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Data Interchange Technique in Future Electric Power Dispatching System

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***Abstract*—In order to fix the defect of large-volume-data transmission and system fault tolerance in the current remote proxy, this paper proposes a wide-area data interaction technology which can be applied to the future power dispatching system by utilizing advanced techniques such as elastic extending, load balancing and fail-over mechanism etc. The distributed proxy dramatically enhances the data transmission scale and system availability by innovating the Power Dispatching Domain System and the dynamic-load balancing mechanism. According to the comparison test, the wide-area data interaction technology can better satisfy the requirement of future big-data transmission in the power dispatching system by providing a superior performance compared to the current proxy.**

Keywords-component; wide-area data interaction; load balancing; power domain; real-time monitoring

I. Introduction

In recent years, the smart grid dispatching control system has been widely used by all levels of dispatching control center of the State Grid Corporation of China, which made great contributions guaranteeing the safety and stable operation of the power grid. However, with the rapid development of UHV AC-DC hybrid large power grid and the full construction of large operating system, and the physical structure of the grid changed significantly, while the coupling of the regional power grid was further strengthened, the grid dispatching operation has been challenged a lot.

Aiming at the new change of grid dispatching mode, many Chinese and foreign scholars have studied the future dispatching control technology. The key technologies of the next-generation scheduling system, such as the data synchronization mechanism of the wide area system, are discussed in [2].In [3], the concept of information stratification of smart grid dispatching control system is proposed, which emphasizes the two-way information interaction in the future smart grid control center is required. In [4], an automatic intelligent dispatching system based on event perception and grid operation trajectory is suggested to implement the accurate grasp of the running status and development trend and process of the power grid. Shen Guorong et al. [5] proposed an integrated application supporting platform to support a new generation of advanced dispatching application. That platform can present the overall status of the power system by integrating independent automation systems. The above-mentioned literature discusses the architecture and key technologies of the future dispatching system. And all of them mentioned the wide-area and real-time data interaction is the core technique of constructing the future dispatching system, but no specific technical implementation is provided.

Based on the existing research, this paper proposes a distributed proxy to meet the future data interchange requirement between power dispatching systems. The distributed proxy satisfies the data transmission requirements in future power dispatching system by implementing a wide-area, real-time and large-scale data interchange technique. This paper firstly introduces the current communication proxy in power system. Secondly, it presented the architecture of wide-area distributed proxy. Thirdly, core techniques used by the distributed proxy are introduced. And then, this paper described the deployments of the wide-area distributed proxy. Finally the future research directions based on this topic are provided.

II. Current Communication Proxy in Power System

According to the requirements of "security protection regulation in power secondary system", when the power dispatching system deployed in the production of large areas, multi-level dispatching proxies can only communicate with each other through the communication gateway. Currently, the cross-level communication of power dispatching system is implemented via proxy process. As shown in Figure I, when proxy process deployed at gateway servers, the system browser could remotely obtain the power flow states and equipment parameters from subordinate institutions. The emergence of proxy process to a certain extent meets the dispatching system wide-area data exchange requirements. However, with the increasing demand for integrated coordination and large-scale power data transmission, the existing data transmission mechanism gradually exposes its shortcomings, mainly reflected in the following three aspects:

- *The* current proxy chooses single-process mode, which leads to a limited system throughput. It cannot support a large-scale data transmission requirement.
- The transmission of electric data such as power grid models and alarm information might be intermittent.

The current proxy forwards data directly without flexibility to expand and capability to load balance. Thus, it is not adapted to the elasticity of data exchange.

- The current proxy only supports data transmission among specified data type. It also cannot guarantee the reliable and efficient transmission of the data since there is no monitoring mechanism during the transmission.

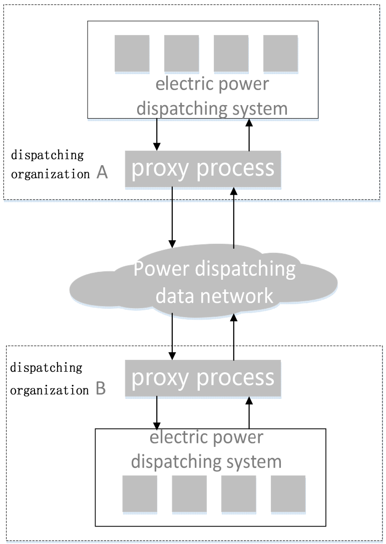

FIGURE I. COMMUNICATION MODE IN POWER DISPATCHING SYSTEM

III. THE MAIN STRUCTURE AND OPERATION PRINCIPLE

A. *Main Structure*

A wide-area distributed proxy is composed of proxies distributed among a list of dispatching proxies in a wide-area data network. It implements the transparent service accessing and data transmission by utilizing the inter-associated power domain names. The structure is shown in Figure II.

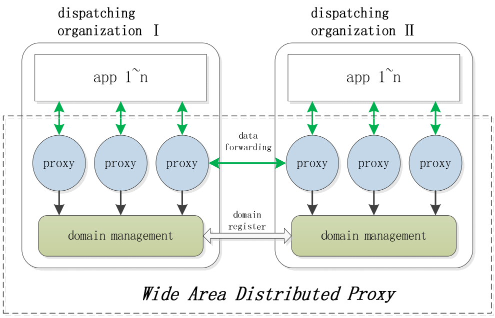

FIGURE II. MAIN STRUCTURE OF DISTRIBUTED PROXY

The wide-area distributed proxy implements multi-proxies cooperation mechanism by utilizing cluster techniques. It provides an uninterrupted data forwarding service by enhancing the proxy's disaster recovery and data communications capabilities.

B. *Functionality Design*

The distributed proxy consists of front-end load-balancers, proxy clusters, domain management, and proxy monitoring. It constructs a loosely coupled, position transparent and protocol independent distributed proxy system architecture by adopting Service-Oriented Architecture (SOA). The function structure is described in Figure III. The front-end load-balancer forwards requests to all nodes of the proxy cluster by using the minimum number of connections weighting algorithm. Then the algorithm selects the optimal proxy node from the cluster to forward requests by calculating weights and real-time connections. After the proxy cluster receives the request, it initiates the domain location request to the domain management. The domain management obtains detailed information such as loading information of distributed proxies from other dispatching institutions. After that, the location information of the optimal proxy node will be sent to the local proxy. The proxy monitor is responsible for tracking the entire data transfer process, making history archives and traffic accounting, which effectively support the execution of distributed proxy.

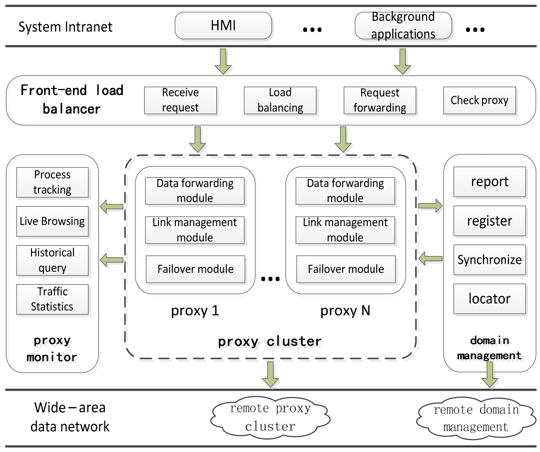

FIGURE III. FUNCTIONS OF DISTRIBUTED PROXY

IV. KEY TECHNIQUES OF WIDE-AREA DISTRIBUTED PROXY

A. *Power Domain Name System*

The power domain name system is composed by the domain name management program which distributes in each level dispatching institution. It increases the flexibility of inter-proxy access by implementing global share of proxies running state information in wide area. On the other hand, the power domain name system supports load balancing access from the local proxy to the remote proxy via domain router, which ensures the efficiency of data exchange in large concurrent access.

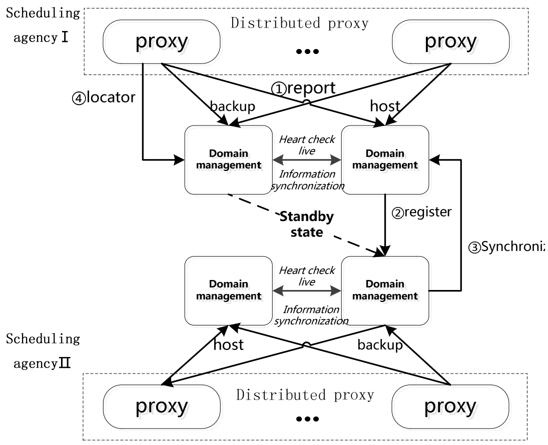

FIGURE IV. PRINCIPLE OF POWER DOMAIN NAME SYSTEM

The principle of power domain system is shown in Figure IV. The domain management programs operate as master-slave and hot backup mode, which allows the master and slave nodes know each other’s state by using heartbeats technique. Thus, it guarantees the security and high availability of power domain name management operation since backup node could automatically recover the work of the master node once downtime occurs.

The domain registration function is the fundamental to allow the proxy clusters from different institutions to exchange data. First of all, all nodes of the proxy cluster must send the heartbeat data to both master node and backup node of domain name system at the same time, so that the data consistency can be ensured for both master and backup nodes. The domain registration is initiated by the domain management host to any other domain management of the remote dispatching institution. The domain name management of remote institution would real-timely push the proxy running status information after the domain name has been checked. Finally, in order to ensure the status information consistency, the domain name master host needs to synchronize the state information with backup host.

The domain routing function implement a complete process of domain name-address mapping and optimal node selection. Once domain registration completes, the local domain name master and backup machine has cached the status information of all the proxy nodes of the remote dispatching institution. After receiving the domain routing request from the proxy node in the system, the proxy state information will reflect to a specific domain name. The state information should include the amount of proxies, the IP address of each proxy and the loading status of each proxy. Then, the optimal proxy node can be selected by the IPDL load balancing algorithm. Finally, a TCP connection can be established with that optimal proxy node. The whole process is fully transparent, while the data exchange efficiency has been dramatically improved in each level dispatching institution.

B. Load Balance of Distributed Proxy

The current proxy is executed based on the single-node mode. As for now, the complex power system dispatching business has caused tremendous operating pressure. Especially when plenty of clients access the service at the same time, the service quality might not be guaranteed since clients have to wait for a long time. Thus, how to improve the load capacity of the proxy has become an imminent problem. The distributed proxy solves the problem of large concurrent request load balancing in the system (client to local proxy) and between systems (local proxy to wide area proxy) by utilizing multi-node collaboration and load balancing technique.

1) In-System Load Balance: The in-system load balance of distributed proxy is implemented by LVS + Keepalived. The principle is shown in Figure V. It consists of front-end load balance cluster (LBC) and back-end proxies. Distributed proxies are connected by local area network, while LBC is the only thing clients could see. Once request packet has been received by LBC, the MAC address in the packet will be transformed into a MAC address of a specific proxy node. Then the proxy node could directly return the sockets to clients after packets received, while all of distributed proxies and LBC must be in the same physical network segment. And LBC needs to share the same virtual address with the proxy. Such structure not only greatly improves the proxy server response time and system resource utilization, but also implements the user's transparent access to the distributed proxy, which hugely enhances the security and robustness of the power system wide-area dispatching service.

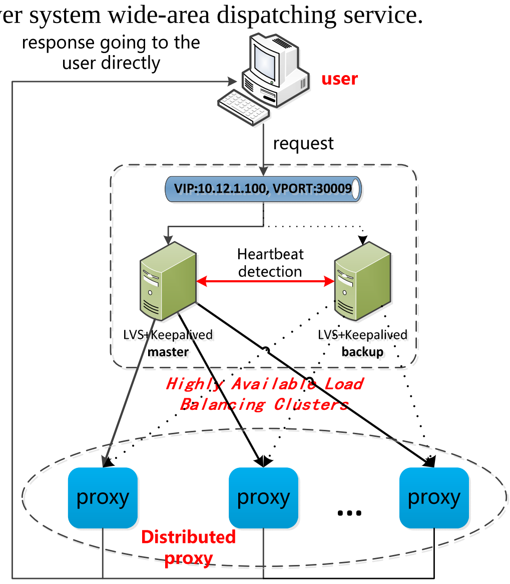

FIGURE V. IN-SYSTEM LOAD BALANCE STRUCTURE

2) Between-System Load Balance: The between-system load balance is implemented by domain name management technique. The structure is shown in Figure VI. First of all, the distributed proxy of dispatching institution B will send the launch information and load status to the domain name management of local institution. Then, dispatching institution

A will send the request to the institution B. Once the request has been approved, institution B could synchronize the real-time load information with institution A. When the institution A is forwarding wide-area data, the proxy only needs to initiate the location request to the local authority domain name management. Domain name management will select the best performance proxy node based on weighted minimum number of connections algorithm, while the IP and port information will be returned. Such structure can effectively solve the problem of distributed proxy load balancing among the systems, which hugely improves the data processing capability of the wide area network, and avoids the data network congestion affecting the normal operation of the power network dispatching system.

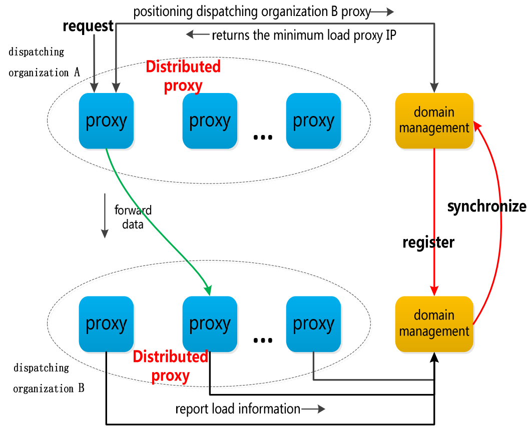

FIGURE VI. BETWEEN-SYSTEM LOAD BALANCE STRUCTURE

C. *Proxy Intelligent Monitoring*

Currently, in the smart grid dispatching system, because of the lack of smart monitor, wide-area accessing information cannot be monitored when data exchanges happen between different institutions. In order to improve the operation and maintenance of wide area distributed proxy and service quality, comprehensive, intelligent, and real-time monitoring of wide area access data in wide area distributed proxies is required. Intelligent monitoring technology not only allows users to real-time monitoring of the efficiency of wide-area access, but also provides a view of wide area access information and information flow statistics. Thus, the intelligent monitoring application in D5000 system is developed to collect real-time and wide-area information. It also provides a user-friendly layout to present information, so that users can more clearly understand the data exchange between the dispatching institutions. The main structure is shown in Figure VII.

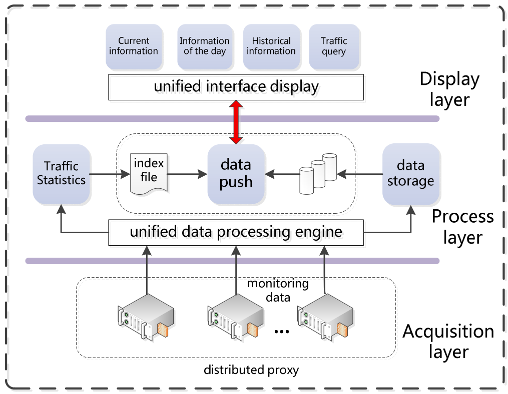

FIGURE VII. PROXY MONITOR STRUCTURE

Resource scheduling mainly consists of the load detection, dynamic management and fault isolation. Load detection enables the dynamic management function to be enabled automatically when the average CPU utilization rate of the proxy cluster exceeds the maximum threshold set by the user or falls below the minimum threshold set by the user for a certain period of time. The dynamic management function automatically increases or decreases the number of proxy nodes in the cluster according to the load change, thus realizing resource self-adaptive scheduling and ensuring the stability of proxy cluster operation. Fault isolation function enables a proxy node in the cluster to automatically removes them and awakes the new node to take over the operation when processing data forwarding requests exceeding user-defined threshold, so that ensures the high availability of the proxy cluster.

Tracking statistics include data forwarding and proxy nodes in two aspects of operational information. Proxy monitoring mainly collects information such as start time, end time, forwarding path and reason of failure of data forwarding, and classifies it according to real-time, day and history. At the same time collecting proxy nodes use system resources and key operating information such as CPU / memory usage, online status and access time per unit time.

The display query function mainly displays the collected data forwarding information, the agent operation information and the fault alarm information in the form of visual interface. Besides that, clients can filter the query according to the data forwarding type, forwarding time, or forwarding path, and generate statistical reports.

V. PERFORMANCE TEST

We simulate the test situation where dispatching institution A sends a request to institution B and receives the response from institution B. We choose the same performance and model servers to build the distributed proxy cluster. The network bandwidth of the test environment is 1000Mb / s. The software and hardware configuration are shown in the Table I.

TABLE I. SOFTWARE AND HARDWARE CONFIGURATION

Server	*OS*	*Kernel*	*RAM*	*Frequency*
ALL	Rocky	8	32G	3.3GHz

A. Large Concurrency Access Test

The dispatching institution A and B each use four proxy gateway machines as the distributed proxy cluster for large concurrency access test. On institution A node, we launch 500 clients. Each of them sends 2 KB request to the distributed proxy per second and wait for 4KB response. Then we gradually increase the number of clients up to 100000. The time consumption is shown in FEGURE IX.

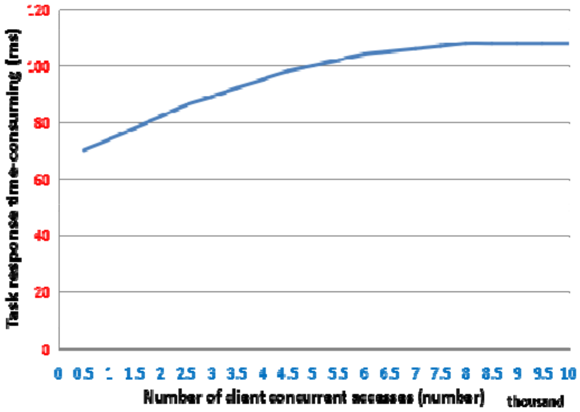

FIGURE VIII. RESPONSE TIME CONSUMPTION

B. Big Data Forwarding Test

We send different size data from institution A to institution B and repeat this process 100 times. The statistic is shown in TABLE II.

TABLE II. THE TIME CONSUMPTION OF BIG DATA FORWARDING

Data Size	***Times***	***Time Consumption***
100M	100	10.1
200M	100	20.2
400M	100	39.5
600M	100	62.1
800M	100	76.6
1G	100	101.2

In the concurrency test, the response time of distributed agent processing task increases with the number of clients, and finally stabilizes at 115 ms. Time taken to transfer data during large data forwarding tests increases as the data grows. No data loss was found in either of the two tests.

VI. CONCLUSION

Based on the deep research on the development trend of dispatching control technology, this paper analyzes the shortcomings of the current remote proxy in transmitting large-scale data and system fault tolerance, and proposes a wide-area distributed proxy architecture to adapt to the future power dispatching system. Wide-area distributed proxy combines the characteristics of typical cloud computing, such as elastic extension, load balancing, fault failover, etc., to ensure the security and efficiency of wide-area data exchange. From the comparison test, compared with the traditional proxy, wide area distributed proxy in the data transmission scale and high availability have greatly improved, can better adapt to the future power scheduling data transmission requirements for the realization of model data center , Power application service, master station integration to provide basic communications architecture support.

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