Micro-service Architecture in Reconstruction and Optimization of GIS Application Service

Xiang Zhang

XiaMen Great Power GEO Information Technology CO., LTD, XiaMen 361009, China
ZX8397@126.com

This paper mainly studies the design and development of the framework of micro-service architecture in GIS application service of electric power business, and how to combine the characteristics of the grid business. The optimization of micro-service architecture enables the new business services to combine the advantages of micro-service architecture with the characteristics of the grid business so as to overcome the defects of traditional single application system and provide a more powerful driving force for the development of power grid business.

1．Introduction

After SG186 and SGERP projects, the State Grid Corporation of China has successfully built system based on GIS and applied it to transport and inspection, marketing, strategy, scheduling and other related professionals, providing strong support for the construction of smart grid and the development of modern companies with a strong power grid as well as excellent asset quality, service quality and performance.

In recent years, with the goals of accelerating the construction of global energy Internet and modern companies with a strong power grid as well as excellent asset quality, service quality and performance, the State Grid Corporation of China put forward higher requirements on the role of information systems to support the entire business and to smooth the whole business process. Moreover, with the rapid development of Internet plus marketing, financial services, e-commerce, electric cars and other new businesses, the response ability of GIS application service should be improved accordingly. Therefore, the existing architecture of GIS application needs transformation to fulfill the needs of the constantly updating future business volume.

2. GIS application service based on traditional single application system

GIS application service is used by State Grid Corporation of China to provide business systems including the operation, inspection, marketing, and planning systems with required maintenance, network topology analysis, and related advanced businesses on GIS graphics such as scope of power failure analysis and line loss calculation. GIS application service is a single application system with traditional service oriented architecture (SOA). The core of service is to implement the business logic through a unified service framework, which defines the service, domain objects and related events, and connects the external systems through SOA. Although it has a logical modular architecture, the application services are packaged and deployed as a whole. The architecture is shown in Figure 1.

The architecture is an integration of the heterogeneous systems within the company. Specifically, the system provides coarse-grained services externally. As for the requests from the external system, GIS application service is regarded as a central platform. Standard technical accesses are provided by the enterprise service bus (ESB) in order to meet the accessing needs of different clients and provide the WebService communication protocol. When there is a request, complex processing is needed, such as the communication protocol parsing, data serialization, deserialization, business process arrangement and service routing. Figure 2 is an interactive process of electric power production management system by ESB bus and GIS application service.
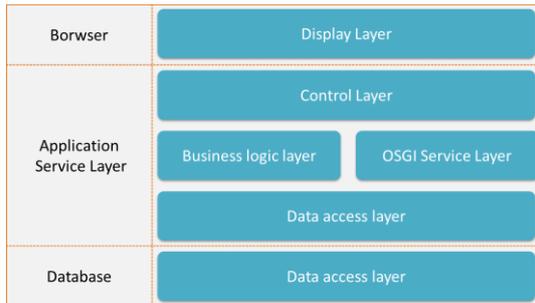
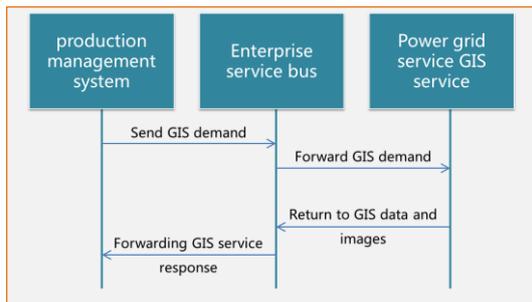*Figure 1: The GIS application service of the single architecture*

Figure 2: Power production business and GIS application service interaction

Although the requirements for the initial construction of the project are determined, the business function can be implemented through the model with traditional three tier architecture. But as time goes by, the whole service system will become more and more cumbersome, and the following problems are exposed.

1) Reliability: since all modules are running in the same process, problems of any module, for example, memory leak, may affect the whole process. This problem is fatal for 7×24hrs running electric business.

2) Reusability: the business management departments of marketing, strategy, scheduling of the State Grid Corporation of China are different in terms of interfaces. However, but for the GIS application service, in order to improve the reusability, the codes should call each other. For example, operation and inspection service achieves the calculation indicators, in which the algorithm can be applied to calculate marketing indexes. The design of different interfaces did not take the call into account, therefore, increasing call interfaces is obtained to solve the problem, which may involve problems including interface testing and inter-department coordination;

3) Communication efficiency and deployment: ESB is a very heavy mechanism. Communication is complex involving a variety of protocols. As the cost of each call is high, coarse grained interfaces are usually provided to complete more work at a time.
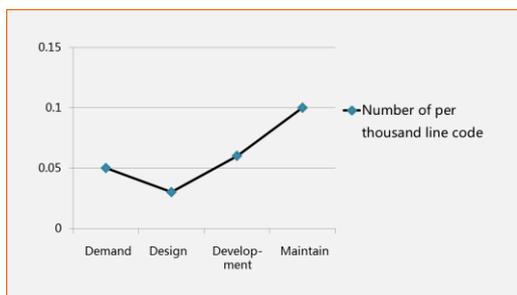

Figure 3: Traditional architecture per thousand line code maintenance work

The centralization of ESB may bring a single point of fault. Moreover, since the service is deployed on the ESB, the level of service is limited. In addition, ESB also contains many business related functions, such as business process choreography, which restricts business expansion. No matter for service providers or users, the centralization of ESB brings problems including high development cost and communication with low efficiency.

4) Fast response and maintenance efficiency: the tight coupling between modules is getting higher and higher, which has fatal impact on the rapid response for demand. A small demand may have great impact on the whole architecture. At each release stage, the cost of per thousand lines of legacy used to modify the remained problems increases exponentially. The increasing trend of the workload of code maintenance in the operation and maintenance stage is shown in Figure 3.

Therefore, in order to cope with the growing demand of business development, the architecture of GIS application service needs to be reconstructed and optimized.

3. Micro-service architecture

Micro service has a distributed system architecture, which divides business into more granular services, making the responsibility of each service single and independent. There are high cohesion within the service, in which details are concealed, and low coupling between the services in order to make the services independent from each other (Yang et al., 2017; Mao et al., 2017). Besides, we build models based on service oriented business domains, and provide unified API interfaces. The idea of micro service not only stays in the development stage, but also runs through the whole life cycle of the software including design, development, testing, deployment, operation and maintenance.

According to the design idea of micro service architecture, the design objectives of GIS application service based on the micro service architecture should be:

1) Application without boundary: interconnection should be achieved within the system, gradually eliminating boundaries, data duplication and system integration.

2) Scene customization: users can flexibly customize the required application functions according to their own business, carrying out personalized assembly according to the needs and preferences, so as to form micro services to quickly meet personal needs.

3) Service-oriented function: pursue atomized and service-oriented business function. Each micro service can support the smallest service unit independently, and do not rely on other micro services. Micro services can easily interact with each other and are characterized by "high cohesion and low coupling".

4) Extensible architecture: the service should be flexible and extensible with small internal service units that can be packaged, deployed and upgraded independently, and can support the flexibility and dynamic expansion of the business application.

5) Uninterrupted service: Based on micro-service architecture, the service should become an uninterrupted operation system. The development of the system function, test realization agility, release, application, operation and maintenance should be constantly on line, supporting the integrated operation of the system, and keeping the continuity of business operation.

The micro service framework designed to fulfill the above goals will have the following advantages in practice:

1) Each micro service component is simple and flexible, and can be deployed independently. The application needs a huge application server to support, integrating the front end, backstage and database.

2) Each micro-service component can be developed or provided by a smaller team or a third party platform, making people more focused so that to provide more efficient and reliable services.

3) With low coupling between micro-services, and high cohesion within micro-services, each micro-service can be extended according to their own needs.

4) The micro-service architecture is irrelevant to language tools, and can choose the right language and tools. For team collaboration, if one group of PHP developers is busy with other business, Java developers of another group can take over the work instead.

4. Micro-service system of power grid service GIS application

Take GIS application in operation and inspection service as an example, the paper will describe how to construct GIS application service based on micro-service system. The GIS application based on operation and inspection service mainly consists of the following main business modules: power grid topology analysis, power grid failure analysis, power point tracing, power outage range analysis; the overall business architecture as shown in Figure 4.

According to the design of micro service, the design of GIS application service for power grid business needs to consider the granularity of micro service first. It needs to define the granularity of micro service according to the business rules. The focus of the design of the micro service architecture is the subdividing business sectors. It is the only entrance to the business rules. It divides the whole business into a small business with high cohesion and simplifies the business.

Micro service completely divides the business, the data and the resources, so as to provide complex processing for non-central nodes, especially for business related processing. Since the server can deal with the business,

it can respond more flexibly to business changes. A good GIS application service based on micro-service should be as available as resources such as water，electricity and gas hydropower coals, without technical and communication barriers, and the different business systems can be called to each other according to the business needs.
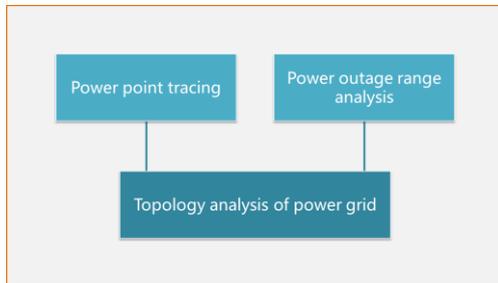

Figure 4: Traffic inspection business architecture

In the design of the micro service of the GIS application, according to the analysis on business needs, business needs can be divided into basic business functions, power grid topology analysis, and advanced application functions based on the basic function including power failure analysis, power point tracing, power outage range analysis. Therefore, services can be subdivided when building a micro-service architecture so that to specify the responsibilities of the micro-service and create hierarchical dependency in the whole system. The service of the basic system is at the bottom, which support various businesses above. The upper service does not need to pay attention to the physical location and internal details of the underlying resources. The upper service contains data resources and business rules of each dimension, and the business logic calculation is carried out by the service at the lower layer. In this way, the whole system is more sharable and the implementation of the business rules is easier.

Therefore, the micro service construction of the operation and inspection service is divided into two levels: the core micro-service and the application micro-service. Most of the GIS applications are realized through the topology analysis and modification of the power grid model. The topology calculation rules of the grid model are very complex since different business scenes have different requirements on the topology. The core micro service layer provides a unified topology, packed it up and provides for various business scenarios. If the rules of the topology are changed, the changes are limited to the internal service while the external business code remains unchanged. It is beneficial to the maintenance of topological relations of power network models and to the efficient query under various constraints.
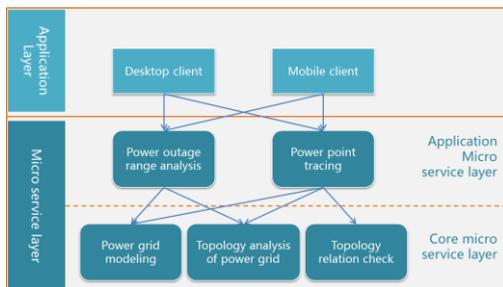

Figure 5: GIS application micro service architecture for power grid service

The application micro service level is mainly based on the actual needs of the business. Combining the results of the topology analysis carried out by the setting conditions of the business. Business-related data can be obtained and edited. For example, if the power outage range analysis is in the business logic, topology analysis can be carried out according to the circuit breaker of the fault point and the topology relation of the power grid so as to find the affected grid equipments. The micro service architecture of power grid GIS application service is shown in Figure 5.

In addition to the update of software architecture, micro services should also be used to update the physical deployment architecture, in which virtual machine and container technology are used to divide a physical machine into multiple sets of environment, deploy the micro service, and to use the server resources more

efficiently. Some micro-services can pack the basic hardware to improve the management of physical resources and to extend the service. For example, the topology analysis service is the basis of the whole business application with high daily access. With micro-services, it can be easily extended horizontally. The service itself is deployed in the standard virtual machine or container. If the the existing hardware resources cannot meet the requirements at the end of a month when large number of indexes are waiting to be analyzed, the services can be expanded through the cloud service.

The interaction mode of micro-services is greatly different from that of the single application system. The single application system connects the client and the server through the traditional SOA mode, involving the heavy traditional communication protocol (DCOM/RMI/CORBA/WebService) and complex data formats (binaries /XML, etc.). In terms of connection channels, lightweight Service Protocols (HTTP) and simple data formats (JSON) are commonly used in micro-services.

5. Optimization of micro-services architecture

No architecture can solve all the problems in the practical application. The GIS application service in grid business needs to be optimized and adjusted in the following aspects in the process of building using a micro-service architecture:

5.1 Service linear dependence

With the use of micro-service, the boundary between micro-services becomes more and more blurry as the requirements become more complex. Suppose that you are working on a case where you need to modify service A, B and C, while A depends on B, B depends on C. In monolithic application, you only need to modify the relevant modules, integrate the modification and deploy them. However, since the level of micro-service architecture is becoming more and more complex, coupling is becoming more and more serious, and the problem of cyclic dependency is everywhere in the micro-service architecture pattern, so this pattern needs to take the impact of related changes on different services into consideration.

In order to solve the problem of service linear dependency, we need to stick to the principle of unidirectional dependency in hierarchical design, so that the system can have a clear dependency, because one direction can never form a ring. That is, high-level services can depend on low-level services, but the same level services can not depend on each other. If there is a dependency between services at the same level, then there is a problem in the hierarchy of service, at which point a higher level service needs to be abstracted or one of the services should be upgraded.

5.2 Communication efficiency

Communication between micro-services uses the HTTP based application layer protocols, but the speed of HTTP request is slow, and a single operation may involve mutual invocation of multiple micro-services. If different micro-services are invoked repeatedly from the server in order to complete an operation, then the time consuming of the HTTP request may become a bottleneck. Furthermore, a user's multiple successive calls to the client run the risk of exposing the system architecture. Therefore, communication between the client and the server can be set up with a API GateWay.

The most important role of API GateWay is to provide clients with aggregation of back-end services, provide a unified service outlet, and uncouple them. To solve the single point of failure or performance bottleneck, Gateway is usually also a cluster where client access control, account management, login management and other aspects are usually dealt with.

5.3 Management automation

After the GIS application service in grid business is designed with micro-service architecture, the complexity of its application development and deployment is much larger than that of single application, so it is obviously difficult to cope with by manual configuration management of operation staff (Zhou and Qi, 2017); Therefore, the deployment architecture of microservices requires the ability to deploy without depending on other services. Because a service has different business responsibilities, a service may assume more hardware resources and network bandwidth than other services, it needs to be able to extend at each micro-service level, for one micro-service failure, it is not possible to affect other services and to ensure the smooth operation of the overall - business.

Docker can be used to provide a deployment plan that meets the above requirements. It can package a micro-service as a Docker image in practice to provide a deployment container for each micro-service, or realize the service extension by changing the quantity of containers in micro-service level extension. The construction, deployment and startup of the service are quite fast by using the Docker container, the service load balance management can be automatically managed through service registration and discovery mechanisms.

5.4 Unified database services

The common design pattern in a micro-service architecture is that a micro-service application corresponds to a database, if more than two micro-services share a single data store, they will be tightly coupled. Changing the structure of a micro-service's data store, such as a table, can cause problems for another micro-service. From a performance point of view, it can be useful for each micro-service to have its own data store, because extensions can become easier and the data store can be hosted on your own server.

However, the GIS application service in grid business, due to the limitation of service itself (Zhang et al., 2015; Wu et al., 2015), the uniqueness of model data and the indivisibility of physical structure exist naturally, if one micro-service stored in one database, such as one database for power grid modeling, and one database for one topology analysis, then two copies of data need to be stored, and the synchronization of data changes between the two databases should be considered, which increases the waste of repeated investment and technical difficulty. A unified database services is required for database services. In order to avoid the bottleneck of database I/O, a memory data service between database and micro-service needs to be added to speed up the speed of data I/O.

6. Application results

The use of micro-service architecture to build the GIS application service of the power grid has achieved good results in the practice. Good results have been obtained in terms of the demand response and the modification and maintenance of the later problems.

With the same hardware, the response capability and data throughput of the service are greatly improved: (with the same hardware configuration, the resource consumption and the response speed per minute of the single application architecture and the micro-service architecture are analyzed on 100 concurrent users within 5 hours).

7. Conclusions

The software architecture is the "soul" of a system. Whether the architecture design can meet the needs of the business development is the key to measure the success of an information system (Li et al., 2015; Zhong et al., 2014). The power business application service based on the design of micro-service application architecture has been repeatedly verified and used in the actual environment. The reconfiguration scheme and the keys for optimization proposed in this paper are proved to be able to satisfy the actual needs which can be used for reference by relevant personnel in following related work.

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