

## The General Idea of Construction of Beijing Geothermal Resources Monitoring and Forecast Information Platform

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### ABSTRACT

With the new environments of big data and the new requirements of Beijing future development, geothermal resources information platform construction was changed by advancing technologies which also can avoid some terrible situations such as information isolated island and repeated construction. Take "Beijing geothermal resources monitoring and forecast information platform" (information platform, for short) as an example, this paper introduced some new thinkings about how to construct the geothermal information platform based on advanced information technologies of multi-dimensional information system, smarter map and internet big data analysis. Key technologies of platform construction will be explained including overall architecture, cloud computing technology, integrated technology of multi-source heterogeneous spatial data, big data processing and storage technology, meanwhile the platform function and applicable targets will be discussed and explained.

### 1. INTRODUCTION

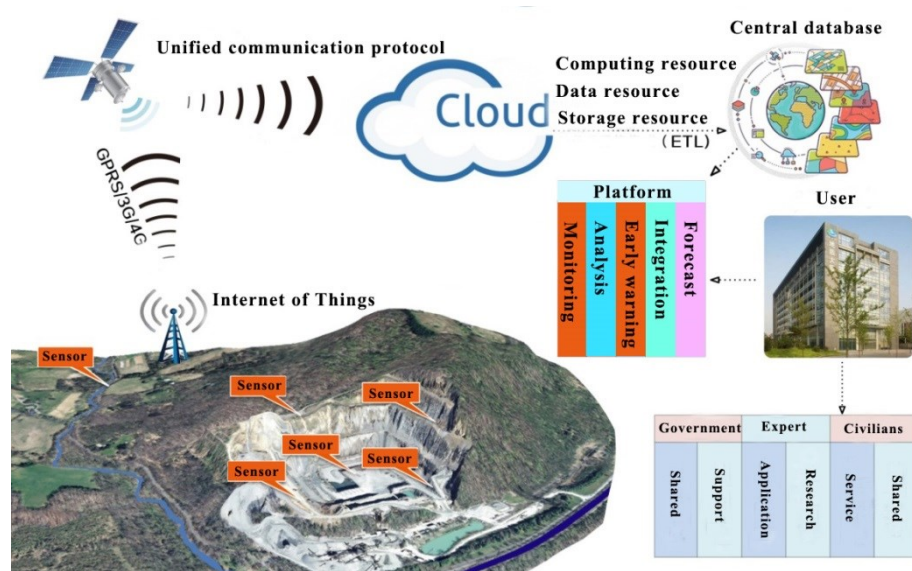
In order to obtain more comprehensive and useful information from the geographical data to deepen the understanding of the geological body, geological phenomena and geological processes, and to better utilize and protect geothermal resources, geological work has become increasingly reliant on mathematical methods and geological information technologies<sup>[1]</sup>. Improvement of inversion and forward modeling of geophysical and geochemical exploration abnormalities<sup>[2][3]</sup> as well as of various geodynamic theories and methods<sup>[4][5]</sup> has enriched the research findings of this field, and promoted the quantification of geology and geological informationalization.

Currently, the emergence of new information technologies represented by cloud computing, big data, artificial intelligence, Internet of Things and mobile Internet has accelerated integration of different fields of economy and society. Major countries in the world have pinpointed the new generation of information technologies as a strategic direction to seek new competitive advantages. Meanwhile, the in-depth mining, analysis, and application of the value underlying big data has been a research focus of different fields, and the concept of big data has played a big role in the construction of smart government and smart city<sup>[6][7]</sup>. Therefore, how to form a brand-new platform construction concept in the geothermal industry, which keeps up with the times, and apply relevant concepts and measures into the construction of geothermal resources monitoring and forecast information platform remains the top priority for geothermal workers in the coming period of time.

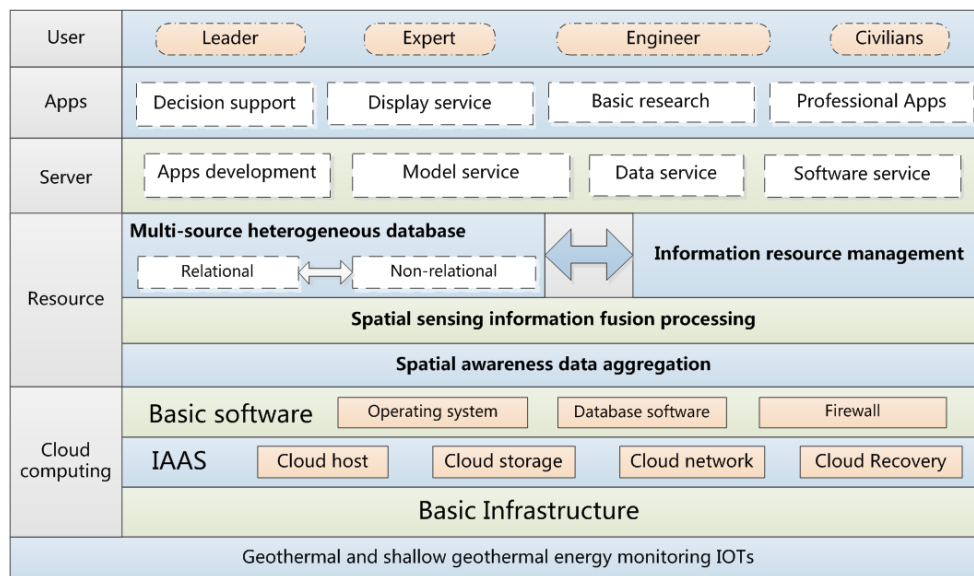
To safeguard the sustainable development of strategic geothermal resources and shallow geothermal energy resources of Beijing, it has become an imperative to get rid of the current application pattern, make a breakthrough of the traditional professional barriers, and introduce a new generation of technological methods (including space sensing technology, Internet of Things, and model technology) to realize the acquisition, processing, integration, integration, analysis and application of the space sensing information in the field of geothermal and shallow geothermal energy field. In the process of doing so, evaluation of the resource carrying capacity is completed through emission, transmission, reception, restoration, integration, evaluation, pre-warning and decision-making of monitored data. The key technologies involved in this process covers optimized design of the monitoring network, selection of monitoring methods and equipment, modeling technologies and pre-warning technologies from professional fields, Internet of Things (IOT) communications regulation technology, multi-source heterogeneous data integration technology, overground and underground integrated three-dimensional modeling technology. This paper focuses on discussing key technologies with a mature construction thinking at an attempt to provide theoretical references for the future platform construction.

### 2. THE PLATFORM CONSTRUCTION IDEAS

Through dynamic monitoring of important geothermal resources and shallow geothermal energy resources concerning urban planning and construction, the bearing capacity monitoring and forecast information platform builds the monitoring and forecast decision-making based on big data and Internet of Things so as to facilitate urban construction and management. The introduction of the geothermal and shallow geothermal energy monitoring and forecast IOT enables the platform to realize effective monitoring of the regional resource bearing capacity, and comprehensively safeguard the sustainable development of the regional strategic geothermal and shallow geothermal energy resources. Generally, the monitoring and forecast information platform consists of the field monitoring network and the cloud information platform. The information platform construction schematic diagram is shown in Fig. 1 below. As the field monitoring network, it serves like a tentacle, which can sense the dynamic changes of geothermal and shallow geothermal energy resources, and can transmit the sensed information to the cloud terminal via the transmission network. The cloud information platform realizes evaluation and forecast of geothermal and shallow geothermal energy resources bearing capacity via the integration of monitored data, and introduction of the professional forecast model.



**Figure 1: Overall schematic of the platform**



**Figure 2: Overall architecture of the platform**

Construction of the geothermal resources bearing capacity monitoring and forecast information platform involves not only construction of the spatial information sensing layer, administrative cloud platform foundation layer, information resource layer, service layer, application layer and user layer, but also construction of smart operation and maintenance, policy mechanism, and cloud safety standards. this platform realizes the whole-process geothermal applications based on “big data”.

The spatial information sensing layer will make use of the IOT technology and standardize the three-layer architecture of the monitoring and forecast IOT to gather the geothermal and shallow geothermal energy monitoring and forecast IOT spatial information, and monitored data. These structured, semi-structured or non-structured data will first be gathered to the basic-level database adopting the distributed architecture via the external administration network. Following that, these data are uploaded to the information resource layer of the platform through the unified data exchange interface and exchange library, and then get stored in the relational and non-relational database, respectively, according to their data type. Finally, all these data are managed by the information resources management system.

The cloud platform basic layer will comprehensively rely on the municipal administration cloud, the latter of which can provide IaaS cloud services for the platform. The platform will rent the computing resources, storage resources and network resources of the administration cloud on demand according to the scale of information resources. Above the architecture and administration cloud, the platform will realize three-level protection standards for information security. The organization will be responsible for the safety operation and maintenance above the virtual layer (not included), and the administration cloud service provider will provide operation and maintenance below the virtual layer. All this will greatly alleviate the workload of professional technicians, enabling them to get fully devoted to service applications. The basic layer of the cloud platform can realize on-demand services of information resources—efficiently adjusting the resource supply or dynamically distribute the resource pool. Demands of the applications are the basis for acquisition of computing resources, such as server time and network resources. The on-demand supply capacity can exactly satisfy

the changing demand of some monitoring and forecast IOT caused by seasonable changes. Besides, since the administration cloud can achieve extensive Internet access, then field and data obtained artificially through field monitoring can be directly gathered to the platform's resource layer via the Internet. This can greatly improve the field working efficiency, and innovate the smart field work method.

The information resource layer will rely on the currently matured relational database, and combine the big data distributed document system (HDFS, GFS, etc.) and non-relational database (Big Table, Hbase, etc.) to realize efficient storage of structured, semi-structured and non-structured data, monitored data, borehole data, physical and chemical exploration, investigation data, and image data. In terms of multi-source heterogeneous data processing, different ETL tools (Hadoop sqoop and traditional ETL) will be adopted to extract the data from the diffused heterogeneous data sources and data from IOT of different professional fields to the middle layer for cleansing, conversion and integration. Finally, the data will be loaded to the data warehouse or the distributed document system to provide decision-making basis for online analytical processing (OLAP) and data mining. In terms of big data processing and analysis, parallel processing and stream processing, represented MapReduce parallel processing technology of Hadoop or Storm stream processing, to accomplish efficient processing and accurate analysis of mass data.

The service layer will resort to the SOA architecture thinking for its construction. The system will effectively package relevant functions, including the application development services (integrated development environment, business model tools, etc.), various model services (pre-warning model, three-dimensional model, etc.) and geothermal data services (data search, data management, Lucene search, etc.), geothermal software services (GIS, OLAP, mining tools, etc.), to achieve the internal strong aggregation of the module and the loose coupling sealing among modules. Following that, these functions are published and applied in the form of network services. Meanwhile, these loose coupling functions and services can be conveniently reorganized and invoked by other systems to accomplish resource sharing and personalized customization services. Therefore, the other entrusted departments and relevant technicians can edit and reorganize the information resources through the service layer to assist in realizing functions of respective information systems and expanding the sharing scope of information resources.

The application layer will group functions into three categories, including functions for decision-making support, functions for display, and functions for basic research. After the completion of the application layer, it will fully support decision-making of government leaders, provide science education, pre-warning and forecast for the social public, and facilitate business management and basic research of geothermal technicians.

### 3 KEY TECHNOLOGIES REQUIRED BY PLATFORM CONSTRUCTION

#### 3.1 Optimized design of monitoring network

How to realize optimized design of the monitoring network is the first issue facing platform construction. Since the monitoring network will be a main source of platform data, lack of a reasonable deployment of the monitoring network structure will make the future pre-warning, forecast and comprehensive analysis groundless. For example, whether the sensors applied to the geothermal well temperature, flow and pressure monitoring are installed to the proper position, particularly in the deep-layer geothermal resources monitoring, will decide the handling efficiency and pre-warning effects of abnormalities. Hence, the first step for platform construction is to deploy and optimize the monitoring network according to the geothermal and shallow geothermal energy monitoring and forecast architecture.

Deployment of the geothermal and shallow geothermal energy monitoring sites is mainly based on three fundamental principles. First, the principle of overall layout and accommodation to key emphases. This means that the monitoring sites should be deployed according to the national monitoring requirements of geothermal fields and the division of regional geological units. At the same time, the distribution of major projects, major functional zones and fault structures in the working area should be taken into consideration to lay out the standard monitoring holes at an attempt to achieve full coverage of the working area. Meanwhile, the original geothermal energy is measured to grasp the distribution characteristics of the regional original geothermal field distribution characteristics. Second, the principle of combining dot monitoring with regional monitoring. To abide by the principle requires one to set up monitoring holes and bury sensors in the shallow-layer geothermal energy for the convenience of monitoring formation temperature changes nearby the heat exchange hole. At the same time, temperature monitoring is conducted of the ground-source-front general pipeline. To grasp the general pipeline temperature changes can help grasp the comprehensive influence of the development and utilization of shallow geothermal energy on the regional geothermal field. Third, the principle of combining the deep-layer geothermal and shallow geothermal development area. In order to gain a better understanding of the changing characteristics of the deep-layer geothermal field under the regional geothermal development and utilization conditions, it is necessary to synchronously observe the deep-layer geothermal well and the nearby shallow water temperature monitoring. This will reveal the influence of the deep geothermal resources exploitation on the shallow underground water, and provide scientific bases for the development and utilization of water resources.

#### 3.2 Multi-source heterogeneous data integration technology

In the future, the platform will introduce the geothermal and shallow geothermal resources monitoring network via the IOT technology, which mainly employs dozens of sensors, including the rain gauge, water level indicator, and camera, and contains complex data types. At the same time, in order to achieve comprehensive analysis, pre-warning and forecast, the platform will also primarily include non-structural data, such as historical data, GIS images, physical and chemical exploration data, remote sensing data, digitalized achievements, and model data. Therefore, how to integrate these multi-source heterogeneous data is a key technology to be resolved by the platform.

This project will make use of the relational database and non-relational database to resolve problems facing multi-source heterogeneous spatial data integration. Structural data represented by some monitoring data, achievement data, GIS data, and borehole data can be put in the relational database (e.g. Oracle) either directly or via the spatial data engine (e.g. ArcSDE). This can make full use of advantages of the relational database, including concentrated data control, high data independence, strong sharing ability, low data redundancy, facilitation of correlation analysis, etc. Meanwhile, non-structured data, such as streaming data, document data, and

digitalized achievement data require the database to be capable of high concurrency reading and writing, efficient storage and access of mass data, high scalability and availability. Therefore, the distributed file system, such as HDFS and GFS, should be matched with the non-relational database (Big Table and Hbase) to build the geothermal non-structured data storage model. At the same time, the parallel programming model, such as MapReduce and Spark, should be used for search, mining, analysis and machine learning of mass geological data, and Hive, a data warehouse tool, can be used for statistical analysis of non-structured data. Meanwhile, ArcGIS is capable of spatial data access and analysis of big data via Hive. Additionally, Handoop sqoop can be utilized to realize the data interaction between the relational database and the non-relational database, and Lucene technology can be used to discover the geothermal and geological data and realize clustered integration of search structures.

### 3.3 IOT transmission technology

IOT is an important part of the new generation of information technologies, and widely acknowledged as a critical development period of the information era. The architecture of IOT is generally made up of three layers, including the “nerve ending”—sensing terminal sensor, and the “nerve center”—integrated network communication infrastructures and front-end application service support system. Among them, the sensing terminal sensor realizes real-time monitoring of automatic data collection and intelligent recognition via various sensors, FRID, GPS, and hand-held machines; the integrated network communication layer achieves rapid and safe transmission and processing of monitored data, which can not only transmit the sensed information bottom up, but also transmit commands up down; the application service support system is mainly responsible for the integration, storage and smart analysis of data collected by IOT to achieve smart applications of a higher layer.

Therefore, the geothermal and shallow geothermal energy at monitoring and forecast IOT should be designed as a whole in accordance with the three-layer architecture of IOT so as to achieve standardized interfaces of sensors at the sensing terminal. Meanwhile, the wired and non-wired communication network based on GPRS, CDMA should be built to realize real-time safe transmission of various monitored data. At the same time, information processing and application based on “big data” can be achieved at the application service terminal to facilitate the leap of various monitoring and forecast information systems from “artificial analysis” to “intelligent analysis”, and to achieve comprehensive monitoring and forecast of geothermal resources bearing capacity.

Construction of the monitoring and forecast information platform will also involve various monitoring facilities, and the sensing facilities adopted vary to different degrees. Due to the variety of manufacturers, it is of vital importance to build a unified data structure and communications protocol. At the same time, a proper real-time database should be selected for various semi-structured, structured and non-structured data having been received. This is also an essential requirement to realize quick processing and emergent handling of monitored data. In the construction process of the IOT communications regulations, sensors should be divided into the unified regulation type, non-standardized regulation type and artificial acquisition type according to their monitoring type, communications type, monitoring subject and data structure. Take the geothermal well monitoring for example. It contains multiple monitoring facilities, including underground water level thermometer, pressure gage, and flowmeter, which can achieve efficient transmission according to unified regulation. The GPS monitoring and video flow media generally realizes transmission via the independent communications regulation and resolving procedure. The other part of field data should be acquired via artificial measurement.

Hence, the platform should refer to relevant national and industrial technical specifications to build the communications protocol for joint transmission of multiple monitoring and forecast IOTs. The involved content includes but without limitation to link transmission procedures, message frame structural frame, and message body part structure, and data transmission assessment. Meanwhile, the IOT sensor reception terminal procedure should be developed on the basis of the protocol, thus realizing management of sensors’ transmission of data, commands and control. At the same time, on the basis of the unified protocol, and independent settlement procedures, an IOT information management system specialized for the platform can be developed to ensure reception, interpret, and change status of the monitored data.

### 3.4 Cloud computing technology

Cloud computing is a brand-new commercial computing model for sharing of basic resources, which emerges with the rapid development of computing, storage and communications technologies. Currently, cloud computing has been reputed as the “revolutionary computing model”. The cloud computing technology is characterized by on-demand service, extensive network access, resource sharing, rapid elasticity, and measurable services, and can provide service models, including Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). These characteristics make cloud computing widely applicable to monitoring and forecast information platforms with a high requirement of computing resources elasticity. The geothermal energy monitoring and forecast IOT built within the platform has obvious seasonable characteristics. During the non-rainy season, the monitoring frequency and transmission frequency of the field sensor usually adopt “day” as the unit. During the flood season, the field data monitoring frequency and transmission frequency will significantly increase to ensure efficient monitoring, pre-warning and forecast. Also, the increasing frequency of data processing by the pre-warning and forecast model will generate a large demand for computing. This requires the monitoring and pre-warning system to effectively respond to the elastic demands of data collection, transmission, processing, storage and analysis for computing resources, storage resources and network resources. The cloud computing technology can well satisfy the on-demand distribution of information resources of the kind.

## 4 CONCLUSIONS

Against the backdrop of thriving technologies of the new generation, information technologies, represented by multi-dimensional geographical information systems, smart map, and Internet big data analysis, should find more wide applications. This paper builds a smart geothermal resources management information platform by referring to the mature framework systems developed at home and abroad, and updating the current framework using the brand-new framework methods. Results show that the platform can comprehensively improve the dynamic acquisition capacity of spatial sensing information, integration capacity of multi-source heterogeneous data, construction capacity of pre-warning and forecast models, and on-demand service capacity of geothermal information resources, and also promote in-depth integration and all-dimensional sharing of mass geothermal information to gradually realize “smart geothermal” in the big data era.

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