# Design and Application of Operation and Maintenance Platform for Water Conservancy Information Assets

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**Abstract.** With the in-depth promotion of water conservancy informatization construction, the water conservancy sector has accumulated information technology hardware and software technology status, ownership, construction mode is more and more complex and variable. The operation and maintenance of these information technology assets in the traditional mode is complicated, and there are multiple maintenance and passive response. Following the trend of the development of digital twin water conservancy, the information hardware and software in the water conservancy industry will become more complex in future. We consider the actual needs of the O&M work in the digital development of water conservancy in Zhejiang Province, so this paper elaborates on the functional positioning of the O&M platform for water conservancy, proposes a technical path and architecture that integrates intelligent gateways and data filtering, we discuss the diagnostic and warning system of water conservancy information assets under this platform. Finally we devoloped a O&M platform for water conservancy information asset which based on the SaaS model. The application results show it could judge multi-source hardware and software failuresquickly and intelligently, it also distribute maintenance tasks automatically, batch maintain water conservancy business application software, reduce the pressure and cost of digital transformation for water conservancy management departments.

**Keywords:** Water Conservancy Informatization; Intelligent Operation and Maintenance; Operation and Maintenance Platform; Fault Analysis; Platform Design

## 1 Introduction

In 2019, Zhejiang province began to promote the digital transformation of water conservancy, and subsequently, there are many cities established a large number of information systems with various uses. These information construction achievements have greatly promoted the high-quality development of water conservancy. With the development of information construction, the hardware platforms such as collection devices, computer rooms, network lines, and parsing servers, as well as software sys-


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tems including business applications, databases, application servers, and middleware, are becoming complex more and more. For water conservancy departments, the traditional project-oriented O&M management model is gradually showing bottlenecks in efficiency: (1)the types of water monitoring equipment are complex, with numerous manufacturers, making it difficult to maintain a high online rate uniformly. (2)due to operational management methods, the speed of locating software and hardware equipment failures is slow. (3)the increase in software quantity leads to an increase in operational complexity. (4)lack of professional personnel. In the face of the increasingly large O&M tasks of water conservancy information systems, it is necessary to improve operation and maintenance efficiency through digital means, which has also become a problem that water conservancy departments need to solve.

## 2 Research Background

For the O&M work of water conservancy information systems, early domestic researchers such as Cai Yang[1] led the development of a water conservancy information system O&M platform. Based on the hierarchical system architecture that includes the collection and monitoring layer, support layer, application layer, and portal, they proposed a business service framework BSF (Business Service Framework) and a business information management model BMM (Business Information Management Model) for water conservancy information system O&M, as well as a unified support library and other key technical solutions. On this basis, Fu Jing et al[2] further discussed the system and mechanism of water conservancy information system O&M work, believing that the lack of strong O&M performance evaluation, weak function of the O&M supervision platform, and shortage of O&M human resources are common problems in domestic water conservancy information O&M work, and they put forward targeted views on evaluating O&M performance, formulating O&M quota standards, and improving O&M technology levels. Wang Lan[3] proposed the concept of "operation and maintenance is better than construction, and upgrading and transformation are better than new construction" when analyzing the development process of water conservancy informatization.

Although some scholars have conducted research on water conservancy information system O&M work early on, domestic water conservancy industry research on O&M work has long focused on traditional water conservancy projects, such as Luan Yichong et al[4] who established an intelligent O&M platform for the Nanjing Sancha River Estuary Gate, using improved ICEEMDAN and RBF algorithms to diagnose and analyze the gate's working status, fault causes, and maintenance plans, achieving intelligent operation and maintenance of the sluice gate. Fang Zhengjie[5] established an intelligent O&M platform for the water gate pump projects managed by the Shanghai, achieving intelligent management and smart inspection of water gate pump equipment. In addition, the combination of water conservancy information system O&M and digital twin technology has become a new trend in recent years, such as Liang Zhikai[6] who developed an intelligent O&M management platform for water conservancy mechanical and electrical equipment based on digital twin technology, introducing multi-source heterogeneous database, multi-physical field coupling finite element simulation technology, and equipment digital twin body construction technology to strengthen the foundation of digital twins and improve O&M's reliability of water conservancy mechanical and electrical equipment. The above-related research work has mainly focused on the O&M of water conservancy projects or water conservancy mechanical and electrical equipment itself, and there is less research on the intelligent O&M of water conservancy information assets.

At present, intelligent O&M of information systems has been applied in the telecommunications, transportation, energy, and other industries. For example, Lai Zhiping[7] studied the intelligent operation and maintenance of urban rail transit communication systems and built a communication intelligent O&M platform based on multi-dimensional collaborative collection and calculation, which can achieve monitoring, early warning, and diagnosis of communication equipment. MartiP[8] built a thematic database for intelligent O&M strategies, it could be helpful when detect rotor malfunction when the estimate differs from the actual measured value.

# 3 System Design and Implementation

## 3.1 Requirements Analysis

By comprehensively analyzing and summarizing the work content of various water conservancy departments for the O&M of water conservancy information assets, the application requirements of the water conservancy information asset operation and maintenance platform are summarized as follows:

(1) Monitor data collection equipment: Collect various types of professional data generated by water conservancy monitoring and collection equipment, such as water level, rainfall, flow, settlement, and seepage pressure, and based on the characteristics of professional data, achieve identification and parsing of different types of message data and interface data, and adopt different data processing methods for standardized data storage. Integrate front-end perception device monitoring data according to business classification standards. At the same time, monitor the operation status of the collection equipment itself, and the monitored data can be set with early warning trigger conditions according to actual business work.

(2) Monitor business applications: Monitor various business systems that are connected, collect application-related operation information, such as application version numbers, network environments, probing status codes, operation logs, database logs, fault codes, and other data information, and integrate application monitoring data according to business classification standards.

(3) Monitor the operating environment: Monitor the operating environment of water conservancy information systems, collect application operating environment information, such as: computing specifications, storage specifications, middleware, operating systems, cloud resource types, alarm information, port information, etc., which can be selectively configured according to index requirements and work requirements.

(4) Intelligent equipment fault diagnosis: Build an intelligent fault diagnosis model based on key indicators of water conservancy information assets, and based on the fault

diagnosis model of key indicators, use fault propagation and fault correlation relationships for positioning, combined with the operating characteristics of water conservancy information systems, analyze key indicators in different system business flows to achieve automatic detection and automatic diagnosis of communication system faults.

(5) Dynamic maintenance. Provide batch maintenance capabilities for business applications through the operation and maintenance platform, achieving batch execution of single maintenance operations. Provide a unified code version control mechanism for business applications to enhance the update and maintenance management capabilities of business applications.

(6) Centralized hosting. The platform uses the SaaS model to unify the entry points for managers and technical personnel, configure operation and maintenance content on demand, display the overall operation of water conservancy information systems, and the progress of operation and maintenance work, helping managers and technical personnel quickly understand the issues they care about and assist in daily operation and maintenance management.

### 3.2 Approach and Methodology

In response to the aforementioned for hardware and software operation and maintenance work requirements, it is necessary to build a set of O&M methods to solve the problem:

(1) adopting a multi-source data intelligent gateway to address issues related to water conservancy monitoring equipment, including data collection and hardware fault location.

(2) developing methods and indicators for fault diagnosis of water conservancy information assets to address issues related to software faults.

(3) adopting automated cloud resource pool operation and maintenance methods to resolve issues related to software maintenance, including software runtime environments and dynamic software maintenance.

(4) establishing a work platform as the operational interface for the operation and maintenance of water conservancy information assets.

### 3.3 O&M Technical System for Water Conservancy Digital Asset

Water conservancy tasks are preliminarily categorized into several thematic areas, including water disaster prevention, water resource management, protection of rivers, lakes, and reservoirs, and management of water infrastructure. Based on these thematic categories, relevant IoT monitoring devices and operational applications are systematically organized. Subsequently, unified classification standards for maintenance objects and diagnostic alert classification standards are established, serving as the technical requirements for the operation and maintenance of digital assets in water conservancy. Building on these technical requirements, various technical measures are integrated to form a comprehensive technical system for the operation and maintenance of water conservancy digital assets, as illustrated in Figure 1.

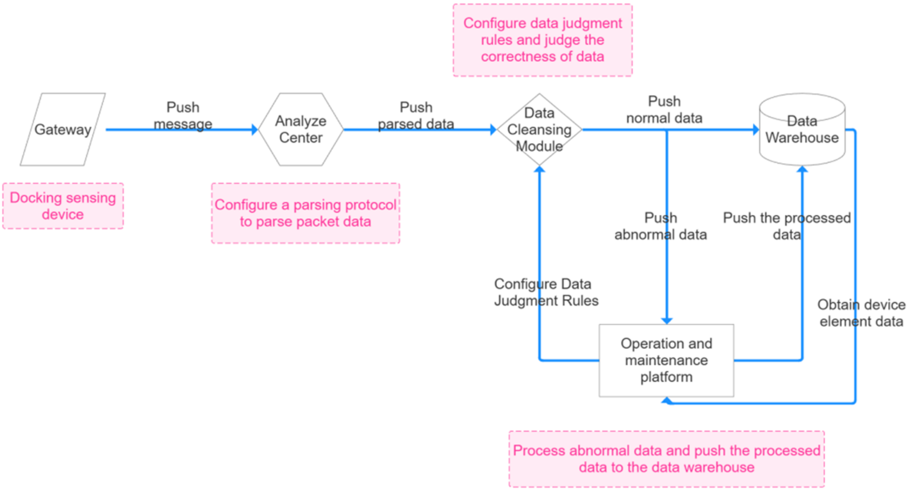


**Fig. 1.** Technical System for Water Conservancy Digital Asset Operation and Maintenance

**Multi-source Data Intelligent Gateway.** Due to the different communication standards used by water conservancy monitoring equipment, the corresponding application systems are not compatible with each other, and the collected data is multi-source and heterogeneous.

Du Shugang[9] proposed an intelligent mine IoT edge data gateway technology approach, which constructs an edge gateway management architecture, connects to the cloud platform with TCP, HTTP, WebSocket, MQTT, and other transport protocols on the upstream, and supports various communication interfaces on the downstream to connect to the perception layer equipment, achieving protocol conversion for different types of networks and unified access to multi-source heterogeneous data from various systems, and applies it to the data collection work of mine automation equipment. Based on this technical approach, a multi-source data intelligent gateway for water conservancy monitoring equipment is constructed through a four-layer technical architecture of data acquisition layer, interconnection layer, data conversion layer, and application layer.

Data Acquisition Layer: Gateways are utilized to collect data generated by various monitoring devices, primarily existing in the forms of data streams (from control systems) and data tables (from application systems), providing foundational data sources for data transformation. The data acquisition layer integrates multiple functions through gateway devices, and the integrated functions are illustrated in Figure 2.

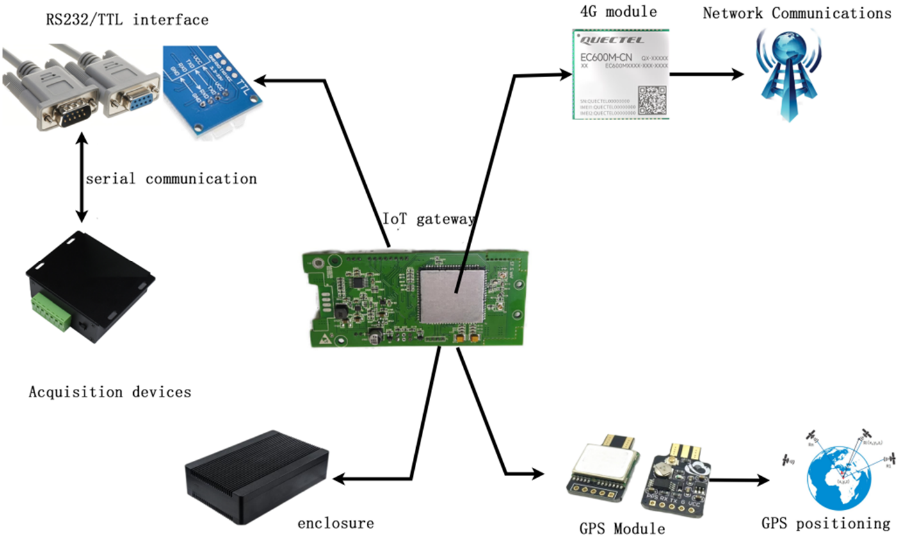


**Fig. 2.** Intelligent Gateway Configuration Framework Diagram

Interconnection Layer: Includes various field communication networks (field buses, RS232/RS422/RS485 serial buses, LoRa wireless communication, and TCP/IP networks). All communication nodes transmit data from the bottom layer to the data collection gateway through the communication network.

Data Conversion Layer: Multi-source heterogeneous data is converted into a unified data format through the data gateway. During the conversion process, the underlying data is transmitted to the data gateway through free protocol interfaces, standard protocol interfaces, and database interfaces on the data gateway. The gateway calls the corresponding data protocol for data conversion based on the data format, and finally maps the different formats of data to the JSON data format. The parsed data is oriented towards the integrated application system in the cloud and is transmitted to the upper application through an appropriate communication method.

Application Layer: Data cleaning programs and operation and maintenance platform-related module programs.

The hardware design of the gateway focuses on the potential impact of the harsh outdoor water environment on data transmission and communication, it consisting of three core modules: the main control module, the routing module, and the multi-mode group interface circuit. The software architecture of the gateway adopts a modular design concept, and writes corresponding data protocol parsing methods according to the protocols of different devices, which are stored in the protocol library in the form of dynamic libraries. After data parsing, the gateway clean up and supplement abnormal data, verify the quality of homogeneous data, and finally encapsulate it into data packets.

**Fault Diagnosis of Water Conservancy Information Assets.** Fault diagnosis of water conservancy information assets is divided into three aspects: water conservancy monitoring equipment, business application operating environment, and business applications, mainly consisting of a fault analysis and diagnosis system and a monitoring and alarm system. The fault analysis and diagnosis system is the core part.

The fault diagnosis process of water conservancy business application software includes fault detection and fault location processes. In fault detection, runtime verification is a lightweight method to ensure program reliability[10], and its basic path is to periodically probing the service, collect relevant information at the functional embedding points during software operation, and compare it with the software requirements specification. If it does not meet the predefined requirements, it indicates that a fault has been detected. In fault location, based on the formal model of water conservancy business applications, obtain runtime information from the returned status codes and fault codes, and locate the fault source through logical reasoning.

**Cloud Resource Pool Automated Operation and Maintenance.** The maintenance mode of business application software is based on Ansible. Ansible's script code is written in a key-value pair manner, and the main content of the code is functional content. Key parameters are replaced with variables. When using the script code, simply assign values to variables to achieve different operation and maintenance effects, and it has ultra-high portability[11]. By writing automated script code for the following operation and maintenance scenarios, a large number of device operations can be quickly completed, greatly improving the efficiency of operation and maintenance.

Batch installation and deployment: Utilizing the monitoring capabilities of Zabbix, and leveraging the Ansible tool to control the batch execution of playbooks on hosts to complete the deployment of Zabbix-server, and to batch deploy the agents on the monitored virtual machines.

Batch information collection: Based on the Ansible tool, information from hardware devices such as servers and network devices can be centrally collected. This information can assist operations and maintenance personnel in understanding the status of the equipment.

## 4 System Architecture Development

To achieve the above goals, the architecture design of the water conservancy information asset intelligent operation and maintenance platform adopts a common layered architecture model, designed as a 3-layer architecture (see Figure 3). The 3-layer architecture from top to bottom is: business application layer, control layer, and infrastructure layer.

(1) Business Application Layer. The business application layer includes: centralized monitoring management, IoT device management, software automated maintenance management, monitoring management, security management risk early warning, op-

eration and maintenance evaluation, each application shares the support library of the control layer, and applications interact and collaborate through Web-Service.

(2) Control Layer. The control layer mainly includes: network management, host management, database management, middleware management, and other various information system infrastructure monitoring and management tools; operation library, personnel library, rule library, resource library, standard library, and other operation and maintenance support libraries provide data support for the upper-layer operation and maintenance management application systems.

(3) Infrastructure Layer. It is oriented towards various cloud resources deployed for water conservancy business applications, mainly based on public clouds.

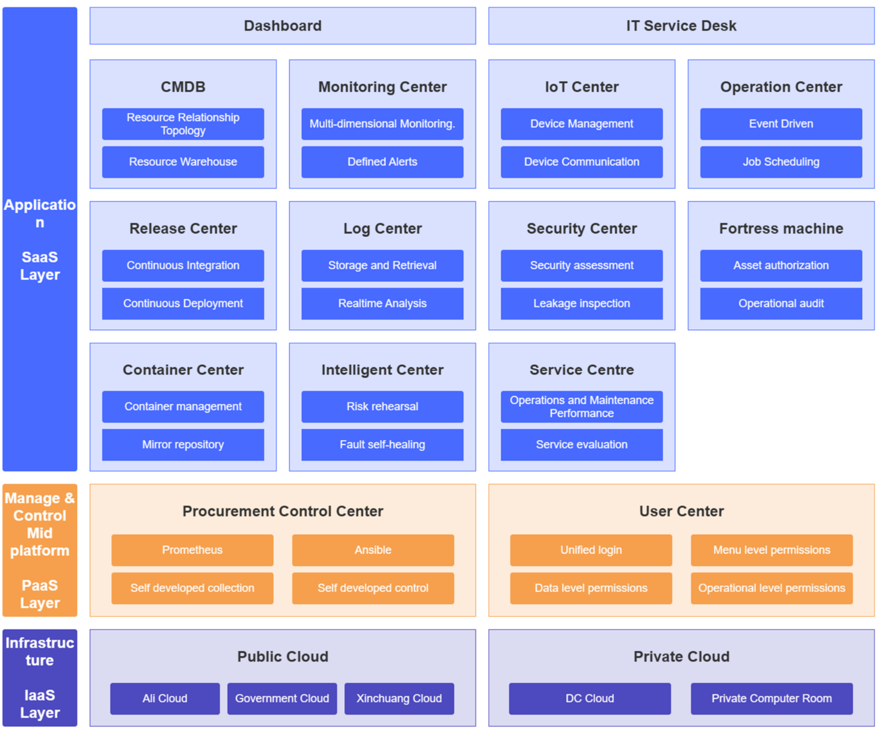


**Fig. 3.** Overall Framework Diagram of Software Application

The platform is developed using JAVA, VUE, build basic support by cloud database resources, and the application is deployed on the cloud platform. The required cloud resources include ECS servers, relational databases, analytical databases, and object databases.

## 5 Main Functional Module Design of the System

The water conservancy information asset operation and maintenance platform is a platform operated by water conservancy information asset managers and technical personnel, and the functional modules include asset center, monitoring center, IoT center, operation center, and other work modules.

(1) CMDB. The CMDB integrates all water conservancy information IoT devices, network facilities, application servers, parsing programs, business applications, databases, middleware, and other types of software and hardware assets, and serves as a maintenance management workstation for basic information of various water conservancy information assets.

(2) Monitoring Center. The monitoring center integrates the data collected by various monitoring tools in the control layer, it can display the operational status of various operational objects, including the status of information system infrastructure and application systems, performs unified data analysis and display, and achieves unified management of network devices, host devices, databases, middleware, and other resources in the water conservancy information system.

(3) IoT Center. The IoT center integrates water conservancy information IoT devices, uses real-time monitoring or predictive data-driven display, mainly including device management, device element management, gateway management, communication management, and data services.

(4) Operation Center. It provides centralized maintenance operation capabilities, realizes batch operation of servers and business applications based on Ansible, such as unified updates, unified information collection, unified start and stop, etc..

(5) Release Center. The water conservancy information asset software code release work platform provides centralized code release workflow control capabilities, version control capabilities, and supports software code level updates and releases.

(6) Log Center. The log center provides log collection, filtering, query and analysis, visualization, alarm, and delivery functions, and can collect and display log messages of water conservancy information assets. The log center has a centralized log management interface and can support fault tracing work.

(7) Procurement Control Center. The procurement control platform for water conservancy information data collection devices and IoT devices.

(8) User Center. The user center primarily manages the operation and support of information systems, integrating people, processes, and maintenance objects in system operation and maintenance work. It supports functions such as role management, configuration management, release management, and operational performance assessment.

## 6 Application of the System

The water conservancy information asset operation and maintenance system has been applied in several counties (cities, districts) in Zhejiang Province. Taking Lin'an District as an example, the water conservancy information asset operation and maintenance system has been in operation for 3 months, accumulating 84 fault alarms and completing 61 operation and maintenance tasks, ensuring the stable operation of IoT collection equipment and information software.

(1) The stability of the IoT data collection system is ensured. Multi-type IoT collection equipment data is stably transmitted and maintains a high rate of parsing, with equipment online rate and data exception rate both reaching the designed indicators. Taking the maintenance work of water level gauges in Lin'an District as an example, after the equipment was connected to the operation and maintenance platform, the equipment online rate increased from 72% to 95%, and the data anomaly rate decreased from 6% to 1%. Moreover, due to faster anomaly alerts and fault location speeds, the average time for equipment status to recover from abnormal to normal was reduced from 14 hours to 6 hours, and the average repair time was shortened to 1 hour（see Table 1）. Due to the small sample size before the platform was operational, the actual improvement could be even greater.

**Table 1.** Comparison of Water Level Meter Equipment Operation and Maintenance Indicators

| Indicator Name | Past | Now | Increase proportion |
|---|---|---|---|
| Equipment online rate | 72% | 95% | 32% |
| Data anomaly rate | 6% | 1% | 18% |
| Anomaly recovery time | 14h | 6h | 57% |
| Average repair time | 2.5h | 1h | 60% |

(2) Improvement in the response time for software fault handling. It can automatically monitor the occurrence time of software faults and the system recovery time. Taking a certain probing test monitoring as an example, as illustrated in Figure 4, it displayed the heartbeat test by probing, fault times and durations could be monitored and identified.


**Fig. 4.** Interface Service Probing Test Heartbeat Monitoring

(3) Enhancement of cloud resource operation and maintenance timeliness. Taking the operation of server shutdown as an example, as illustrated in Table 2, the average improvement ratio reaches 70%, as the number of operational objects increases, the time saved becomes more significant. In the scenario of upgrading server software, the average time spent on the task has also been significantly reduced.

**Table 2.** Server Operation Timeliness Indicator Comparison

| Indicator Name | Past time consumption | Current time consumption | Improvement ratio |
|---|---|---|---|
| Single server | 5 min | 3 min | 40% |
| Two servers | 8 min | 4 min | 50% |
| Five servers | 18 min | 6 min | 66% |
| Nine servers | 40 min | 8 min | 80% |

## 7 Conclusion and Expectations

This work has established a rational O&M system, enhancing the efficiency of maintenance and management of water conservancy information systems. The technical system and work platform built in this work are open, allowing for the expansion of usage scope and the number of systems that can be connected according to needs. It is user-friendly for porting to other regions. However, due to adaptation issues, it is currently limited to the water conservancy industry.

The technology of water conservancy informatization is still being continuously promoted and popularized. The use of this O&M platform can reduce the pressure of O&M work in the future, ensure that water conservancy monitoring data is more accurate and effective, make software work more stable, guide more water conservancy management work to shift to the network. In the future, it is necessary to focus on developing models and technologies for fault analysis and intelligent decision-making, and continuously improve the efficiency of the intelligent operation and maintenance platform. It is also possible to further combine the requirements of the "Technical Outline for the Construction of Digital Twin Basins (Trial)" to increase operational support for digital twin systems, build a more comprehensive operation and maintenance service, and alleviate the pressure of water conservancy information O&M work.

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