Video-Oriented Autonomous Network White Paper

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ZTE CORPORATION

Preface

At present, to accelerate autonomous maintenance and self-optimization of networks, most of the mainstream telecoms operators have developed the core strategies on the systematic construction and evolution of autonomous networks, set the corresponding aspirations, and chosen a clear path to fulfill these aspirations. Based on aspirations and solution architecture, operators have developed or are developing corporate standards suitable for their own growth. They have reached a consensus on the standardization of scenario cases, reference architecture, classification standards, technical specifications, and effectiveness measurement. With these standards, the implementation of autonomous networks has the basis, and data label barriers between different vendors can be removed, laying a foundation for enhancing industrial collaboration and promoting the development of autonomous network ecosystem.

As video is an important application based on operators' basic networks, autonomous networks for the video service platform and content distribution become a topic that requires serious consideration. This white paper explains the research background, status quo of the domestic and foreign markets, solution architecture, application scenarios, and future aspirations. Relying on research into the video application of autonomous networks, the paper shows some innovative thinking about autonomous networks from the video service side and smart operation and maintenance (O&M) service. ZTE is looking to provide reference and guidance in terms of technologies, products and solutions for the video-oriented autonomous network in the industry.

Contents

01 Background

As IPTV services (including internet-based TV services) have developed for over 10 years, telecoms operators now have huge user base. According to China Ministry of Industry and Information Technology (MIIT), by the end of October 2022, the total number of IPTV subscribers of operators in China reached 374 million, and the penetration rate of fixed broadband (583 million subscribers) reached 64.2%. Therefore, operators need to think about how to implement autonomous management of video networks under high concurrency and how to deal with network problems in a timely manner to offer high-quality video experience.

The management of operators' networks is closely related to digital evolution. In 2025, China's digital economy is expected to rise to CNY 65 trillion yuan, and the revenue from information services is expected to rise to CNY 20.4 trillion yuan. Digital economy continues to grow at a high speed and shows trends towards digital industry, industrial digitalization, digital governance, and data monetization. Cutting-edge ICT technologies such as 5G, AI, and cloud/edge computing become more mature and enable convergence and innovation, driving digital transformation of various industries.

While giving operators new opportunities to develop video networks, digital transformation also poses challenges in terms of operation reliability, O&M efficiency, and maintenance cost.

- **Video quality:** New services require diversity in networks. It imposes strict requirements for the connectivity, bandwidth, latency, and reliability of private networks. The ToC (To Customer) video services require smooth viewing experience. For example, if live channels cannot meet the requirements, automatic active/standby platform switchover by channel is implemented.
- **O&M efficiency:** As network technologies evolve, telecoms networks become increasingly complicated. To increase O&M efficiency, it is required to introduce new technologies and methods to implement automated and intelligent O&M.
- **Operation cost:** There are many automation breakpoints in the O&M process of telecoms operators. The connection of these breakpoints

requires human intervention. The existing devices and devices for capacity expansion increase the expense of hardware maintenance and insurance, and the O&M cost is typically incremental year-over-year.

In recent years, to respond to these challenges, international standards organizations, mainstream operators, and equipment vendors have developed concepts like autonomous evolving network, Intent-Based Networking (IBN), and autonomous network. After considerable discussion, autonomous networks have been recognized as an important development direction in the telecom industry. Supporting self-configuration, self-healing, and self-optimizing, autonomous networks can offer end users services with zero wait, zero touch and zero trouble. For operators, such networks become a new evolution trend for video services. [1]

02 Current Development Status

At present, with research and development of autonomous networks popular in the industry, many international standards organizations have updated the relevant technical specifications. The three major operators in China, China Mobile, China Telecom, and China Unicom, and companies like ZTE and Huawei are actively engaged in the drafting and technical promotion of autonomous networks.

2.1 International Standards

The international and domestic standards for autonomous networks are developing. Considering the industrial needs from TM Forum and International Telecommunication Union (ITU), major standards organizations such as 3GPP work actively to promote the development of international autonomous network specifications and accelerate the implementation of CCSA standards in China.

The Autonomous Networks Project (ANP) of TM Forum was established in May 2019, with the aim of defining fully automated zero wait, zero touch, zero trouble innovative network/ICT services for vertical industries' users and consumers. Meanwhile, TM Forum has also arranged the development of standards across multiple standards organizations, with the goal to reach a consensus on the autonomous network concepts, frameworks and key ideas and to promote cross-organization collaboration. At present, TM Forum has released multiple

autonomous network standards, involving architecture, evolution levels, intent-driven operations, and closed-loop control. [2]

In December 2020, ITU Focus Group on Autonomous Networks (FG-AN) was established to support standardization activities of autonomous networks. The released Y.317X-series include standards in requirements, architecture and hierarchy of intelligent networks like autonomous networks. The specific intent, perception and sandbox standards are still under research. As the chairman of the FG-ML5G and FG-AN network architecture team, ZTE is in charge of five standards in ITU-T SG13 and one standard in ITU-T SG2.

In Release 16 (R16), 3GPP started to define standards and specifications related to autonomous networks. Its SA5 working group involves the most autonomous network specifications, including autonomous network classification, closed-loop control, intent-driven network management, and management data analysis.

The autonomous network standardization of China Communications Standards Association (CCSA) is carried out by several technical committees, especially the network management and operation support committee (TC7). The core content of autonomous networks is intelligent operation management, so its standardization is of great significance to the construction and development of autonomous networks. Since the 33rd meeting of CCSA TC7 in July 2021, 25 projects on autonomous network standards and research have been initiated. ZTE takes the lead in several topics, such as functional architecture, technical architecture, system architecture, and level evaluation.[3]

2.2 Practices in the Industry

The three major operators in China aggressively drive the evolution and implementation of standards, effectively promoting the growth in the autonomous network industry.

China Mobile is the first operator in the industry to set the goal of achieving level 4 (L4) autonomous network by 2025. To reach this goal, the operator takes 4 steps, including developing industry standards, top-down design, digital capability building and application, capability evaluation and analysis. Combined with the practice of building complex networks, China Mobile suggests an innovative autonomous network architecture targeting customer

development and leading quality to implement management of resources, services and customers, with network elements (NEs), networks, services and business involved. Based on this, it defines the autonomous capability level models, sorts out sub-scenarios related to models, defines the detailed standard levels from L1 to L5, and arranges one or two times of network-wide capability rating comparison every year to identify weaknesses and improve capabilities. To overcome these weaknesses, China Mobile has planned the new-generation “25N” network management system to guide its provincial companies in comprehensive capability building. In addition, it has developed the Jiutian AI platform to construct four AI capabilities, including intelligent perception, diagnosis, prediction and control. It provides provincial sub-nets with general AI computing and algorithm models based on the AI platform. By aggregating AI capabilities and applications from many provinces, mature applications and capabilities can be duplicated and promoted rapidly on a large scale, improving the overall AI capabilities.

China Telecom has taken the autonomous network construction as a key part of its “cloudification & digital transformation” strategy, and has set the goal of achieving L4 autonomous network capabilities by the end of China’s 14th Five-Year Plan. Its own new-generation cloud-network operation system implements the whole-process autonomous network capabilities, including customers/partners, products, services, and cloud-network. It has also conducted deep exploration of agile service launch, intelligent management of network lifecycle, and autonomous O&M. China Telecom will work on the evaluation of autonomous network levels, autonomous capabilities for cloud-network operation, and industrial ecosystem partnership to improve the autonomous network capabilities.

China Unicom has also set the goal of achieving L3 autonomous network in 2023 and L4 in 2025. In 2021, it developed the concept of “zero wait, zero trouble, zero touch and zero risk”, as well as “self-planning, self-configuration, self-healing, and self-optimizing”. China Unicom adopts the three-layer target architecture, including application layer, platform layer, and network layer. With this methodology, the operator and equipment vendor can benefit from each other and build a sustainable ecosystem to fuel the growth of autonomous networks.[3]

2.3 Autonomous Network Video Application

At present, the research on the video application of autonomous networks, such as OTT and IPTV, has just begun in the industry. However, there have been many similar researches on the automated and intelligent O&M of video networks.

Major equipment and service providers also actively engage in the intelligent O&M of video networks. ZTE's solutions like Big Video system monitoring and smart scheduling have already been widely adopted by operators, helping operators address problems such as uneven distribution of video resources and network fluctuations. For TV services, ZTE helps operators guarantee the smooth running of video network systems to reduce costs and increase efficiency. In addition to the video service platform and Content Delivery Network (CDN), video networks also involve content sources, core networks, transport networks, wireless networks, fixed networks, and terminals, covering a wide range. ZTE has been committed to optimizing end-to-end video networks to achieve an autonomous system covering the full range. With this concept, ZTE has developed an innovation in the video-oriented autonomous network architecture. Based on a unified O&M platform, ZTE has introduced automation and intelligence in the service configuration domain, real-time monitoring domain, troubleshooting domain and disaster recovery domain to improve the O&M efficiency in a centralized manner, implement automated monitoring and troubleshooting, enable intelligent O&M early warning and repair, and improve home broadband quality and system robustness. This innovation drives the evolution of video network O&M towards self-discovery, self-healing and self-optimization.

Operators have also engaged in the standardization of video-oriented autonomous networks. China Mobile has enriched the specifications and requirements of video applications in its released autonomous network standards. Meanwhile, it has given provinces guidelines about video O&M to improve the routine maintenance efficiency for systems and services and drive the evolution towards autonomous network. For its new-generation "2-5-N" network management (NM) system planning, China Mobile has released specifications for the CDN workbench, with the aim of improving automation and intelligence of TV service O&M. This move will help build autonomous

networks for TV services, standardize O&M interaction between the headquarters and provinces, and achieve better O&M. It also increases the importance of video applications in the autonomous network planning.

03 Aspirations

With the intent to gradually achieve autonomous O&M of big video services, the video-oriented autonomous network adopts data-driven self-learning and self-evolution to achieve autonomous O&M of the existing network and help operators simplify service deployment, reduce manpower, and improve efficiency.

To fulfill these aspirations, ZTE has been working on services, openness and values. First, instead of NEs, ZTE takes services as the center to promote resource scheduling and improve network O&M efficiency. Second, ZTE supports sharing of data and capabilities and openness to assistance mode, focusing on the co-existence with operators. Third, video-oriented autonomous network is the embodiment of the digital transformation of operators' video O&M. The sequence of system transformation should be decided based on customers' requirements. The upgrade of product system architecture, operators' network reconstructions, and skill improvement of the O&M staff should all consider what matters most to customers.

Considering the status quo of video networks in the industry and its own development pace, ZTE designed a progressive strategy to fulfill aspirations by providing some granularity on scenario functions. First, in 2022, ZTE drove the automated upgrade of autonomous networks from L2 to L3, achieving unified management of the complex O&M tools and automation of routine maintenance. In 2023, ZTE is expected to enable its intelligent improvement from L3 to L4, implementing early prediction of poor video quality, intelligent decision-making when poor video quality occurs, and self-healing of the video system. In 2024 and beyond, ZTE is expected to achieve L4 and then a higher level, realizing topological twins of video networks, as well as continuous iteration and optimization of intelligent model algorithms for more scenarios. The O&M staff are expected to be able to coordinate global resources with only a simple interaction page, and problems can be solved quickly in the early stage.

04 Target Architecture

4.1 Features

With the aim of reducing costs, increasing efficiency, and supporting services, the video-oriented autonomous network has the following features:

- **Flexible load balancing:** Usually, CDN resources are allocated to users nearby based IP addresses. In case of spikes in traffic or unstable user behaviors, significant increase in load of some devices may lead to service quality deterioration. However, with ZTE's video-oriented autonomous network, the load of CDN nodes and devices can be predicted through AI analysis. Therefore, some spikes in load may be predicted and load balancing can be performed in advance. And even when spikes in load occurs, load balancing can be performed immediately to avoid quality deterioration and guarantee service quality for users.
- **Precise content operation:** Usually, when channel service is abnormal, the solution is to switch to the standby live broadcast service center to ensure rapid service recovery and deal with the content problem of the active center later. However, ZTE's video-oriented autonomous network can monitor the active/standby live source channels in real time. When a channel of the active live source is abnormal, it automatically switches the source channel, which greatly increases the switching efficiency. In this way, viewers can always enjoy high-quality content, and different content providers can improve their content quality.
- **End-to-end cross-domain collaboration:** Video service is associated with the end-to-end home broadband quality. The analysis of video quality problems based on only CDN has its limitations. Because content sources, service platform, home gateway, and terminal probe may also affect video quality. Therefore, ZTE's video-oriented autonomous network is committed to build an end-to-end problem locating system from content source to terminal to precisely locate video quality problems.

4.2 Solution Architecture

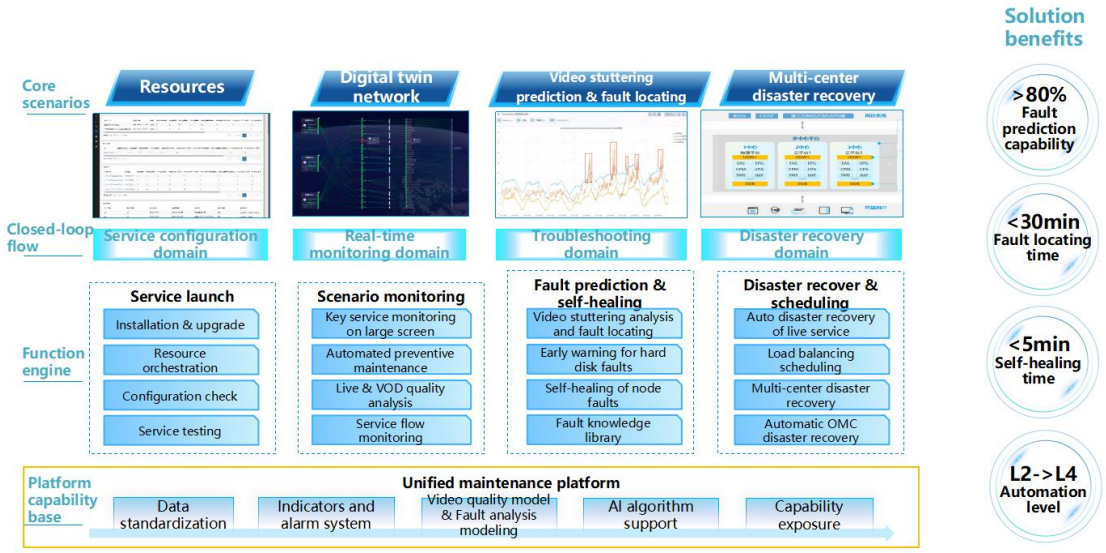
ZTE has developed the video-oriented autonomous network solution based on

its understanding of autonomous networks and product practices. With a unified O&M platform, ZTE enables centralized, automated and intelligent O&M in four domains, including the service configuration domain, real-time monitoring domain, troubleshooting domain, and disaster recovery domain, driving the evolution of video system O&M towards self-healing, self-repair and self-optimization.

The unified video O&M platform is the foundation of the video-oriented autonomous network. The improvement in autonomous capabilities of video O&M requires a set of standard data indicator systems, including standard data collection system, indicators and alarm system, quality deterioration and fault graphs, and AI recognition and attribution algorithms. Based on this, various data from NEs, devices and vendors can be aggregated for better understanding of the performance, resources and faults, improving the unified analysis and decision-making capability.

The entire video-oriented autonomous network is divided into four domains based on O&M process. The service configuration domain involves service provisioning, including the installation and upgrade of NE software, resource orchestration, configuration check, and service testing, meeting the needs for automated execution at the service configuration side. The real-time monitoring domain enables customized monitoring for different scenarios. Preventive maintenance (PM) tasks can be pre-configured and then automatically delivered accordingly. The live and VOD quality can be analyzed by scenario based on logs. And the NEs involved in the service process can be tracked and monitored. For the troubleshooting domain, faults can be predicted in advance or be fixed by self-healing, which includes identifying the cause of video stuttering and decision-making, early warning for hard disk faults, self-healing of node faults, and fault knowledge library. For the disaster recovery domain, it supports automatic disaster recovery of live broadcast service. Live broadcast service can be guaranteed in case of faults, with users unaware of any changes occurring. With load balancing, CDN device faults can be greatly reduced. With multi-center service platform, disaster recovery capabilities of the existing network can be greatly improved to make sure TV services perform well. Meanwhile, the Operation and Maintenance Center (OMC) requires the automatic disaster recovery capability to make sure its O&M perform well.

Figure 1 ZTE Video-Oriented Autonomous Network Architecture



05 Application Scenarios

5.1 Unified O&M Standards

ZTE's video-oriented autonomous network enables unified O&M management of scattered O&M portals, platforms and tools. This requires unified data standards, ranging from data collection, preventive maintenance and monitoring, quality deterioration alarms, to troubleshooting experience library. This set of unified standards is of great significance for the O&M process. For the video-oriented autonomous network, ZTE has widely promoted and applied the big video O&M standards in the industry, including the video indicator standards and quality deterioration evaluation standards.

5.1.1 Unified Video Indicator System

A separate video indicator system needs to be established for the NEs and devices involved in the video system, including hardware indicators, RR scheduling indicators, and CDN service indicators. With comprehensive monitoring, O&M staff can effectively detect problems of the video system.

Table 1 Hardware Indicators

Indicator	Dimension
Average idle usage of CPU	Device
Memory usage %	Device
Free space % of system disk, space usage% of media disk	Device
Hard disk I/O utilization%	Device
Outgoing and incoming I/O of network interface card (NIC), outgoing and incoming I/O of device	Device
Soft interruption	Device
Number of TCP links	Device
NIC packet loss%	Device
Disk IOPS	Device
Hardware temperature	Device

Table 2 RR Scheduling Indicators

Indicator	Dimension
Scheduling success rate	Scheduling nodes, devices
Number of requests	Scheduling nodes, devices
Number of successful redirections	Scheduling nodes, devices
Scheduling time (ms)	Scheduling nodes, devices
Max. capability value	Scheduling nodes, devices

Table 3 CDN Service Indicators

Indicator	Dimension
Average latency of first packet for back-to-origin requests	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Average latency of first packet for service	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Back-to-origin traffic	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Service traffic	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Back-to-origin HTTP response code	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices

Request hit rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Byte hit rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Back-to-origin download rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Service download rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Back-to-origin bandwidth	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Service bandwidth	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Service success rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Back-to-origin success rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Load rate	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices
Number of concurrent users	Service types (VOD, Live TV, TSTV, Catch-up TV, etc.), nodes, devices

5.1.2 Unified Quality Evaluation System

To meet operators' higher SLA requirements, ZTE has established a set of evaluation indicator system to quickly detect, solve and avoid problems. With the CDN-Quality of Experience (C-QoE) to evaluate CDN service quality and performance, including effectiveness and availability, CDN service can be greatly optimized.

In 2018, ZTE established and standardized the KPI and KQI system for CDN, dividing the CDN-related KQIs that affect the video service into five categories. For different services such as OTT and CACHE, the corresponding KQIs can be selected for evaluation, as shown in Table 4. Built on the CDN indicator system and based on AI big data analysis and experience library, C-QoE converts KQIs into a rating system associated with user perception. The fixed values confirmed by O&M experts are used as static benchmark values to replace the original ones obtained through statistics. In this way, the interpretability and predictability of the solution can be enhanced. The more the

actual values deviate from the benchmark values, the lower the C-QoE value and the poorer the service quality, as shown in Table 5.

Table 4 CDN Service KQI

5 Categories	Corresponding KPI
Request interaction	Service 5xx%, service 4xx%, service download rate, first packet latency of service, service success rate, etc.
Back-to-origin interaction	Back-to-origin 5xx%, back-to-origin 4xx%, back-to-origin download rate, first packet latency of back-to-origin requests, back-to-origin success rate, etc.
Capacity	Bandwidth utilization, storage utilization, etc.
Cache	Hit rate, gain rate, etc.
Hardware resource utilization	CPU occupancy, disk read/write, NIC load, hard disk storage, etc.

Table 5 Fixed Benchmark Values of Expert Experience Library

Indicator	Benchmark (Calculated based on history data)	Value that indicates fault (Expert experience)
First packet latency	120ms	200ms
500/503	0.05%	0.1%
CPU	60%	90%
Bandwidth	60%	90%
Disk read/write time	50ms	200ms

5.2 Centralized O&M

The IPTV/OTT O&M involves many NEs, and each NE has its own O&M tools. The basic NE resource management, configuration management, upgrade and installation may involve many maintenance tools based on the use of the client, which increases the learning and use costs of O&M staff.

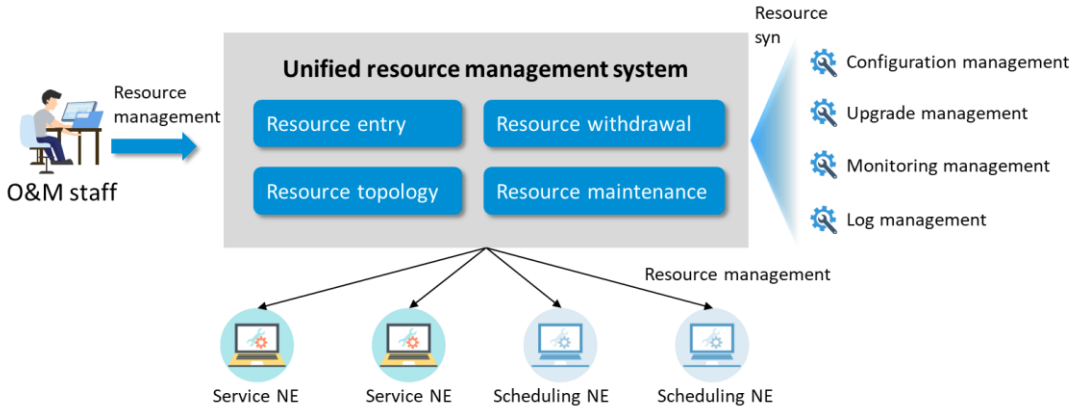
However, the unified O&M of the existing network can improve the O&M efficiency and better support the evolution of in-depth functions.

5.2.1 Unified Resource Management

The unified resource management system enables rapid and centralized management of all the service platform and CDN resources. It supports centralized resource management (online and offline) and planning (service, storage capability planning and configuration) of all the related NEs. It also supports resource discovery and update.

With the unified resource management system, once resources are imported, they can be used at several places, ensuring consistent resource data.

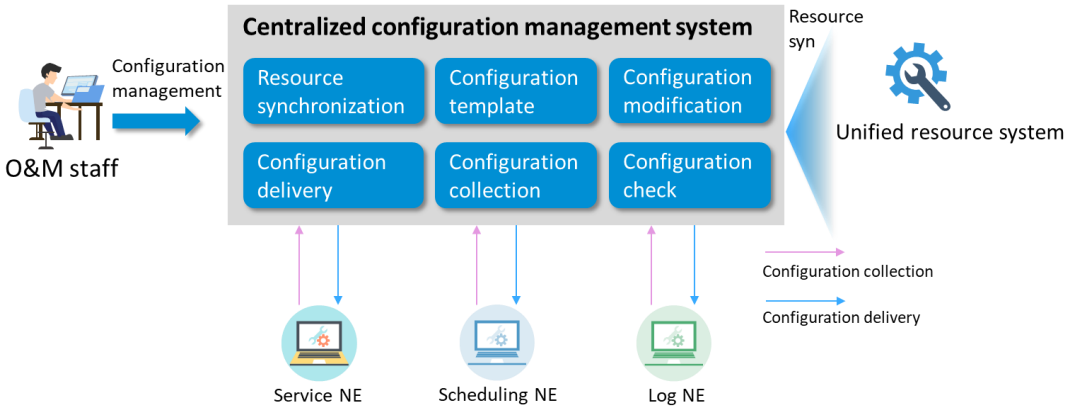
Figure 2 Resource Management System Based on Unified O&M Platform



5.2.2 Unified Configuration Management

Centralized configuration management system enables standardized and centralized configuration management of all the service platform/CDN NEs. The O&M staff can maintain configuration items on the visual WEB page, realizing standardized, visual and centralized configuration management. The detailed functions include configuration template import, modification to configuration items, configuration delivery, configuration collection, and configuration check.

Figure 3 Configuration Management System Based on Unified O&M Platform



5.2.3 Unified Monitoring

Service assurance for holidays and major events has always been the top priority, which is also a key focus for operators. The O&M staff can configure the corresponding monitoring templates in advance. During holidays, these monitoring templates can automatically go live for service assurance. The service and hardware indicators of key service NEs, such as concurrency, latency, load, and success rate, can be visually displayed on one screen. With data visualization techniques like map, trend chart, histogram and heat map, the demonstration can be more vivid. The Prometheus and Granfana template editing functions enable flexible and rapid customization of the large screen for different offices.

Key service monitoring on large screen: For key service NEs like RR, live TV center, VOD center, CP and EAS, their service and hardware indicators, such as concurrency, latency, load, and success rate, can be visually displayed on one screen. Data visualization techniques like map, trend chart, histogram and heat map are supported.

Hardware monitoring: Supports hardware such as NICs, disks, temperature, power supplies, fans, and file systems.

Log monitoring: Collects and analyzes service logs of the device system in a centralized manner. Monitors and analyzes errors in hardware, user service flow, and user and content access.

Figure 4 Monitoring System Based on Unified O&M Platform

5.3 O&M Automation

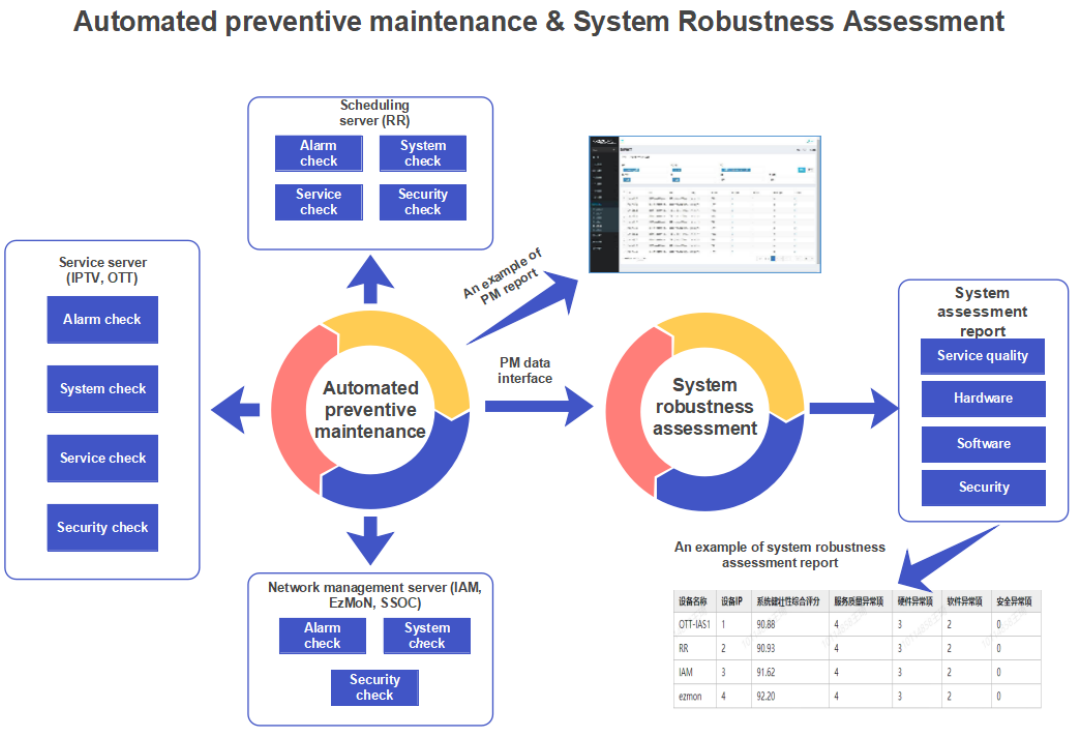
5.3.1 Automated Preventive Maintenance

Automated preventive maintenance is an important supplement to routine monitoring and alarms. It can detect potential system problems and handle them in advance to avoid possible problems. According to the four quadrants of the Time Management Matrix, it is not urgent but important for the system.

Based on the automated preventive maintenance data, indicators and alarms, system robustness assessment enables comprehensive modeling of service quality, hardware, software and security to identify hidden troubles of devices. It defines the system with four categories: healthy, low risk, medium risk, and high risk. With its guidance, the front-line O&M staff can handle problems in

advance.

Figure 5 Preventive Maintenance System Based on Unified O&M Platform



5.3.2 Automated Testing

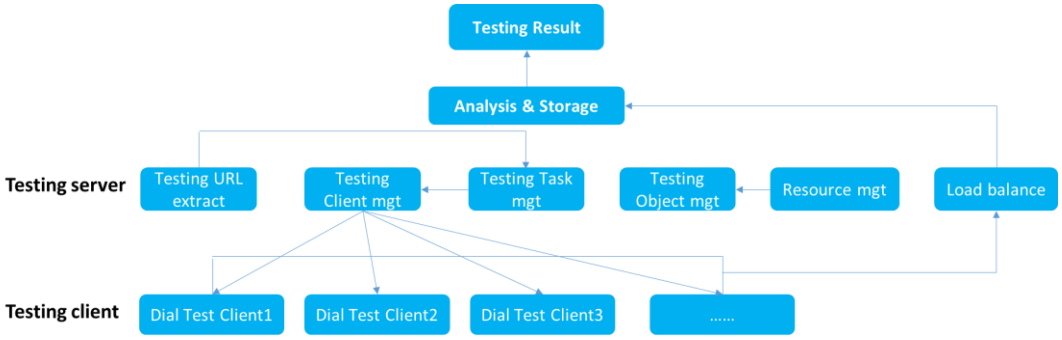
Automated testing verifies service functions of the system to ensure functions of all the NEs on the existing network are consistent with that in the testing environment. It can be used to verify upgrade effects, newly launched functions, and functions of each platform under gray release conditions.

- The centralized testing function is integrated into the unified O&M management platform for unified operations. Installation of extra software is not required, and function expansion is easier.
- In addition to the testing results, it also shows the testing flow in a graphical way. The execution data, for example, the time spent on each operation, can help detect and locate problems.
- Besides the built-in core flow to guarantee easy and fast operations, it also provides the customized function for testing flow, capable of testing

customized functions.

- Different from third-party testing systems based on the network layer, the centralized testing does not require installation of hardware on the switch and does not need to add complicated computing resources. By focusing on function testing in scenarios, it can detect service flow problems more accurately.

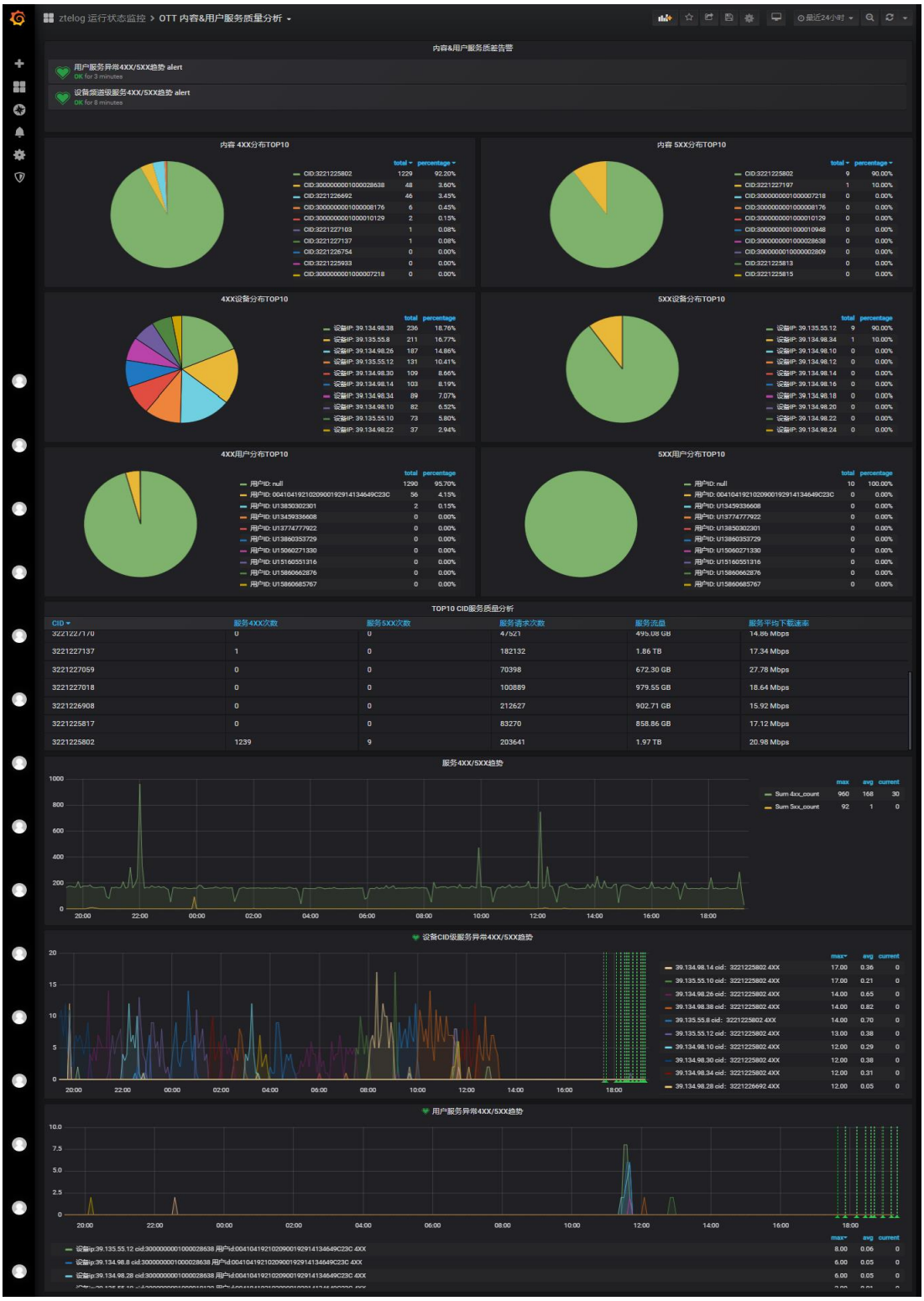
Figure 6 Testing System Based on Unified O&M Platform



5.3.3 Automated Fault Analysis

Automated fault analysis strategies have been developed for various fault scenarios during video O&M, for example, live channel content/user service quality, top service quality, and fragment recording service quality. For live channel service quality, the system counts the total number of error responses such as 4xx and 5xx for index and fragments to guide O&M staff to analyze quality of the specific channel content. If there are too many error responses, O&M staff can check the corresponding content. With top channel errors updated dynamically in real time, O&M staff can control the channel service quality in a timely manner to improve maintenance efficiency and reduce user complaints. The system tracks service scheduling to learn the service status of the target nodes. If the number of service scheduling times is too high, O&M staff are reminded to check device status of the corresponding target node. For nodes with multiple devices, top error response codes can help O&M staff locate the specific device.

Figure 7　Fault Analysis System Based on Unified O&M Platform



5.4 Intelligent O&M

5.4.1 Video Fault Prevention/Fault Analysis

An autonomous network requires the construction of an automated O&M system corresponding to its level. To reach this goal, the following four needs must be fulfilled: detection, diagnosis, prediction, and optimization.

First, ZTE has built a multi-NE and multi-indicator monitoring system that takes fault prediction algorithms as the core. The system addresses the bottleneck of manual monitoring of numerous device indicators and enables the following functions: learning of historical data, automatic modeling, value prediction, setup of upper and lower bounds (normal range), and alarms for abnormal values. In this way, the system is able to monitor massive indicators and raise alarms in real time during the O&M process, moving away from depending on experience. In addition to alarms for abnormal values, the system also supports fault preprocessing, enabling automatic recovery process even before faults occur. Meanwhile, based on the above-mentioned algorithms, it also enables delimitation of normal and abnormal values and alarm functions, quantifying the evaluation of the CDN system robustness.

Second, ZTE has built a fault locating and delimitation system with decision tree algorithm as the core. When faults occur, instead of depending on manual analysis, the system can rapidly analyze indicators to find abnormal ones, locate faults and implement fault delimitation. Thanks to rapid fault locating, delimitation and analysis, it is able to correct single fault or a group of faults immediately to prevent them from spreading and causing large-scale impact. In addition, the system also enables self-repair of some faults and fault tree topology view.

The above two systems work together, enabling better troubleshooting. By analyzing the historical data for modeling, the fault prediction system predicts potential faults and prevents it from occurring. By learning historical fault data and abnormal data of the related indicators, the fault decision tree system enables quick fault locating and delimitation, so that faults can be fixed rapidly.

Figure 8 Fault Prediction Algorithm - Single Indicator Prediction

5.4.2 Device/Content Self-Healing

5.4.2.1 Live Source Disaster Recovery

For operators' disaster recovery of live sources, ZTE's video-oriented autonomous network can implement intelligent active/standby switching of distribution network for multicast-based live broadcast by channel. It monitors and analyzes content and channels of the active/standby live sources in real time. On the one hand, when a channel is abnormal, the system automatically switches to the standby live source to provide service. Such switching by channel can avoid the waste of resources caused by platform switching due to certain abnormal channels. It can also serve users with better channel resources to improve user satisfaction. On the other hand, relying on historical data and prediction algorithms, the system can predict channel quality deterioration, raise alarms in advance, and support intelligent switching, guaranteeing proper live broadcast services.

5.4.2.2 Multi-Center Disaster Recovery

ZTE has proposed a multi-center disaster recovery solution for the video

platform O&M security of its video-oriented autonomous network, rather than the traditional active/standby mechanism. Each center is an independent platform, capable of providing complete services. In this way, the video-oriented autonomous network is able to predict the platform status and raise alarms by using the video quality model algorithm. When a center is faulty, users can be automatically scheduled to other centers, without human intervention. The switching can be completed within minutes, with users unaware of any changes occurring. Data synchronization is implemented in DDB mode. Changes in data of one center are synchronized to other centers in real time to ensure the synchronization efficiency of multi-active centers.

5.4.2.3 Device Fault Self-Healing

For the repair of device faults, the video-oriented autonomous network solution adopts the C-QoE system for automatic isolation and recovery. This system is updated constantly based on AI learning and makes scientific assessment of devices. When the score is lower than the threshold, the device is automatically isolated, and quality assessments are given continuously during the recovery. When the actual value is higher than the threshold, progressive recovery of the device is implemented. This solution can be used together with fault analysis and locating. When a faulty node is detected, the system uses C-QoE to check the health of each device in this node, automatically isolates the faulty device for repair, implements O&M self-healing, and ensures the device self-healing takes less than 5 minutes.

06 Future Outlook

The autonomous network is definitely an evolutionary trend and its development does not just take place overnight. The video-oriented autonomous network is one of its branch and is closely related to automation in other professional networks. For the future development of the video-oriented autonomous network, the following needs to be advanced.

1. Implement unified specifications, define a top-down design, interface

standards and viable rating system, and promote collaboration between vendors.

2. Continuously enhance underlying capabilities, and upgrade data, computing, infrastructure, business models, ecosystem, and experience.

3. Integrate knowledge and AI to better meet the application requirements of video-oriented autonomous network. For telecoms networks, there have been a wealth of communication theories and experience. The current focus is to digitalize the existing experience and integrate it with AI algorithms to promote the intelligent network development. Moving forward, evolving together with computing network and cloud network, the autonomous network will be able to schedule computing network resources more flexibly and achieve continuous network optimization.

ZTE is looking to work closely with operators to keep improving its methodology for building the video-oriented autonomous network. Meanwhile, ZTE will gradually launch related pilot, expand application scenarios and scale to explore new algorithms and applications. ZTE plans to realize full autonomy of video network in a single domain, and then enable all domains with its autonomous capabilities. In addition, by promoting use of algorithms as required, ZTE will help operators rapidly improve their autonomous capabilities. Together with operators, ZTE is looking to play to its strengths to build an improved centralized maintenance system. [3]

According to ZTE, the video-oriented autonomous network has not only enabled the digital transformation of video O&M for operators, but also driven the transformation of cooperation models. With a large number of intelligent and automated applications introduced, video O&M efficiency can be significantly increased. In the future, operators will gradually reduce investment in the traditional O&M that depends heavily on people and increase investment in knowledge. As the whole society is embracing knowledge economy, payment models based on knowledge and capabilities will also be accepted in the communications industry, slowly changing from paying for labor to paying for scenarios, algorithms and rules. In a knowledge economy, operators and partners will create new opportunities to light up the future video-oriented communications industry and enable intelligence to benefit everyone.

Appendix

Acronyms

Acronym	Full Name
AI	Artificial Intelligence
ICT	Information and communications technology
CHBN	Customer、Home、Business、New
CDN	Content Delivery Network
OTT	Over The TOP
OMC	Operation and Maintenance Center

References

[1] *ZTE Autonomous Evolving Network White Paper*

[2] *Autonomous_Networks_Empowering_Digital_Transformation_Chinese_Version_ v3.0.0*

[3] *ZTE Autonomous Network White Paper*

[4] *China Mobile Autonomous Driving Network White Paper*