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Design for Improving the Architectural Capabilities of Complex Network Intensive and Scalable Early Warning Release System

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Abstract: In order to solve the problems of high coupling and poor scalability of the traditional monomer early warning release system architecture, multi-level deployment in a complex network environment will lead to high investment in software and hardware and cannot achieve intensive multi-level deployment. This paper realizes the goal of system scalability by introducing micro service architecture and technology stack and realizes the goal of resource intensification by introducing the idea of a data forwarding agent. The designed architecture scheme has been practically applied in the "Jiangxi emergency early warning information release system software platform (phase I) project" (hereinafter referred to as "provincial emergency"), which meets the needs of flexible deployment of multi-level applications across meteorological wide area network (WAN), business private network of other commissions, offices, and bureaus, government extranet, Internet and other complex networks, and fully verifies the scientificity and rationality of the scheme. It has achieved the goal of intensive and scalable construction of provincial emergencies under the complex network environment, greatly improved the early warning capacity and communication capacity of emergencies and comprehensive disasters, provided a reliable guarantee for disaster prevention and reduction, and provided a reference for the construction of current and future early warning release system and capacity improvement project.

Keywords: Early warning; Architecture; Microservices; Intensification; Extensible; Power enhanced

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1. Overview

In the past two decades, an average of more than 200 million people around the world have been affected by natural disasters every year [1], and natural disasters have led to frequent workplace safety accidents, which have caused long-term negative impacts on society, economy, and the environment. The emergency early warning information release platform has provided a good guarantee and support for disaster prevention, mitigation, and relief.

On the international front, the book Institutional Partnership for Multi-Hazard Early Warning Systems documents seven examples of hydrometeorological and other hazard early warning systems, covering a variety of climate regimes and stages of economic development, from industrialized countries such as Germany, France, Japan and the United States of America. Bangladesh, the island nation of Cuba, and the megacity of Shanghai [2], demonstrated good practice in multi-hazard Early Warning systems (EWS) [3].

Domestically, the governments of 31 provinces (autonomous regions and municipalities directly under the central government) have successively formulated measures for the release and management of emergency early warning information at the provincial level [4]. The governments of many provinces (autonomous regions and municipalities), including Beijing, Shanghai, Guangdong, and Tianjin, have set up emergency warning information release centers, completed or are under construction provincial emergency warning information release systems, and incorporated their operation and maintenance into local financial security [5].

2. Early warning microservice architecture design

2.1. Overall requirements

Considering the current state of the network, the emergency early warning information distribution center (hereinafter referred to as the early warning center) operates within the meteorological wide area network (WAN). The provincial, municipal, and county (district/city) networks are interconnected, while private networks of other commissions and offices are physically isolated, and there is isolation between government networks outside provinces and cities. The network architecture design scheme connects provincial, municipal, and county (district/city) horizontal commissions, offices, and bureaus through the government extranet. Meanwhile, the early warning centers at the provincial, municipal, and county (district/city) levels access the meteorological WAN vertically for the production and release of emergency early warning information.

The final implementation scheme includes deploying a set of applications and databases in the information center of the provincial Meteorological Bureau to support three-level applications at the provincial, municipal, and county (district/city) levels. Additionally, a set of applications is deployed in the Demilitarized Zone (DMZ) of the provincial and municipal Meteorological Bureau information center to enable two-level deployments for provincial and municipal multi-agency applications while meeting the isolation requirements of provincial and municipal government external networks.

2.2. Functional design

Several business function subdomains are identified through domain decomposition, and each business function domain corresponds to a subsystem. Subprocesses are generated by the re-decomposition of the subsystem and then gradually decomposed and refined iteratively, and the subprocesses that finally reach the level of user interaction are called atomic processes [6,7]. Functional design mainly includes eight subsystems, as shown in **Figure 1**.

2.3. Microservice architecture design and implementation

Integrated Development Environment (IDE) using Eclipse has been adopted to streamline software development processes, leveraging the numerous advantages of the Java programming language. Java's strengths include high development efficiency, robust running speed, support for distributed transaction processing, scalability, object-oriented design, robustness, security, platform independence, portability, compatibility, multi-threading, and dynamic features.

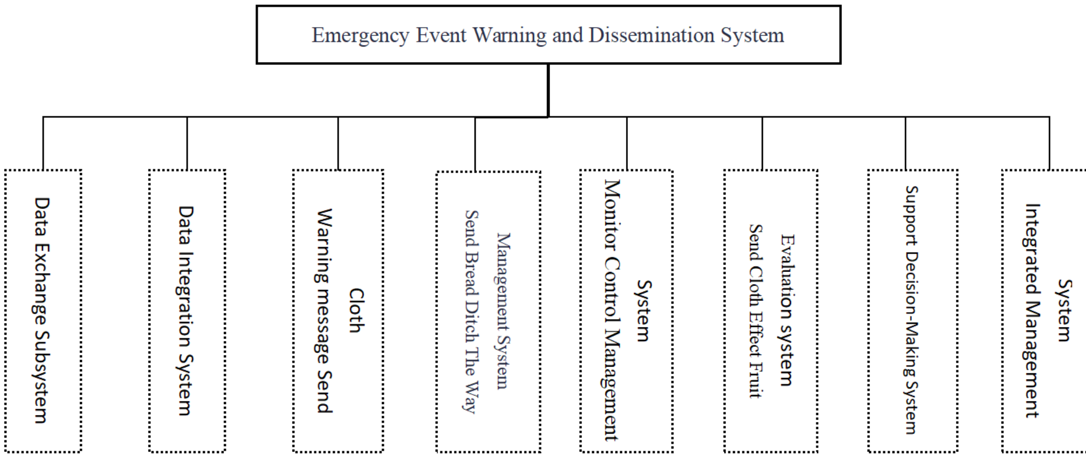

Figure 1. Functional structure

For front-end development, the framework utilizes Vue.js and HTML5, while the back-end development is based on the Spring Cloud Alibaba [8] distributed one-stop development solution. This back-end framework integrates Spring Boot[9], SpringMVC, and MyBatis [10] to implement the control layer, data model layer, business logic layer, and data storage object microservice development [11]. The architecture uses Spring Cloud Gateway as the API gateway [12], OAuth 2.0 [13] for unified authentication, Sentinel [14] for flow control and service degradation, Nacos [15] for service registration and discovery, a distributed configuration center, and Seata [16] for distributed transaction processing.

The system also incorporates advanced tools to handle data and monitoring. Canal enables real-time incremental data transmission of MySQL in a containerized environment powered by Docker, while Redis is used for real-time incremental data and basic resource storage of MySQL. Zabbix ensures visual monitoring of system services, software, network, and hardware resources.

For messaging and logging, Kafka is utilized for subscription message storage, while Logstash collects, analyzes, and filters log messages for formatting purposes. Elasticsearch supports data search, analysis, and storage, and Nginx provides load balancing to optimize system performance.

The development pipeline is further enhanced through the integration of Jenkins, Kubernetes, Git, Maven, and Docker repositories to implement a robust DevOps workflow. This combination ensures efficient, automated processes for continuous integration, deployment, and management of microservices. **Figure 2** shows the microservice architecture.

3. Intensive scalable deployment architecture implementation

The system is deployed on the provincial and municipal private cloud infrastructure, as well as the government network, to achieve vertical integration of applications across the provincial, prefecture, and county levels. It also facilitates the horizontal integration of a multi-department joint warning and release platform. This deployment ensures unified resource management, standardized development environments, and application support, thereby enhancing system efficiency and security.

To support Internet-based microservices, resources such as websites, apps, microblogs, WeChat, Doudou, emails, and direct emergency reporting systems are deployed within the DMZ's Internet resource pool. This setup

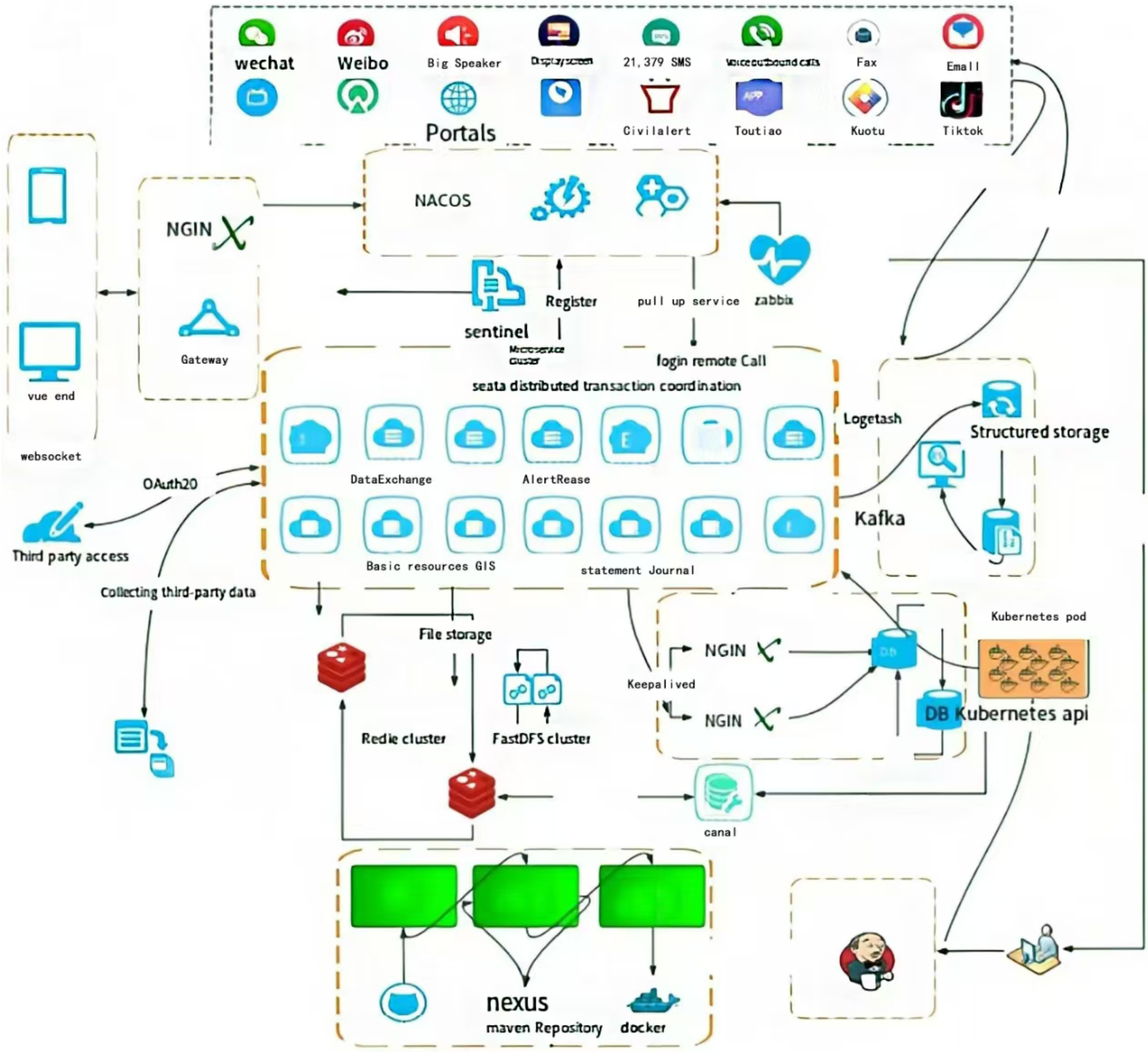

Figure 2. SaaS microservice architecture

enables resource sharing across provincial, city, and county levels.

The nodes at both provincial and municipal levels adhere to the requirements for information security level protection and national e-government engineering construction projects. They are designed to comply with the system's third-level protection standards, ensuring robust security measures are in place [16]. The architecture for the new deployment is illustrated in **Figure 3**.

4. System operation effect

From January 1, 2022, to September 13, 2022, the municipal and county commissions and bureaus of XXX Province released statistical reports on the types of early warning information issued by the province, as shown in **Table 1**.

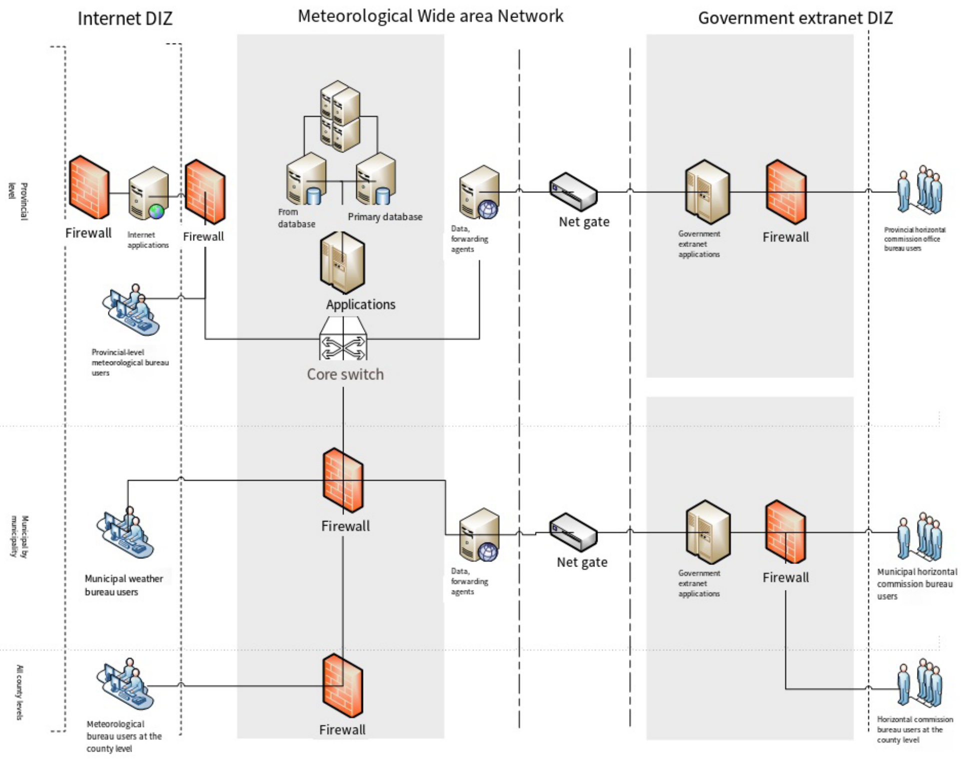

Figure 3. Intensive deployment

Table 1. Statistical reports on the types of early warning information issued

Information Type	Early Warning Information					Text messages	WeChat	Microblog	Mail	Outbound	Loudspeaker	Display screen
	red	orange	yellow	blue	Total		Number of Follows	Number of Fans				
Fog	7	352	1,261	0	1,620	579,918	888,050	7,521,634	230	8	81	149
High winds	0	2	221	1,701	1,924	791,902	1,587,368	13,162,952	761	143	0	0
Heavy snow	2	5	23	142	172	78,397	172,044	871,720	24	1	0	0
Thunder	0	376	23	0	399	4,161,942	4,093,761	39,975,673	3,420	198	0	0
Hailstone	0	30	23	0	53	9,554	16,561	639,100	11	0	0	0
Heavy Rain	95	674	23	677	1,469	1,453,376	1,267,287	20,058,410	1,230	2,503	0	0
High temperatures	438	4,023	23	0	4,484	3,412,831	2,653,870	15,143,004	1,992	2,987	0	0
Total	542	5,462	1,597	2,520	10,121	10,487,920	10,678,941	97,372,493	7,668	5,840	81	149

5. Conclusion

This architecture has been applied in 16 prefectural cities, 27 municipal districts, 12 county-level cities, and 83 counties in Ningxia and Jiangxi. The practice proves that the provincial surge architecture meets the requirements of intensification, scalability, and security in a complex network environment.

Disclosure statement

The authors declare no conflict of interest.

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