Hybrid Computing Hierarchy based on-Line Analysis Service for Power Dispatching and Control System

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***Abstract*—Energy Internet is characterized by electricity as its core operation pattern, its stable and safe operation requires real-time and efficient online calculation and analysis to obtain operation status of the power grid. Under the centralized and unified dispatching cloud computing mode, the rapid increase of grid physical model and measurement data will inevitably affect the efficiency of online analysis service. Combining with concept of edge computing, this paper firstly designed the architecture of hybrid dispatching cloud and dispatching data network based online computing process was built. Through performing necessary data calculation and analysis at the substation level or subordinate dispatching and control centers, it reduces the amount of data uploaded to the dispatching cloud center. Then the concept of service-oriented was used to design the service hierarchy and implement detailed online analysis services. Finally, power grid model data was used to verify performance of topology analysis and calculation process in the way of decomposition and coordination computing mode.**

Keywords—Energy Internet, Dispatching Cloud, Edge Computing, on-Line Analysis Service

I. INTRODUCTION

Energy Internet(EI) is the manifestation of cyber physical system reflected in energy field. It's essence thought are connection, integration and service, and using advanced information technology based on concrete physical and communication network entities aims at form energy supply and demand response platform characterized by openness, peer-to-peer, interconnection and sharing, which meet differentiated energy need of energy users. Electric power is the core feature of energy internet. Ensuring safe operation of energy Internet is the basis of providing stable energy supply. Especially, it is most important to realize efficient control and real-time online calculation and analysis of power transmission-receiving terminal system. With regard to improving the operational control capability of energy internet, a model free deep reinforcement learning algorithm which is applied to obtain desired efficiency control was proposed in[2]，and bottom-up energy management approach in [3],a robustness and minimum operation cost optimization method was proposed to further improve control performance in [4], a controlled power distribution strategies through energy router in lower-voltage grid and islanded micro-grid scenario were also proposed in[5][6]. To improve real-time calculation and analysis level of energy Internet operation, multi-core architecture and Graphic Processing Unit(GPU) based are respectively achieves efficient solution to a large number of computing processes in energy management system[7][8]; Concepts of cloud computing such as virtualization, hierarchy and service were also referred to design dispatching and control cloud system[9], which integrates IT software and hardware resources, data and applications distributed in dispatching centers at all levels through dispatching data network. Yet it realizes unified management, unified storage, unified calculation and unified on-line analysis for power network physical model, measurement data and online application analysis, but it also causes rapid growth of data received by the dispatching and control cloud center and the problem of data transmission delay.

Edge computing is a new mode that can performs necessary computations on access network consists of varies types of smart equipment [10]. Edge computing calls for processing the data at the edge of the network and develops rapidly as it has the potential to reduce latency and bandwidth charges, address limitation of computing capability of cloud data center[11].Internet of Things era is coming closer，edge computing is to allow the edge servers to get involved to help the IoT devices with computing, storage, and networking[12][13]。

According to the characteristics of edge computing, extracting topology analysis and calculation from online computing application of power system monitoring system and encapsulated as service can reduce the amount of input data among dispatching and control centers, which will also further improve response speed of online analysis service to users. This paper designs a hybrid dispatching cloud system based on cloud computing and edge computing, and studies online computing process in cloud computing environment, then concept of service-oriented is used to realize online computing service, designs the hierarchical online computing services, and finally topology analysis is simulated as edge computing node to verify transmission efficiency in distributed and parallelization environment.

II. HYBRID DISPATCHING CLOUD SYSTEM

A. Architecture Design

First, The system mainly includes three parts: dispatching cloud logical entities, edge computing and display units, online analysis and calculation service engine, as shown in Figure 1.

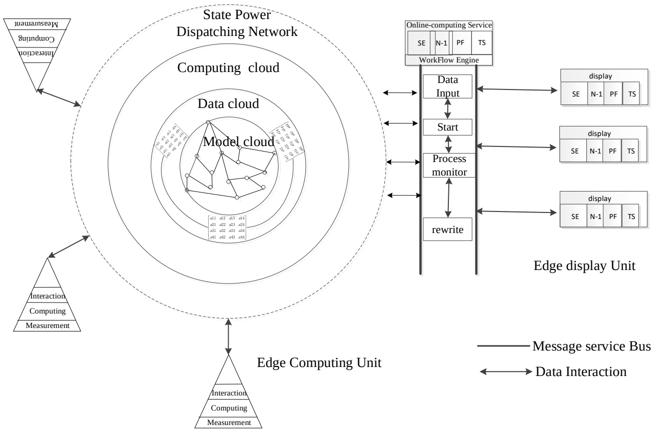

Fig. 1. Hybrid dispatching cloud architecture

1) Dispatching cloud logical entities

Dispatching cloud logical entities is a logical unified infrastructure service platform consists of all kinds of dispatching infrastructure such as physical devices and communication equipments. They are dispersed in dispatching control centers at all levels and can be unified managed through state power dispatching network . In this way, user and upper applications can get online service and data from interface of platform instead of direct access physical resources. Based on the platform, power grid model cloud, measurement data cloud and computing cloud are constructed together to provide unified online computing services.

2) Edge Computing and Display Unit

In the field of electric power dispatching, edge computing unit is substation monitoring and control system or regional dispatching and control centers. They are supervised by dispatching cloud and can cooperate with other edging computing unit to complete specific application calculation through state power dispatching network. It mainly includes three parts: measurement unit, local computing unit and interaction unit. Measurement unit manage local sensor network and data storage management; local computing unit not only can obtain system operation status by basic calculation of measurement data, but also accept commands of dispatching cloud and perform necessary control operation; interactive unit is responsible for interact with dispatching cloud and other edge computing units. Edge display unit is mainly user-oriented. It provides privilege login authentication, online computing access, data display and statistics functions, access online computing services and resource acquisition through state power dispatching network or public internet.

3) Online Computing Service Engine

Online computing service engine is the core of online computing service. It integrates into the service-oriented design concept, and packages every kind of online computing business into a job which act as application service at the top. Computing service driver engine generates job instance, drives its execution, and also manages interacting with the message service bus. The engine does the necessary real-time data interaction with grid model cloud and measurement data cloud, manage computing resources and tasks in unified approach through message service bus, and realize t decomposition and coordination way of online computing process.

Hybrid dispatching computing characterized as distributed and parallel. On the basis of distributed storage and centralized and unified management of the whole power grid model and measurement data, a workflow engine for on-line analysis business and a decomposition and coordination message service bus are established. Except edging computing phase, model cloud, data cloud and computing cloud are deep coupled into a cooperative computing way that only a power grid needs one calculation and each subordinate dispatching control centers and users obtain the operation information of their own authority in the subscription mechanism.

B. *computing process analysis*

The Service-oriented architecture is adopted to design an online computing service architecture featuring functional module servicing and distributed parallel computing. It includes job management service, data model service, data interaction service and some computing service units that implement specific functions. Computing service driver engine executes online computing service processes in a unified management way, as shown in Figure 2.

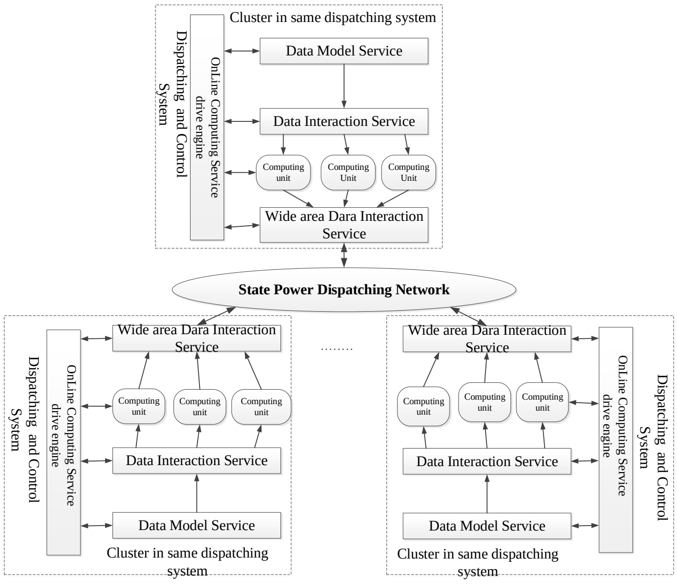

Fig. 2. On-line computing process

This architecture supports both local cluster and wide-area distributed service deployment mode. Job management service responds to computing requests and is responsible for generating instances of computing service units and performing specific calculations. From dispatching computing resources prospective, computer clusters in different dispatching centers are in a peer-to-peer position. Wide area data interaction service(WADIS) is designed to perform data interaction and collaboration computing in state power dispatching network. Data model service includes two parts: one is integrated collaborative modeling, maintenance, splicing and sharing of power grid physical model; the other is wide area splicing of computing model, which provides input/output data interface for computing service unit. Data exchange service includes data transmission between local area network clusters and within wide area network. Computing service unit is part of specific function to realize online computing applications. In addition, these service unit instances are packaged and executed by job management service instance. At the same time, it cooperates with computation service driver engine, decomposition and coordination computational service bus to manage task assignment/mapping and service scheduling in response to online computational requests.

III. ON-LINE COMPUTING SERVICE

A. *online computing hierarchical services*

Virtualization of cluster resources, standardization of operation platform and data interaction, and functional modules service are prerequisites for hybrid dispatching cloud to provide end user with convenient and scalable online computing service. On the basis of infrastructure service layer and resource management service layer, online computing software as a service is divided into three parts: service request, role instance and service instance according to execution sequence. Its structure is shown in Figure 3.

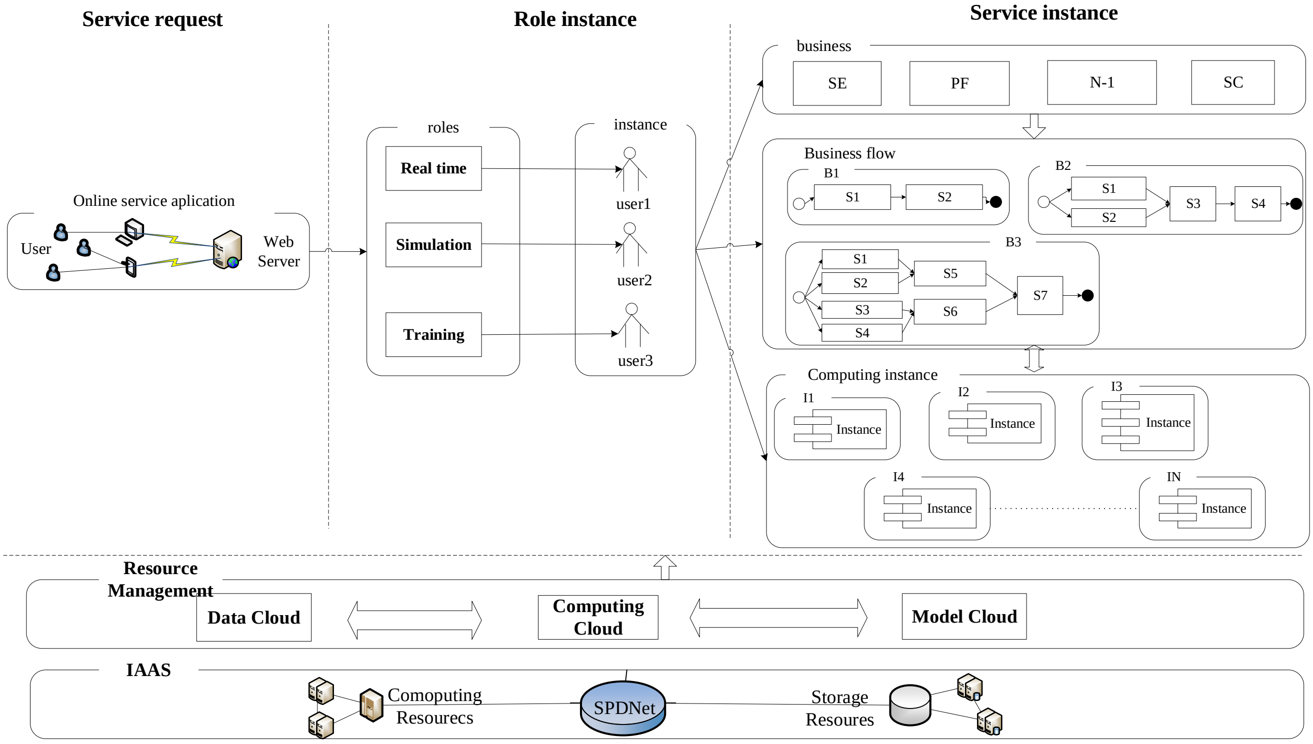

Fig. 3. On-line computation services hierarchy.

Request service is responsible for responding to online computing service initiated by users through terminal. Role instance analyses and classifies service requests of users, generates user instances according to different application status such as real-time, simulation, training simulation. It also manages computing privileges of user instance to execute service instances, and monitors the execution process of service instances. Service instance carries out specific online computing business, which is divided into three layers: function, process and computing service instance. Function layer describes online computing business performed by user instance. Process layer describes computing process of specific business function, and chooses coarse-grained or fine-grained distribution mapping according to configuration of the user instance. Computing service unit is the basic component of online computing process, which are managed by service instance layer to interact with data cloud and model cloud, in the meanwhile implement online computing business in distributed and parallel computing mode.

B. *online service procedure*

Online computing service driver engine cooperates with decomposition and coordination computing service bus to provide online computing services, and manages computing service sheets including meta-service and monitoring calculation process. Its procedure is shown in Figure 4.

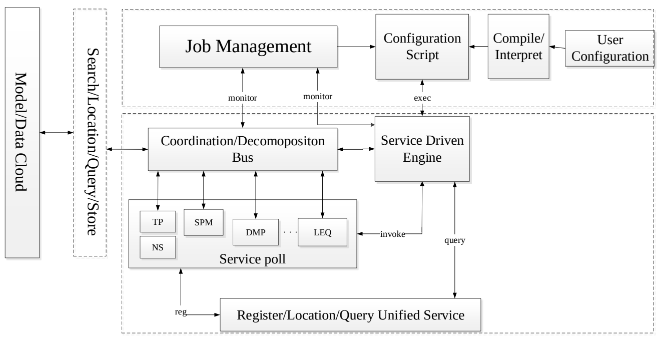

Fig. 4. online computing service procedure.

User configuration function caters to professional programmers. Each function module is encapsulated, registered as a service unit in service pool. After then decomposition and coordination computing service bus manage them and form into executable programs invoked by driver engine. Computational service driver engine drives these programs to run periodically in real time, at the same time it can respond to user requests and support event triggering events. So the online computing service instance running is characterized as low coupling and dynamic configuration. In addition, authorized users can edit and compose various online applications in simulation state and choose computing mode to implement each functional module.

IV. Test Case Analysis

Topology analysis service is basic service for online computing applications [14], and it was used to simulate as edge computing unit. Power grid model with data size 50MB was used to test efficiency of serial, distributed and parallel topology analysis service in cloud environment.

First, grid model is divided into two parts: m1 is a surplus data except for central china power grid, m2 only contains central china power grid. Both of them run on two Linux operating systems (named s1 and s2 respectively) under 100M LAN communication environment. The machine configuration is CPU: 2*2.5GHz, 4*16GRAM. The thread number of multithreaded parallel topology calculations is 4. There are three kinds of topology analysis service test cases including distributed parallel and serial mode to be carried out. Distributed test case is that s1 and s2 do topo-analysis simultaneously, and transfer s2 result to s1. S1 spliced s2 into the whole network computing model. Parallel test case is that topology analysis is running in a single machine with four threads concurrently. Serial test case is that power network model is not splatted, and the whole is calculated by single-machine in only one thread. Topology analysis times in different cases shows in Table 1.

TABLE I. Topology Analysis Time Comparation(s)

Computing mode	Format conversion	Trans Time	Splicing Time	Topo Time	Total Time
Distri	0.72	1.26	0.003	1.3	3.183
Parallel	0.71	0.1	0.002	1.2	2.012
Serial	2.38	0	0	1.4	3.78

In two-machine LAN environment, compared with the serial mode, distributed mode can reduce time of topology analysis due to reduction of computing scale (from 25MB to 5MB), while data transmission time occupies most of the time consumed as a whole; Parallel mode with 4-thread has the highest efficiency of topology analysis without considering communication bandwidth. It has three times speed ratio compared with serial mode. Therefore, in hybrid dispatching cloud system, communication bandwidth is the key factor of affecting topology computation service efficiency.

V. Conclusions

Smart sensor devices deployment and improvement of network make it possible for edge computing to be applied in power grid dispatching system. But network communication bandwidth is still far less than memory, which will reduce online computing speed when grid scale is small in distributed mode. As long as grid model size is large and measurement data is also enough, the online computing service performance will be improved in this mode. A large number of edge computing devices were deployed in state power dispatching network, this increases volume of data transmission and also bring security and credibility issues. Trust authentication and data encryption mechanism suitable for hybrid computing architecture needs to be further studied.

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