General structural design

Based on the abovementioned architecture of the cloud digital oilfield and with the aim of providing cloud data services, further refinement was made for the data resource, functional component, and application layers and the cloud data service architecture with “a center, three layers, two buses, and two sub-functional systems.” The center indicates the presence of one central main database level. The three layers are data source, central main database, and data application. The two buses are data integration and data service. The two sub-functional systems are data quality control and standard and cloud data service management.

3.3.2 Analysis of the hierarchical model of architecture

Figure 4. Framework of the cloud data service of a digital oilfield
(1) Data source layer

The data source layer supports the collection, management, and application of all types of professional data from the aspects of the exploration and production sector, oil company management, oil extraction plant, and professional services company. It uploads the data to the central main database as the data source. According to business needs, data sources can be divided into professional, production, and real-time data. According to data type, data sources can be divided into raw, results, and management data. From the perspective of data integration time, data sources can be divided into historical and normalized data. From the perspective of data storage methods, data sources can be divided into Oracle, SQL server, Access, Excel, and text files. From the perspective of the nature of data, data sources can be divided into static, dynamic, and real-time data.

(2) Central main database level

In accordance with the protection strategy for data assets, to safely, correctly, and completely store and manage all types of professional raw data and the results of the data for exploration and development, the layer should have the following characteristics: unique data source, absence of data redundancy, it is the main data source of the application system, having a standardized regular data-updating mechanism, having a high degree of data sharing, and can give full play to the potential value of data assets. Moreover, it should be able to realize reasonable storage settings of the database and reduce data maintenance costs.

Given that many professions are involved in upstream oil industry research, management of data needs is complicated. Different storing methods and system structures are involved. Therefore, the central main database for digital oilfields is not a database at the physical level, but a system composed of multiple physical databases characterized by a unified data model and logical integration. For this reason, through a comprehensive analysis, we developed a construction program of the central main database that is composed of a large database, a central main database of exploration and development, and a research results database. These three databases form an integrated central main database under uniform management through shared main data.

(3) Data application level

The central main database manages the data to support all types of comprehensive applications in the upper layers. According to the application type, it can be divided into auxiliary decision making, development, production and operation management, and exploration and development of integrated research. Aside from providing direct data support for these integrated research applications, according to different types of research needs, the central main database also provides a model of re-organization in different ways based on application characteristics.

(4) Data integration bus

The data integration bus is a means of technical realization provided for the data from all types of data sources to be submitted to the central main database. To shield the difference between different data sources from the central main database, a unified data integration bus needs to be built between the data source and central main database to create a path for different data flowing from different professional data sources to the data center. For the data integration bus, aside from analyzing the existing professional database construction, we need to establish a universal data extraction, transfer, and loading (ETL) mechanism and conduct a corresponding data quality inspection based on unified norms and standards of the central main database to keep records of problem data and provide feedback. For historical data, the method of one-time migration is used to perform the entire migration. For normalized data, according to different update frequencies, different ETL strategies are developed, and continuous data update and synchronization are realized automatically or manually.

(5) Data service bus

The data of the central main database are stored and managed in accordance with the storage requirements and standard specifications of the data center. However, at the application level, given that the purposes of applications differ, the means to use these data also differ; therefore, a unified data service system is required to prevent the difference at the application level from affecting the central main database.

For terminal data users, a data organization and display mode that suits the habits of users is required. Thus, a customized mechanism must be built for users to quickly organize data so that it can support different user habits and business expansion.

For researchers specializing in comprehensive subjects, a mechanism for rapid data exchange is necessary to transfer and load the data of the central main database to the application system in a format approved by the integrated application software. Consequently, fast and seamless connection between the central main database and the integrated application software system can be realized.

For software system developers, a database-independent data service mechanism must be provided. The relatively mature one at present is WebService, and the integrated bus in the data center needs an underlying data package that supports WebService to prevent the developer from improperly using the underlying database and to ensure the security of the database.
4. Result Analysis And Discussion

Constructing a service platform of cloud data for digital oilfields involves a large amount of workload. With the studies conducted by the oilfield enterprise, the data architecture of the data integration platform would continue to extend and expand, which poses a great challenge to database management, operation, and maintenance. To this end, in this study, based on metadata management theory, we preliminarily achieved the design and implementation of a functional system for cloud data service and management, as shown in Figure 5.

![Figure 5. Diagram of the service management of cloud data](image)

![Figure 6. Model admin interface diagram](image)
The system is a powerful tool to maintain the vitality of the central main database, and it adopts a thin client B/S mode design. According to the main existing problems, the system performs four main functions: model management, data bus management, data service bus management and data quality control system management. The purposes are to track resource development changes, provide statistics on data storage, establish a meta-model database, track model changes, publish a data dictionary, and build an exploration and development data cloud platform that integrates model metadata management, data integration, data management, and data service applications. The main performance is as follows:

1. Automatically upgraded model management(Figure 6, it is generated by application of Chinese version). Users can query and browse professional and central databases. The functions include database instance and upgrade and downgrade of the main database. Therefore, the life cycle of the central main database can be extended.

2. Automatically integrated data distribution management(Figure 7, it is generated by application of Chinese version). Automatic incremental integration management is conducted for data from different professional databases flowing to the central main database.

(3) “One-stop” data service management(Figure 8, it is generated by application of Chinese version). With customizable data service applications, it can provide one-stop data service for application systems or professional software of exploration and development.

5. Conclusion

To establish highly efficient and inexpensively integrated information platform solutions, we adopted the design method of integrated architecture of enterprises and the
metadata-based object-oriented development model based on the design concept of cloud computing. We conducted research on the cloud data service management system for digital oilfields. The following conclusions were obtained.

(1) Constrained by its management system, China’s oilfield enterprises need to construct a genuine information integration platform. With its advanced “loose coupling” and “ready-to-use” design concept, cloud computing can realize highly effective management of oilfield information and enhance the competitiveness of enterprises.

(2) Data are an important carrier of oilfield information, and the cloud data service platform is a sub-platform of the cloud data service platform. It is also an example of cloud data oilfield, and it can be generalized as an architecture containing “a center, three layers, two buses, and two sub-functional systems.”

To examine the main business needs of oil and gas exploration and development, we specifically investigated the architecture of the cloud data service platform for digital oilfields. However, we only preliminarily realized the design of a management system. The scope of data coverage and application functions require further in-depth study.

References


