TM Forum Introductory Guide

Autonomous Networks Realization Studies

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Executive Summary

Realizing Autonomous Network is equivalent to constructing a brand new social-technical system inside CSP (Communication Service Provider) that can deliver the Autonomous Networks' zero-x experience and self-x capabilities vision. This document provides the common approach and reference solutions from leading CSPs, to serve the purpose of helping CSPs develop their strategies and priorities during the realization of Autonomous Network.

1. Introduction

The Telecom industry has been precise on the vision and the business and operation drivers for Autonomous Networks. The market demands it, the CSPs need it, and previously insurmountable technology difficulties now have feasible solutions thanks to AI/ML. Now is the time to focus on how to realize Autonomous Networks.

Autonomous Networks is not just about enabling technologies nor a short-term project. Realizing Autonomous Networks is equivalent to constructing a brand new social-technical system inside CPS that can deliver the Autonomous Networks' zero-x experience and self-x capabilities vision. The new system will redefine all aspects of CSP function to become more agile, efficient, scalable, human-friendly, partner-friendly, and user-friendly. Strategic planning and tactics are essential to ensure success by balancing multiple key factors: short-term and long-term ROI, human and machine coordination, swift progressing and safety, the organizational transformation from Telco to TechCo while maintaining current daily operations.

Many CSPs have already started the Autonomous Network journey. While each CSP has its priorities and strategies, there are common patterns that we can identify through the lens of the Autonomous Network framework. This document specifies common challenges and general approach to realizing Autonomous Networks and describes reference solutions that various CSPs are engaging.

This document (version 2.0) is based on the previous version (version 1.0) and combines with the latest progress in AN implementation practice by industry partners, especially CSPs. This document demonstrated the implementation of the "four key elements of autonomous networks (vision and target architecture, grading standards, performance indicators, operation Practice)" as the core methodology. Gave the best practices of leading CSPs such as China Mobile in "promoting self-intelligence networks on a large scale, hierarchical evaluation and self-intelligence ability improvement, and construction and evaluation of effectiveness indicators" to promote self-intelligence. The theoretical framework of network implementation methods is becoming mature, providing method guidance and practical reference for more CSPs to carry out AN planning and deployment, and helping CSPs to formulate their strategies and priorities during the realization of ANs.

This document summarizes 39 commercial solutions in 4 categories: Enable Verticals, Customer Experience, Business Growth, Efficient O&M, and Green Energy. Covering 5G to B, cloud network integration, enterprise private network/private line, high-quality home broadband, DC/ All high-value business scenarios such as network energy conservation, covering all network majors such as transmission, IP, mobility, and access, not only show the enthusiasm of the industry to develop self-smart networks, but also provide the most direct reference case for CSP to carry out application innovation.

2. Challenges of Large-scale Realization

As an increasing number of CSPs plan and deploy ANs, challenges are surfacing. TM Forum's Autonomous Networks White Paper 3.0 identified six main challenges and offered ideas to address them. But new problems keep emerging, so the six challenges have been expanded in 2022 as follows:

1. **How to measure the business value and O&M effectiveness of ANs?**
   Can L3 or L4 ANs help CSPs provide new services and expand the digital markets in various industries? How can L3 or L4 improve service quality and experience? What benefits can L3 or L4 offer to improve network resource usage, lower O&M costs and improve O&M efficiency? These key problems need to be considered when carriers formulate AN strategies and evolution paths.
2. **How to implement a level-based autonomous closed loop and finally enable agile services and business closed loops?**
   The implementation of ANs requires cross-layer collaboration between networks and operations systems, and cross-domain streamlining of core, bearer, transport and wireless domains. How can CSPs develop autonomous capabilities from bottom to top and implement a level-based autonomous closed loop? How can they quickly integrate underlying capabilities to enable agile services? How can they facilitate AN construction based on business value in a top-down manner to achieve a business closed loop? These problems are yet to be resolved by CSPs.
3. **How to develop the L4 target profile for each network domain and set the evolution path?**
   What is the L4 target profile of each network domain? What new digital services, business models and service capabilities can be provided? What are the technical features? What is the target architecture? What specific technical capabilities need to be developed? What new operations changes will emerge? What are the evolution paths and how to select them? These are the questions to be answered by CXOs of CSPs and all industry partners.
4. **How to deploy full-stack AI and leverage the collaboration between cloud-based centralized AI and network-based distributed AI?**
   Introducing AI to communications networks in order to upgrade highly complex networks to ultra-intelligent systems has become the industry consensus. However, what is the target architecture for ultra-intelligent systems? Is it a centralized ultra-intelligent brain that commands the entire network? Or is it an efficient and collaborative distributed cerebellum? How will CSPs deploy full-stack AI in a coordinated manner? How can they leverage the collaboration between cloud AI and distributed AI? The entire industry needs to jointly explore these questions and find win-win answers.
5. **How to enable industry partners to collaborate and innovate, build a healthy ecosystem, and upgrade and evolve at the same time?**
   The implementation of ANs involves theoretical research and technological breakthroughs in multiple sectors including communications, IT, AI and automation. Many concepts and technologies are still being defined and verified. How can the positioning and collaboration of all parties be standardized? How will the sectors strike a balance between return on investment and developing cutting-edge technologies? How to design a schedule for upgrades and evolution is a challenge that must be overcome.
6. **How to establish process mechanisms and develop skills for ANs?**
   Tremendous efforts have been made to use machines to equip employees with O&M capabilities and transform the troubleshooting mode from ticket forwarding, which is a long process, to device self-healing or one-hop closed-loop processing. How will CSPs upgrade employees' skills to implement automatic and intelligent

O&M? How will they inject O&M knowledge, train, and supervise machines in a low-code manner? Answering these questions is key to the successful implementation of ANs.

7. **How to establish unified evaluation standards?**
   Many CSPs and suppliers have been working on the objectives of L3 and L4 autonomous capabilities. However, due to different methods of evaluation, multiple evaluation scopes and varying degrees of understanding, it is difficult to compare and evaluate the ANL of industry players. Therefore, it becomes necessary to jointly define unified evaluation standards.
8. **How to perform systematic planning and deployment?**
   It is challenging for CSPs to perform ANL evaluation on all products, services and domains. Plus they must correlate standards at the domain level and promote cloud network operations autonomy for the entire network based on the unified goal, planning and strategies.
9. **How to evolve capabilities efficiently?**
   It is difficult to build the mapping between ANL evaluation results and effectiveness evaluation results based on business and service objectives. It is also challenging to effectively identify weaknesses of autonomous capabilities, coordinate the autonomous capabilities of the system with those of network+cloud, and adopt agile iteration to evolve to the higher levels of Ans

3. Method and Practices for AN Realization

3.1. Method: Four Key Elements to AN Implementation

Implementing Autonomous Networks requires an all-around, systematic and continuous network transformation. TM Forum has aggregated industry best practices and summarized four elements key to AN implementation: Creating a vision and target architecture Adopting the AN levels Using effectiveness indicators to measure the business value and service effectiveness of ANs Establishing operations practices to develop automated and intelligent capabilities for networks and support systems efficiency. These elements are expected to help more CSPs plan and implement AN in a faster and more systematic manner. Figure 1 illustrates how the four elements fit together, and a more detailed explanation follows.

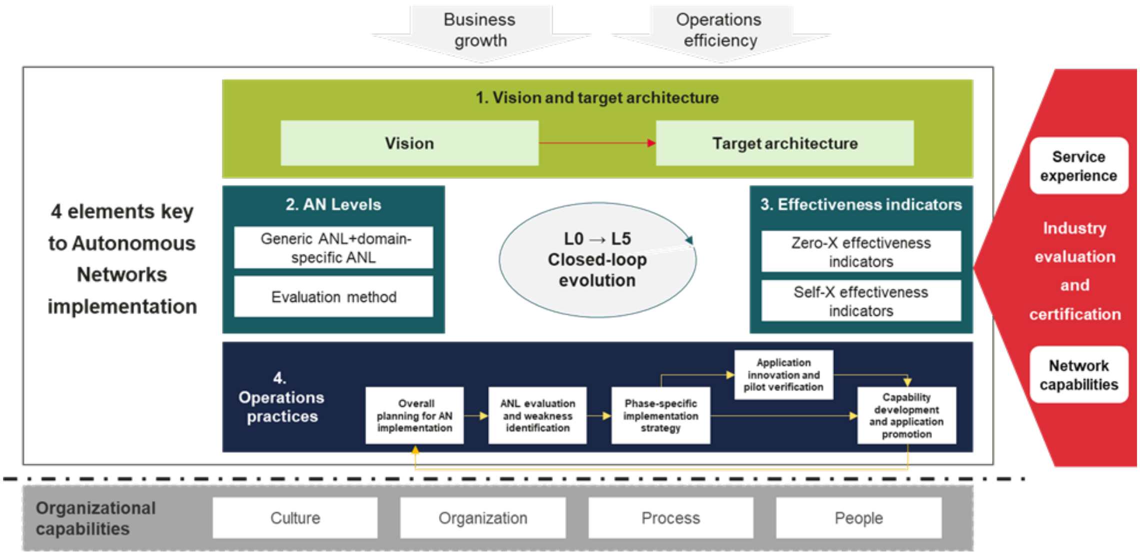

Figure 1*: Four key elements to AN implementation*

1. Vision and target architecture – the AN vision and objectives are defined to improve business growth and operations efficiency based on the overall corporate strategy and industry trends (for example, business scenarios like computing power network). Based on the live network architecture and running status, key trends (for example, 5G-Advanced, cloud-network synergy and digital symbiosis) are considered to develop a mid- and long-term target architecture in order to guide AN construction.
2. AN Levels – CSPs must also adopt generic ANL, domain-specific ANL and the corresponding evaluation methods to fully and objectively measure the ANL. The evaluation process requires setting up baselines and identifying weaknesses to formulate phase-specific objectives and improvement strategies. Then, CSPs can launch technical research and develop innovative applications to meet the autonomous capability requirements at each level. Finally, CSPs can verify the results, optimize strategies in real time and improve resource utilization. 26 < Back to Contents | Method and practices for AN evaluation

3. Effectiveness indicators – it is important to measure the business value and service effectiveness of AN in terms of service growth, customer experience and operations efficiency. The value of these indicators lies in two aspects: 1) visualizing and quantifying the effectiveness and benefits of AN evolution and 2) aligning the development of autonomous capabilities with the enterprise strategy and service development trend. Effectiveness indicators are selected based on the Zero-X and Self-X visions. Effectiveness indicators and ANL are two key AN evaluation factors that jointly facilitate the fulfillment of the AN vision.
4. Operations practices – improving autonomous capabilities for networks and operations systems is also key. From the network (including NE) perspective, the focus is on improving converged sensing, self-configuration and native intelligence. From the operations system perspective, the focus is on improving requirement translation, end-to-end resource orchestration and cross-domain O&M optimization. In order to accelerate large-scale AN deployment, the industry has summarized a five-step operations practice method for reference:
    a. AN implementation planning;
    b. ANL evaluation/weakness identification;
    c. strategy and direction selection;
    d. application innovation/pilot project verification; and
    e. capability development/application promotion.

Organizational capabilities and industry evaluation Organizational capabilities are also a crucial factor for AN implementation. The network operations department, including the corporate culture (system), organizational structure, work processes and skills, need to be adjusted or optimized to adapt to the construction of ANs. Then industry evaluation and certification can verify the result of AN implementation.

Industry organizations or authorities need to provide an evaluation environment and launch ANL evaluation and certification based on unified standards. Authoritative evaluation and certification increase credibility, help CSPs better serve industry customers and promote win-win industry development. Unified evaluation standards can help carriers improve network and service capabilities and provide customers with a Zero-X service experience. A well-founded evaluation environment facilitates innovation and verification of technologies and applications, cross-vendor collaboration, and end-to-end streamlining of business processes. The following sections provide several best practices to help readers better understand the four elements key to AN implementation, evaluation and certification.

3.2. Practices of AN Level (ANL) Evaluation

3.2.1. China Mobile's ANL Practice

First company to target L4 at scale for production by 2025

As the first CSP in the industry to propose the goal of reaching L4 by 2025 and deploying large-scale practice, China Mobile has proposed the target architecture and specific vision of "zero-waiting, zero-failure and zero-contact", together with "self-configuration, self-healing and self-optimization". The company's target architecture is shown on the next page.

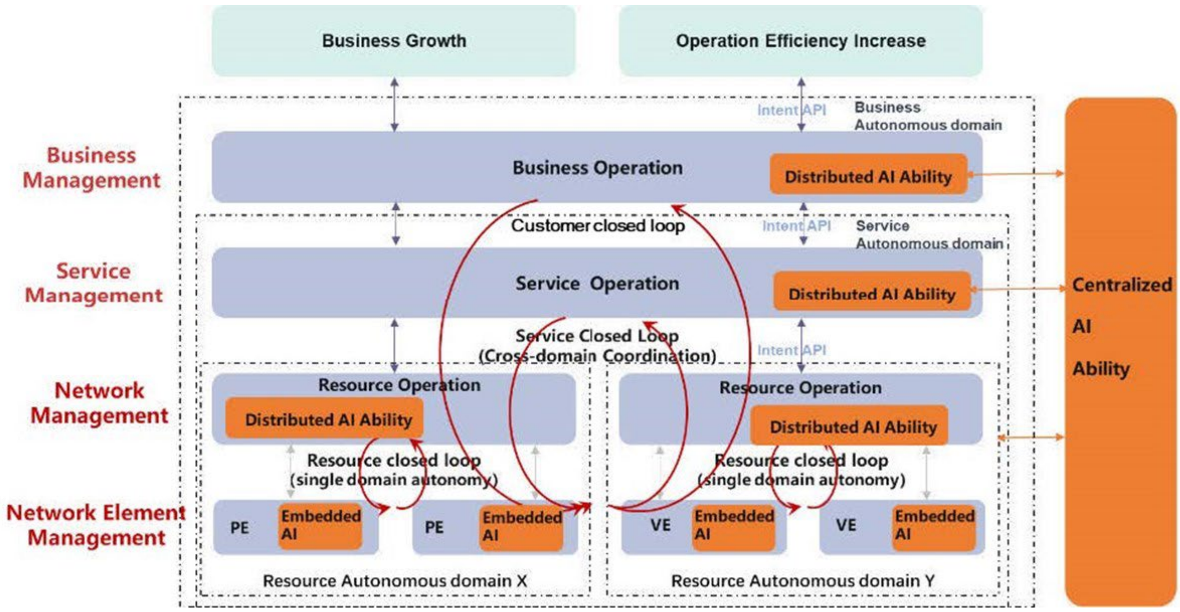

Figure 2*: China Mobile's target architecture*

First systematic level evaluation methodology and practice

Technical assessment covering the full lifecycle – China Mobile has built and practiced the first systematic evaluation system in the industry, including six workflow domains: network planning, deployment, maintenance, optimization, operation and inventory management.

Thirty-seven types of core capabilities are continuously sorted out and improved around customer response and network quality. Based on the 3D model of "operation workflow-network domain-service domain", 298 sub-tasks are further sorted out in five major network domains and three categories with 12 key services provided. The scope of sub-tasks is defined in detail and enriched into 1,328 task context/scenarios to lead 31 provincial companies to apply digital intelligent capabilities closely around the requirements of various domains and services.

China Mobile has defined a maturity model as shown in Table 1 to guide the system implementation. It refers to the DIKW (data, information, knowledge, wisdom) system and aims at the step-by-step construction of system cognitive ability.

Level	Typical characteristics	Description
Level 0	Offline manual implementation	Offline manual implementation
Level 1	Online recording	Manual implementation, online recording
Level 2	Statically configured rules	Automatic implementation driven by statically configured rules
Level 3	Dynamically programmable rules (policies)	Automatic implementation driven by dynamically programmable policies
Level 4	Intelligence assisted auto-generation of rules	Automatic implementation driven by AI assisted (if needed) knowledge, with continuous learning and rapid evolution
Level 5	Self-evolution	Automatic implementation capable of self-evolution and adapting to changes

Table 1*: China Mobile's AN maturity model Level*

Based on the model, a clear, unambiguous, operable, and detailed definition of level requirements for all levels should be given to all the task context initially identified. After technical assessment of each scenario, the average score of all scenarios included in each task is calculated as the level of this task. The level of the evaluated network is the average score of all the tasks defined by it.

Continuous improvement – combined with the effectiveness indicators, weakness of the system is determined according to the technical assessment result. As each task clearly corresponds to a management responsibility subject/department, the department is responsible for the continuous improvement and subsequent enhancement of this task. Through continuous construction and improvement of autonomy of network elements, the operations and maintenance center (OMC) and network management systems, the digital intelligent transformation and upgrading of those tasks is realized in a closed-loop manner.

3.2.2. China Telecom's Practice: AN Characteristics Across ANL

China Telecom accelerates the construction of cloud-network operation autonomy; focuses on closed-loop operations; faces customers, partners, products, and network + cloud; matches the development stage of cloud-network integration; and defines the intergenerational characteristics of cloud-network operation self-intelligence. The company is defining these characteristics across ANL as shown in Figure 3.

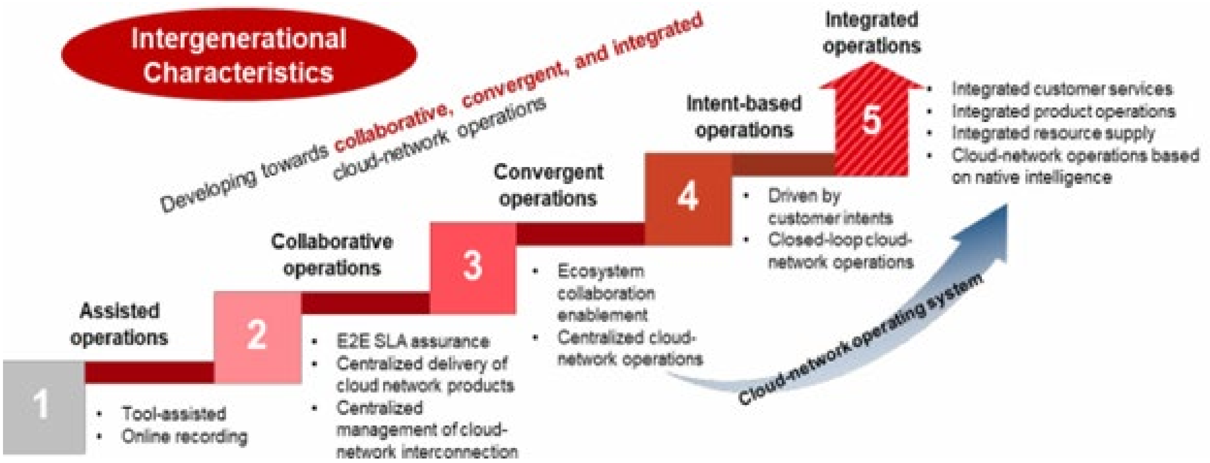

Figure 3*: AN characteristics across ANL*

3.2.3. China Unicom's Practice: ANL Evaluation

In the process of practicing AN, China Unicom met some challenges such as how to practice ANL improvement, enhance cross-layers and cross-domain collaboration, and develop a clear evolution path. To solve these challenges, the company has created a systematic top-level design which took "AN level evaluation, capability building and value verification" as key actions.

- **ANL evaluation** – to measure the current status of AN capabilities, China Unicom defined an ANL that consisted of two parts:
- **Generic ANL:** as a framework, the generic ANL was used to unify the characteristics of each level and evolution direction of the AN. China Unicom broke it down into five operation flows and 43 operation tasks and defined generic levels for every operation task.
- **Domain-specific ANL:** the function of domain-specific ANL was to make the level feasible and implementable and to guide the AN capability development for network and service domains. China Unicom developed domain specific ANL by focusing on key network and service domains and combining the special characteristics of different domains. Currently, domain-specific for wireless and transmission network, 2H and 2B services have been developed. Table 2 shows the L4 ANL criteria of task "Network optimization - Performance deterioration prediction" as an example.

Operation flow	Network optimization
Operation task	Performance deterioration prediction
Generic AN Level criteria	L4: System predicts network status trends and identifies potential risks quantitatively and accurately
Wireless access Domain AN Level criteria	L4: System detects mobile service experience change and predicts risks in real time, including air interface performance deterioration prediction, performance deterioration caused by burst mobile traffic, user experience deterioration prediction for RF change or power saving, etc

Table 2*: L4 ANL example*

- **Capability development** – to promote specific domain AN capability planning and development, China Unicom formed the "capability map" for each domain. AN capabilities were split into network layer, platform layer and application layer based on domain ANL criteria.
- **Value verification** – to evaluate and verify the effects of AN evolution, China Unicom set up the AN effectiveness indicator based on the goal of customer-oriented agile service and network intelligent operation.

China Unicom is conducting network-wide AN practice based on domain-specific AN level criterion, generating the AN capability map, and evaluating the effect and value of the AN implementation for the achievement of the AN objectives.

3.2.4. MTN's Practice: Define the Domain-Specific ANL and Evaluate per Sub-scenario

MTN Group aims to have accurate evaluation of ANL for each network per technology domain and guide its operating companies to be innovative from a technology-specific perspective. Based on the generic ANL criteria defined in 2021, MTN defined domain specific ANL criteria for 43 operation tasks per technology domain. In 2022, MTN established two work streams: defining domain-specific criteria and evaluating per sub-scenario in the technical domain.

1. **Define the domain specific ANL criterial**

Operation Task	Transmission Network: Task Evaluation Criteria
Network resource design	L3: The system automatically calculates service (EOO, client, and OSU) routes based on the source and sink, SLA requirements (delay/hop count), and protection level. Service provisioning requirements can be configured and orchestrated, and the solution is manually confirmed. The system automatically evaluates whether functions (such as connectivity, bandwidth, and delay) meet requirements based on real-time data and determines whether to meet requirements manually. L4: The system automatically calculates service (EOO, client, and OSU) routes based on the source and sink, SLA requirements (delay/hop count), and protection level. Service provisioning requirements can be configured and orchestrated. Automatically evaluates whether SLAs (such as capacity, bandwidth, and latency) are met online based on real-time data. The system automatically determines the optimal solution.
Resource prospecting and evaluation	L3: The system automatically evaluates network resource design results and evaluates whether network requirements (such as network connectivity and protection requirements) are met. L4: The system uses the AI model to implement intelligent resource survey (e.g. SRLG identification of shared optical cables route, readiness of OTU resource). When an AI model needs to be iterated, it can be trained and loaded manually.

Table 3: ***Transmission network operation task example***

1. **Evaluate per sub-scenario in technical domain. Live network scenarios for each task in the specified technology domain are listed clearly, and domain-specified ANL criteria are used to evaluate per sub-scenario.**

Operation Task	Sub-scenario
Network resource design	• OTN network client-side lease line service • OTN network ODUk EOO lease line service • OTN network OSU EOO lease line service • OTN network EOS/EoSoO lease line service • OTN network ODUk EOO cloud connectivity service • OTN network OSU EOO cloud connectivity service

Table 4: ***Sub-scenario list example***

3.3. Practices of AN Effectiveness Indicators

3.3.1. China Mobile's Practice for Effectiveness Indicators

Based on the TM Forum Metrics Framework (GB935), and the positioning and value of effectiveness indicators, China Mobile recommends a top-down method for developing effectiveness indicators. This method includes three steps:

- **Step 1:** Develop an effectiveness indicator framework based on user value and O&M value.

There are generic and detailed indicators. Generic indicators measure the general automation and intelligence level of the entire network. Detailed indicators are domain- and service-specific indicators. The principles for selecting the indicators are highly relevant to AN and have the following objectives:

- **User value indicators** are designed to fulfill the Zero-X vision and improve the experience of users including industry customers, individual consumers, and partners. For example, zero-wait (average service provisioning duration), zero-touch (user self-service rate) and zero trouble (service availability).
- **O&M value indicators** are designed to fulfill the Self-X vision and reduce network O&M costs and improve O&M efficiency such as self-configuration (automatic configuration rate), self-healing (proportion of preventive and predictive O&M tickets) and self-optimizing (energy efficiency improvement rate).
- **Step 2:** List effectiveness indicators based on the service development and network maintenance objectives.

China Mobile selects the core capability automation rate as a generic indicator, which measures the proportion of L2 core capabilities. In addition, 24 detailed indicators and an indicator model are defined. Table 5 provides an example:

Category	User value indicator – zero-wait	O&M value indicator – self-optimizing
Domain	Business service	IP network
Indicator Name	Duration of business private line service provisioning	Automation rate of IP traffic optimization
Formula	= ∑Ticket provisioning duration/ Number of tickets	Number of auto-optimized link/ number of all links*100%
Period	Hourly/weekly/monthly	percentage
Target for L4 2025	Hourly	90%

Table 5*: China Mobile's effectiveness indicator example*

- **Step 3:** Define phase-specific targets and different types of views to apply the effectiveness indicators and launch related practices.

Based on the effectiveness indicator list, develop and deploy corresponding IT systems. Define effectiveness indicator baselines based on the status quo. Set phase-specific targets (which can be continuously optimized). Table 6 provides an example.

Indicator	Baseline	Target for 2023	Target for 2024	Target for 2025
Average provisioning duration of site-to-cloud private line services	1 week	1 to 3 days	1 day	8 hours

Table 6*: China Mobile's effectiveness indicator target example*

The evaluation results of effectiveness indicators can be used in multiple scenarios. For example, the management view can be used to visualize the status and trend of the indicators. The production view can be used to identify capability weaknesses in order to better develop and improve AN capabilities.

3.3.2. China Telecom's Practice for Effectiveness Indicators

To measure the business value of cloud network operations autonomy, China Telecom defines the effectiveness evaluation standard framework, which includes ultra-premium customer experience, ultra-fast telecom services and ultra-intelligent cloud network operations. This framework, shown in Figure 4, can evaluate the contribution of improving the autonomous level to product services, customer experience and operations efficiency.

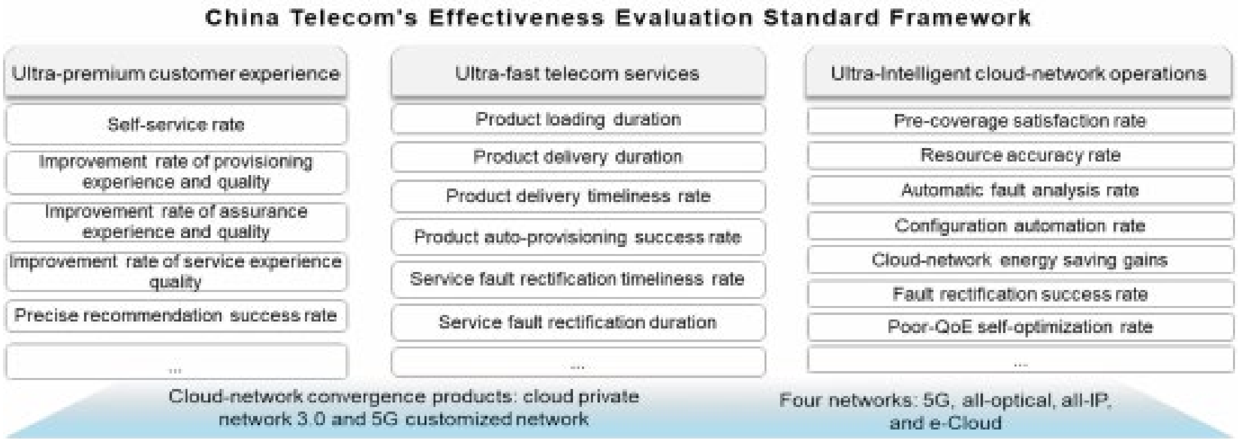

Figure 4*: China Telecom's evaluation framework*

China Telecom maps the operations phase and products used in this phase with the effectiveness evaluation standard framework and breaks down the end-to-end indicators for cloud-network convergence products into system and professional network indicators. The name, formulas and data sources of each indicator are defined. The indicator baselines and the year-by-year improvement goals (absolute values) for the next three years are also defined based on live network data analysis. These indicators will drive the development of autonomous capabilities and level evolution. Table 5 on the next page describes some of the indicators and targets.

Product	Indicator	Baseline	2023	2024	2025
5G customized network - 5G slice private lines	Service delivery timeliness rate	--	10%	10%	5%
	Automatic provisioning success rate	--	20%	10%	10%
	Fault rectification timeliness rate	--	1%	0.5%	0.5%
Cloud private network 3.0	Service delivery timeliness rate	--	10%	5%	3%
	Automatic provisioning success rate	--	10%	10%	5%
	Fault rectification timeliness rate	--	1%	0.5%	0.5%

Table 7*: China Telecom's effectiveness indicator targets example*

3.4. Operation Practice

3.4.1. The First Large-scale AN Operation Practice in China Mobile

China Mobile's AN operation follows the closed-loop method of "industrial standard promotion, top-level design, digital intelligent capability building and application, evaluation and analysis", and systematically promotes the capability improvement and autonomous evolution of the whole network. Figure 5 shows the process.

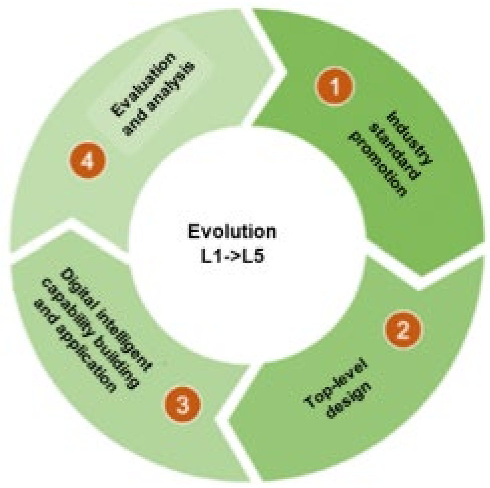

Figure 5*: China Mobile's closed-loop method*

- **Industrial standard promotion –** China Mobile has been actively contributing to the industry standards and guide all parties in collaborative deployment. Practices are summarized and shared as multiple TM Forum assets to promote shared growth.
- **Top-level design –** China Mobile has put forward the target architecture of "2 objectives, 3 layers and 4 closed loops". Thirty-seven key capabilities have been defined, covering the full lifecycle of network operation. Autonomy evaluation has been evaluated from both the technical side and application side to better reveal the deployment effect of autonomous network.
- **Digital intelligent capability building and application –** vendors are guided to improve built-in automation and intelligence of network elements, centralized data acquisition and control of OMC. The company continuously optimizes the OAM process, rules and policies, and data model to improve single-domain autonomy and cross-domain collaboration, vigorously promoting AI innovation.
- **Evaluation and analysis –** 31 provincial branches are organized together to carry out capability evaluation around key domains and services. The best innovative products are selected and deployed on the whole network. Through the evaluation, shortcomings are identified, and improvement plans are formulated to promote future ANL enhancement.

4. AN REFERENCE SOLUTIONS

4.1. Enabling Verticals

4.1.1. China Mobile: Eastern Data and Western Computing Force

Eastern China has a developed economy and therefore demands a large amount of computing power, but it faces tight restrictions around energy consumption and high electricity costs. On the contrary, western China is rich in clean energy and has a wealth of data centers (DCs). Western China adopts cost-effective, single-bit technology to store and process data, but computing demands in this region are quite low. This is causing companies to look at how to better promote the complementary advantages of the developed economy in the east and the abundant renewable energy in the west to solve the challenge of maximizing the efficiency of clean energy in the country.

Solution

China Mobile gives full play to the resource advantages of the whole network, comprehensively promoting the capability improvement of the Autonomous Network. Through construction of its Jiutian AI platform, the company is building a nationwide, non-real-time computing power support base to achieve eastern data trained in western China. Figure 6 shows how it works.

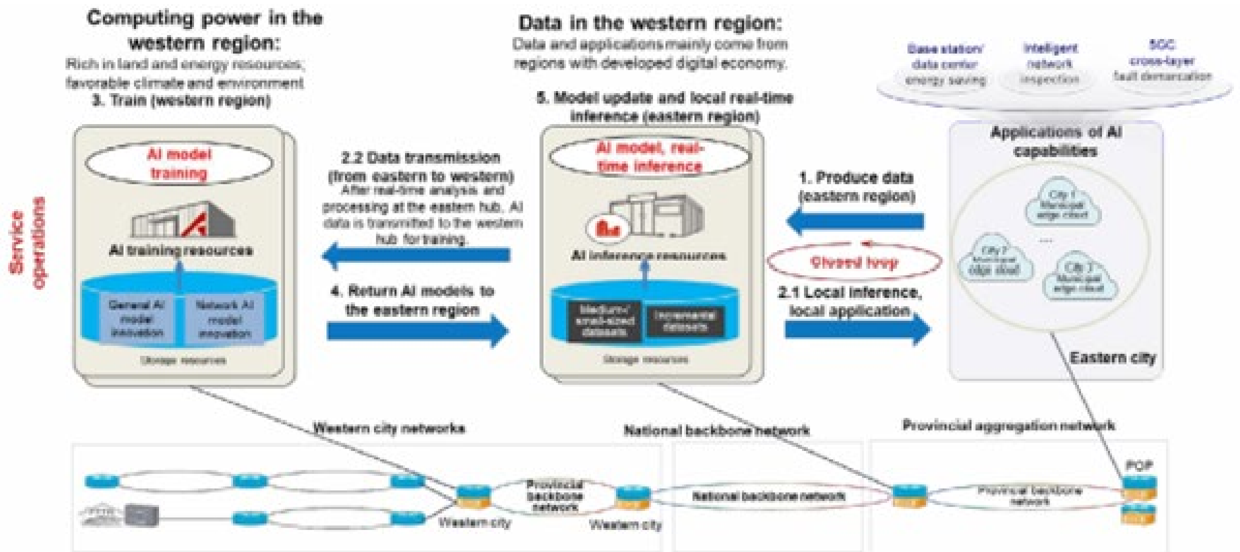

Figure 6***: China Mobile's Jiutian AI platform supports energy optimization***

The platform consists of two layers: centralized node and distributed edge node. The centralized node provides centralized AI training ability and shared platform resource. When data is generated in fulfilling business demand in the east, the system transmits the data to the western hub and completes the unified training in the Internet data center (IDC) located in the west using the abundant clean energy. After the training is completed, the AI model is sent back to the east, and the local edge nodes close to the user in the east complete real-time inference and decision-making to effectively improve the energy efficiency of overall IT resources.

Application and benefits

The AI ability of “eastern data trained in the west” has already been applied in many scenarios, including wireless base station energy saving, IDC energy saving, intelligent inspection, cross-layer fault location in the 5G core, network traffic prediction, etc. China Mobile continues to build AI centralized training and inference capability and provides Self-X operation capabilities such as “AI centralized self-training, self-analysis” to provide customers with Zero-X experience.

Collaborating with China Unitech and Huawei, this solution has been piloted in China Mobile Zhejiang and Shaanxi. In terms of AI training and inference, by building a centralized AI platform the utilization rate of IT resources is greatly improved. The AI training server, storage space and power resources are saved. The carbon emissions are reduced by 30%, and the overall efficiency is optimized.

4.1.2. China Telecom & MTN : Cloud-Network Convergence

Since 2020, global enterprises have accelerated their business migration to the cloud, and gradually moved their key information systems and core production systems to the cloud.

Cloud-network convergence is a network architecture reform and network capability upgrade which is driven by business requirements and technological innovation. It is a concept that CSPs put forward which aims to take advantage of their infrastructure such as "wide area network, large-scale DC, and territorial services" and provide end customers with cloud-network convergent business and services.

Business scenarios		**Customer expectation**	**Cause analysis of the gap**
Smart operation of cloud-network convergence	**Service provisioning**	• Access to the cloud anytime, anywhere. One network into the multi-cloud • One-stop on-demand ordering and change of cloud-network business, instant activation • Cloud and Network service is provisioned separately for one customer order • Cross provincial service is provisioned segment by segment. Lack of cross service, cross domain orchestration and collaboration • Work order scheduling and business configuration activation has a lot of manual participation	
	Quality management	• Differentiated SLA • End-to-end deterministic SLA can be guaranteed • The integration of SLAs of all segments of the network	

Business scenarios		Customer expectation	Cause analysis of the gap
		does not equal the end-to-end SLA • The end-to-end SLA monitoring and predicting autonomy is weak	
	Fault management	• Zero interruption of customer-side business • Fast fault repair • The mapping relationship between networks and services is complex, and cloud special lines require multi-segment pipeline splicing to achieve end-to-end service connection • Insufficient business/fault self-repair capabilities, interprofessional fault root cause analysis is still a problem	
Cloud Private line		• Online self-service • Fast TTM of new service • Guaranteed differentiated SLA • Zero-X operational experience	• Complex protocol, inefficient manual cloud, and network configurations • No support of network slicing • Inconsistent and unpredictable service experience • Inefficient fault location, prediction, and analysis

Table 8*: Overview of challenges and expectations of cloud-network convergence*

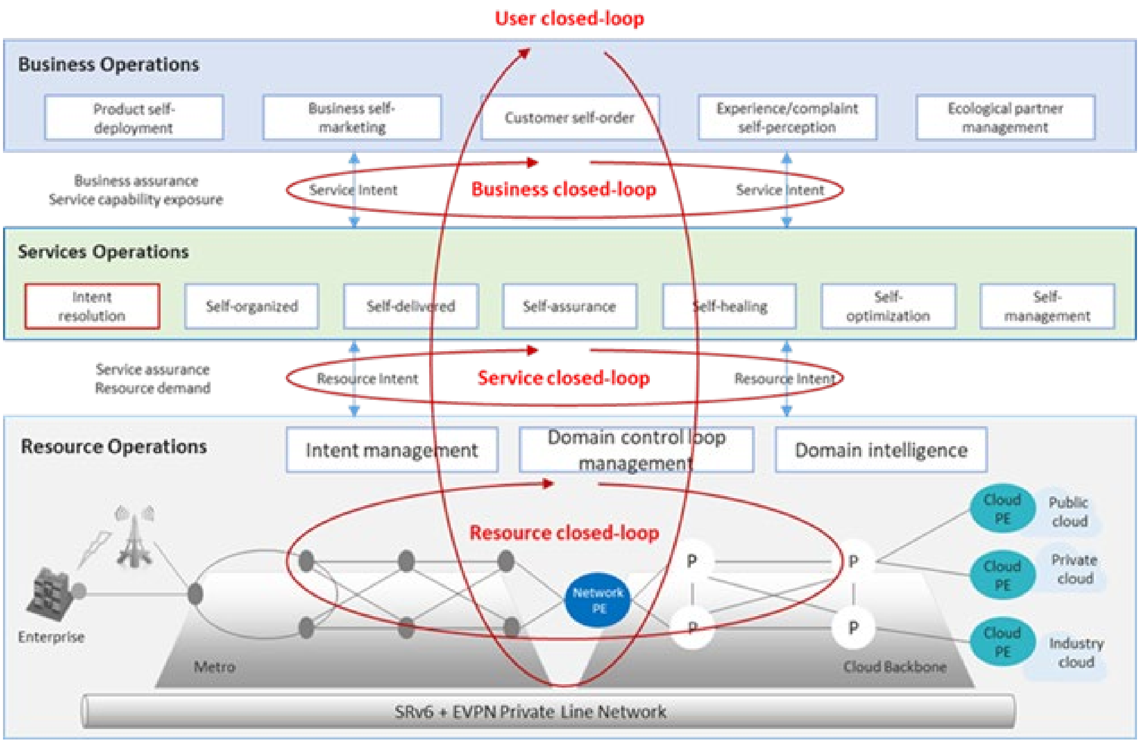

Figure 7*: Intelligent Cloud-network convergence business solution*

China Telecom: Smart operation of cloud-network convergence

Cloud-network convergence has become a top priority for many governments and enterprises when they migrate to the cloud. However, in production scenarios such as "service provisioning, quality management, and fault management", there are still problems such as "inconvenient ordering, long provisioning cycles, inconsistent cloud and network experience, difficult end-to-end SLA guarantees, and slow service repair/fault handling", which is still far from the expectations of customers.

The cloud-network convergence smart operation solution adopts the architecture and concept of "network moving with the cloud and cloud-network integration", It introduces "SRv6, flow detection, AI and cloud-network intelligence and other ICT technologies and cloud-network operating systems to comprehensively improve multiple automation and intelligence capabilities such as “real-time self-awareness of cloud-network resource topology and status, unified and self-organized resources, self-generated SLA policies, self-configured service activation, self-organizing, self-guarantee, self-healing and self-optimization of service quality and cloud-network failure”. The business scenarios below show which autonomous network capabilities are used:

- Service provisioning: The business operation layer provides industry templates for government and enterprise customers. It can take customers’ orders and change cloud-network services in one-stop and on-demand. It integrates customer requirements for "SLA and cost", automatically generates SLA strategies and drives service and resource operation layers for configuration. The service operation layer is based on the cloud-network unified operation support system, integrates the capabilities of each segment of business activation, and self-organizing cloud and network resources in a unified manner to achieve customer-oriented one-click activation. Finally, the resource operation layer deploys cloud-network points of presence (PoPs) to support users to enter the cloud quickly and from any location. The resource layer opens the underlying capabilities to realize the automatic configuration of VPNs, tunnels, slices, etc., to support the rapid opening of services.

- Quality Management: Service quality and customer experience drive the single-domain autonomy and cross-layer link in the closed-loop of the service and resource operation layer. The business operation layer provides cloud and network business visualized self-management clients for government and enterprise customers. These enable internal operation and maintenance, and they build a comprehensive view of cloud and network information, supporting intelligent marketing, agile activation, and cross-domain collaborative operation and maintenance. The service operation layer collects the resource status and service quality information of each segment of the network (autonomous domain) in real time, visually presents the service SLA situation, realizes end-to-end SLA analysis and prediction and self-guarantee. It also automatically generates self-healing or self-optimization strategies. According to the service requirements, the operation layer can sense, analyze, and report the quality of each segment of the network in real time based on technologies such as telemetry and flow detection, and realize self-healing or self-optimization of the network based on SRv6 technology.
- Fault Management: The Service operation layer provides mapping relationships between the business and the network, aggregates the cloud and network service information of each segment and triggers the service fault recovery intent. The Resource layer translates the intent through the cloud and network resource orchestration and scheduling with zero interruption. Each autonomous domain of the resource operation layer automatically reports alarms/faults and completes self-healing actions such as resetting and restarting for rapid fault recovery.

For high-level autonomy capabilities, the "intent resolution module" is developed to build general intent resolutions and reverse translation capabilities to provide capability support for the three operation layers to achieve 4 intent based closed loops.

The cloud-network integrated agile opening and smart operation solution adopts a unified planning, single-domain autonomy first and then cross-domain collaboration for pilot verification and production network deployment. At present, large-scale deployments of the three scenarios of "service provisioning, 5G service quality management, and fault management" has been achieved, with the following results:

- No waiting, hour-level service provisioning: 5G slice configuration and number signing are automatically activated throughout the entire process, which has been implemented in more than 30 customer projects in the four provinces of Beijing, Guangdong, Jiangsu and Zhejiang. The entire process of product deployment and launch, from order acceptance to opening is automated. Product loading has been upgraded from monthly/weekly to hourly level, saving more than 20 man-days per project on average. The autonomous network level has been upgraded from L2.1 to L3.0.
- Differentiated, end-to-end SLA guarantee: Through 5G full-service intelligent perception and diagnosis capabilities, it can realize linkage alarm dispatch and end-to-end self-closed loop. At present, the first-level system has been deployed in China Telecom's 31 provincial subnets, and it has begun to run, analyze and process data from 31 provinces, and carry out SLA monitoring and assurance. The autonomous network level has been upgraded from L1.9 to L2.7.
- Zero-failure, minute-level business recovery: AI automatic identification of cloud-network hidden dangers have been deployed in China Telecom’s 29

provincial subnets, realizing hidden risks minute-level discovery, business minute-level recovery and fault hour-level processing. The failure automatic processing rate reached 40%, the major incident business automatic recovery rate was 60%, and the processing efficiency increased by 85%. The autonomous network level has been upgraded from L1 to L2.

MTN: Cloud Private Line Convergence

Cloud Private Line convergence needs to be established to support online self-service for subscribers, supporting network slicing, guaranteeing differentiated SLA, and supporting zero-X operational experience. However, gaps still exist due to complex protocols, complex cloud network configurations, lack of service visibilities, and operational difficulties in fault detection and analysis. To successfully implement cloud-private line convergence, **automation** and **autonomy** are required to guarantee network readiness and augment operation services.

The 3-layers with 4-closed loops framework of figure 19 above is applied in the lifecycle of cloud-private line convergent process as detailed below:

- Resource layer closed-loop: hierarchical slice based private network is constructed with SRv6+EVPN, programmable and self-optimizing paths, and telemetry-based SLA real time awareness and visualization per service. Network service API interface is enabled to the upper OSS layer for a fast service request.
- Service layer closed-loop: Operation service efficiency is improved with zero-X service experience, with self-X capabilities. For example, service fault recovery can be performed with zero-interruptions through complex, cross domain fault demarcation and analysis, which drive self-optimizing and self-healing at the resource layer. The status of the recovery will be reported back to the service layer for smart operation and maintenance.
- Business layer closed-loop: This layer is enabled with one-click fast scheduling, one-hop to the cloud, and one-network wide connection business service capabilities. Business intent is driven at the upper business layer and interacts with the lower service and resource layer with open APIs. This drives efficient scheduling of cloud-network resources with AI algorithms, establishes cloud access paths across domains and minute-level multi-cloud access to construct a hierarchical slice based private network providing guaranteed differentiated services for high value customers.

China Mobile: Automatic Provisioning of Cloud Network Services towards Enterprise customers

Traditional cloud-networking service provisioning is performed manually, and it involves multiple different steps, including service analysis, resource survey, command compiling, verification and testing. End-to-end service provisioning usually takes several days.

China Mobile has developed an IP Maintenance Platform, where AN capabilities are implemented to significantly improve service provisioning efficiency in combination with containerized and micro-service architecture. Using the 3-layer AN framework, the detailed technical path is as follows:

- Real-time network awareness: The resource operation layer provides real-time collection of network status and performance in each autonomous domain with several protocols, such as simple network management protocol (SNMP), command-line interface (CLI), NetFlow, telemetry, and two-way active management protocol (TWAMP). The service operation layer makes a high-level end-to-end analysis of autonomous domains.

- Zero-touch service provisioning: Based on the overall real-time status of network, the service operation layer dynamically calculates the optimal path and executes automatic configuration. AI-powered network path calculation is adopted to get the result within only a few seconds. The resource operation layer provides dynamic and accurate resource allocation for service provisioning.
- Self-managing enables high-efficient agile deployment: The resource operation layer provides atomic abilities with Netconf (a high-efficient & complete-transaction protocol). Common capabilities can be quickly developed on demand and be shared and reused in multiple cases. The service operation layer assembles these capabilities to achieve a service-oriented ability for the business operation layer to invoke.

The IP Maintenance Platform enables AN features such as zero-touch, and zero-wait to the end-to-end process from service subscription to service provisioning, reducing the total time of fulfilling cloud-networking services to only a few minutes. This improves customer satisfaction and increases the autonomous network level of China Mobile from L1 to L3.

4.1.3. Flexible Computing Network Scheduling

Global enterprises are accelerating the process of cloud access. Carriers are looking to leverage their advantageous networks and computing power to streamline computing power in the society, centrally and flexibly schedule computing power from different sources, and provide enterprises with more convenient, secure, and reliable cloud access experience. However, the scale and direction of enterprises' digital traffic are uncertain. Around 30% of traffic needs to be scheduled across different provinces on the entire network, creating daunting challenges to carrier network coverage, timeliness of on-demand provisioning, and flexibility of network-wide scheduling. Collaborative cloud-network development needs to be accelerated to promote cloud-network integrated O&M.

- **Rapid coverage of transport capacity:** Carriers quickly deploy quality networks for enterprises in order to support digital transformation of enterprise services.
- **Quick acquisition of transport capacity:** Optimal network paths are recommended based on enterprise intents, such as latency SLA, computing resources, and traffic calendar.
- **Transport-computing power collaboration:** Cloud access circuits and inter-cloud interconnection circuits can be deployed or removed on demand within a few seconds, adapting to traffic changes and elastic bandwidth, and allowing enterprise applications to flexibly obtain computing power.

The flexible computing network scheduling solution focuses on deploying basic transport capacity for carriers' all-optical networks. The capabilities to self-sense and self-configure transport capacity are implemented to quickly develop resources for wide coverage computing networks and access premium cloud connections in one hop.

Network self-sensing: Real-time seconds-level or milliseconds-level sensing is implemented across the entire network, between clouds, and on cloud access connections. The network latency, bandwidth, and usage, as well as the usage of top N cloud pool resources and other information can be perceived and visualized on the GIS map.

- Inter-cloud transport capacity matrix: From the computing power perspective, clearly displays network information (including latency, bandwidth, and usage) of interconnected computing resource pools after self-owned and social computing power are applied to the network.
- Latency circle for cloud access transport capacity: From the enterprise perspective, renders the latency circle (1 ms - 5 ms - 20 ms) for quality transport capacity in order to identify the distribution of computing power available to enterprises.

Network self-configuring: The transport capacity of each cloud pool on the entire network is displayed from enterprise perspective to facilitate the deployment of high-quality networks with low latency and elastic bandwidth. Quality cloud access paths are intelligently recommended based on the SLA (latency, bandwidth, and availability) of enterprise cloud access. Cloud access paths for millions of NEs can be scheduled and deployed within just a few seconds, implementing on-demand elastic scaling of network connections (deployment and removal).

China Unicom Guangdong and Huawei are the first to jointly deploy this innovative solution to select paths based on service requirements and perform elastic scaling of cloud access connections during peak hours, improving SLA assurance. This solution helps China Unicom quickly achieve 100% coverage of high-quality transport capacity and deploy a service ecosystem.

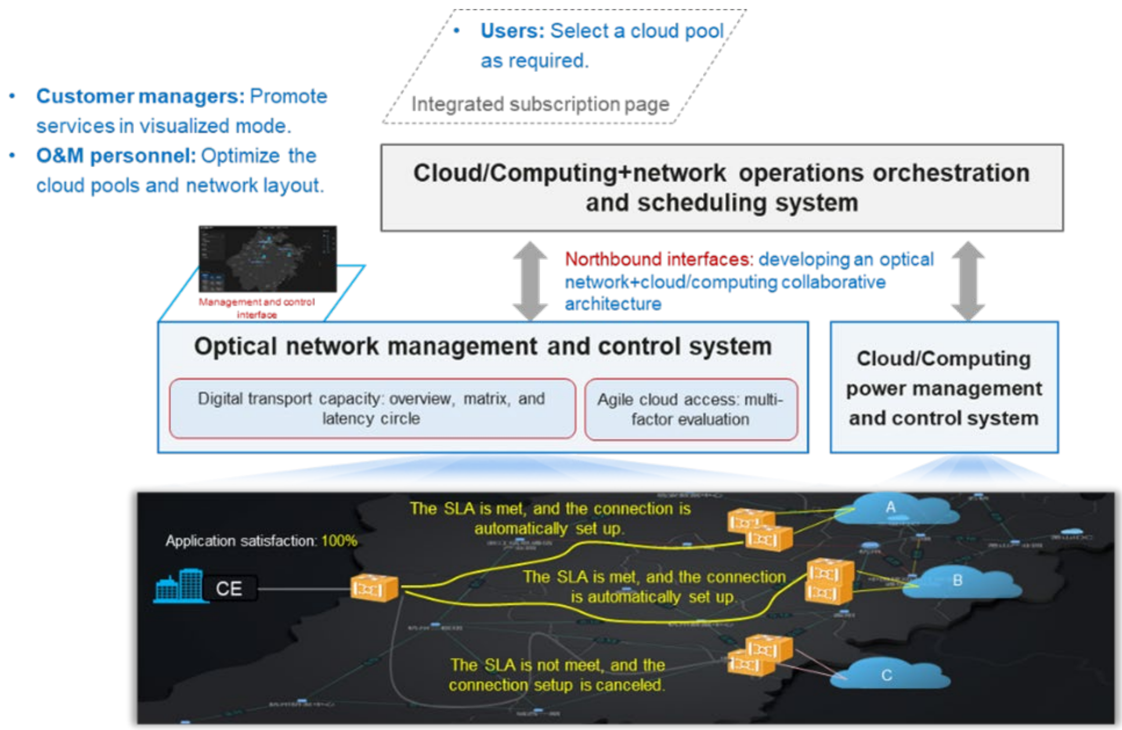

Figure 8*: Flexible Computing Network Scheduling*

4.1.4. Enabling Verticals Autonomous Networks Hyperloops Enabling Smart-X Industries – Smart Tourism/Stadium

With the Covid-19 pandemic impacting business and daily life in so many ways, just imagine the new "disruptive" services that will emerge. They will be completely autonomous, designed for zero-touch and zero-fault operations and autoscaling based on experience expectations. This use case from a recent TM Forum Catalyst championed by five CSPs from around the world looks at how AN can help this new normal for the on-site and on-premises hybrid environment.

Telecoms and industry verticals focus on both "operational efficiency" and "business growth", providing agile business and support models to maintain or enforce resiliency in unforeseen crises and get new revenue even during tough periods. To address this new normal, service providers need to realize autonomous ICT services with autonomous digital enabling services, while simultaneously solving the challenges of cross-domain/cross-vertical and hybrid networks for innovative new services.

In phase three, the smart tourism/stadium Catalyst is scoped as a key entry point for AN services in a digital marketplace. This includes both global experiences as a citizen on-site and remote viewing of matches on-premises as a part of the citizen journey through on-demand AN (including zero-touch operations, closed loops and business intent).

In the demonstration, a tourist visiting a place (either real or virtual) needs a seamless experience based on their preferences. The needs could be mostly dynamic and at that moment have to be served without any complexity, which might cause an unpredictable surge in demand on infrastructure, and this surge might require manual operation. Deploying massive, dedicated networks dynamically and flexibly, while ensuring sustainability and efficiency becomes a big challenge.

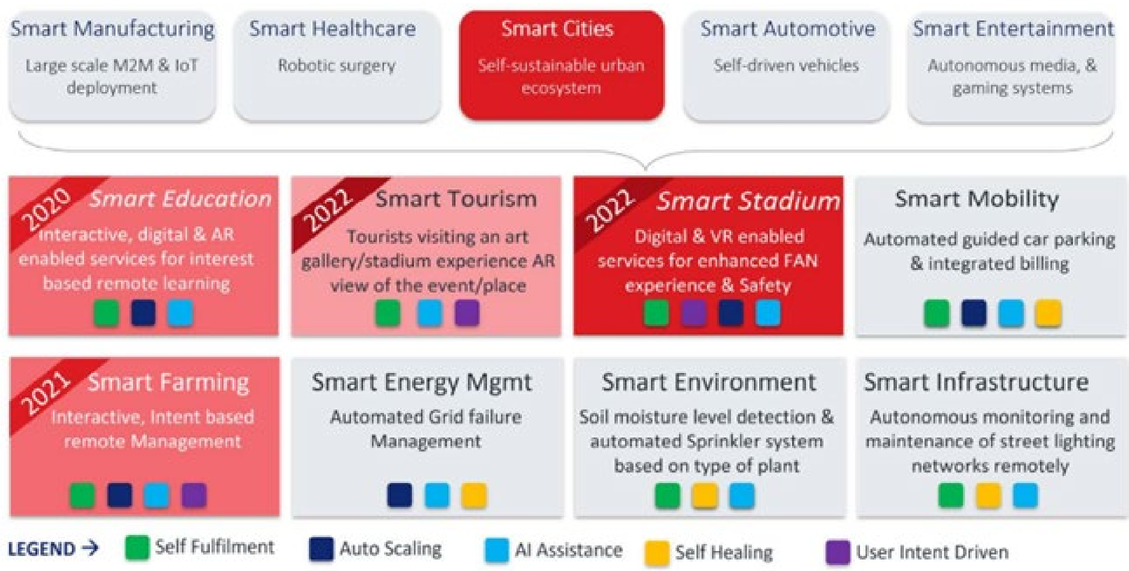

Figure 9***: Examples of vertical use cases that benefit from ANs***

Smart tourism and stadium services are trending use cases where ANs are key for CSPs to deploy smart solutions and services that can enrich a fan's experience and safety and increase the CSP's profitability by providing value-added services dynamically. These solutions will require the connection of many IoT and mobile devices that are densely populated within a stipulated area gathering lots of information such as location, footfall, trending demand, etc.

One of the key questions CSPs are exploring is how they can improve fans' experience with autonomous drones and cameras to enrich game experiences and extend live-like experiences even in cases when fans are not allowed to be in the stadium. The drones and cameras will be connected to a wireless access network, and they will keep capturing the game at various views and positions, streaming live video feeds to the fans via an app on their smartphone or VR headsets. Connectivity solutions like private 5G can deliver massive bandwidth and meet demands for very low latency. Machine learning and AI will use the information from image and video analytics to provide the best fan experience – tracking their favorite player, for example. AI can also enhance safety – by quickly detecting fights or brawls that may break out, for example – and recommending immediate actions.

The Catalyst is described in more detail on the next pages, considering 1) architecture; 2) enabling smart stadiums and self-service fulfillment; 3) intent-based operations; and 4) scalability and efficiency.

1. **Solution architecture powering ANs**

To achieve ANs for vertical use cases, maturity is required across several loops including resource, service, business and user. The simplified architecture to achieve this maturity is shown in Figure 10, followed by an explanation of each level of operations.

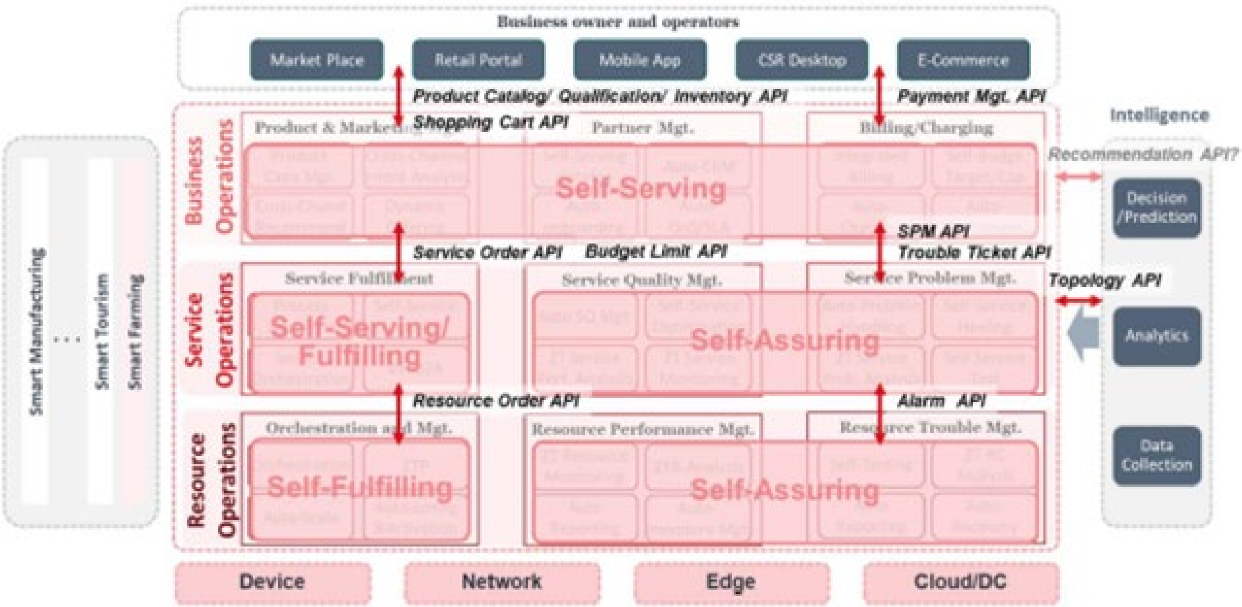

Figure 10***: Simplified solution architecture of Ans***

- **Business operations (BO)** – this layer presents business rules and business intent for self-planning and self-marketing (e.g., self-ordering, including autonomous order-to activation) to facilitate zero-friction products for users.
- **Service operations (SO)** – this layer represents autonomous service lifecycle management comprising self-ordering, self-organizing, self-managing and self-assuring. It captures business intent and governs the accurate translation of service intents to resource intents.
- **Resource operations (RO)** - this layer represents autonomous resource management functions to self-organize, self-manage and self-assure the

physical, virtual, and logical resources in order to fulfill the resource intents and address the customer's requirements.

CSPs can monetize and support Smart-X industries like smart cities (smart stadium, tourism, farming, energy), smart manufacturing and smart healthcare by leveraging the above vertical/domain-agnostic technical architecture.

Governance and business limits of autonomous operations

While ANs and the autonomous operations processes designed to support them make great use of AI and machine learning, the activities of those new capabilities must be put under governance processes and roles, monitored and observe defined business limits. While governance and monitoring can be executed in advance and in hindsight, defining business limits is an activity that needs to be executed in near real time.

Repair and scale activity provided in autonomous operations is a huge benefit, but measures must be in place to avoid activity that is against the CSP's or customer's business interests. This is playing out differently in B2B and in B2C scenarios.

For the observance and execution of these business limits as budget caps or spending limits, new capabilities are needed in business support system (BSS) components. A business process within the business/service/resource closed loop needs to execute the checks, and a proposed "budget limit" or "business limit" API needs to be available to check against the defined boundaries on the CSP and customer side.

1. **Enabling smart stadium/tourism**

CSPs can monetize the smart stadium/tourism use case to empower stadiums and sports clubs and to enrich fans' experience with experience and safety. They can also enable constant time-efficient management of stadiums by leveraging Zero-X experiences based on the AN business and technical architecture across the layers including edge cameras and drones, video capability, edge containers, virtualization, automated to autonomous operations, AI and insights analytics, and 5G. The reference architecture to achieve AN for smart stadiums or tourism is depicted in Figure 11.

Figure 11*: Smart stadium use case*

For example, a tourist visiting Paris for the Olympic Games would like to have augmented maps to guide them through public transportation and to get dynamic fan experiences at the venue or stadium. This is an example of autonomous tourist/fan experience and safety.

The smart stadium scenarios described above aim to demonstrate autonomous behavior across all loops (explained further in the next section) with the 5G network as the connectivity backbone and video analytics capabilities at the edge. Autonomous self-service fulfillment is depicted in Figure 9 as an example of usage of AN capabilities. More details can be found *in this Catalyst white paper.*

Autonomous self-service fulfillment

One of the key elements of providing seamless autonomous services to fans is zero-friction service fulfillment. It's a leapfrog transformation in terms of quality of service from manual and time-consuming workflows to autonomous self-ordering and self-managed networks. Autonomous self-service fulfillment workflow aims at seamless experience in services extended to fans and optimizing total cost of ownership for the service provider in managing the stadiums.

Key elements of the autonomous workflow depicted in the figure aim to deliver zero-friction services to fans:

- User intent management
- Service and resource usage requirements (QoS/QoE/SLA)
- Zero-touch service provisioning and onboarding
- Autonomous service delivery
- Dynamic resource scale in/out and optimization Closed-loop remediation with intent
- Budget limit-based service delivery

Figure 12*: Self-ordering*

1. **Intent translation and decomposition study**

Service providers and end customers (users) have varied demands for services over a network. While meeting end users' demands, service providers want to minimize the amount of data that is transmitted to reduce operating costs and respond quickly to maintain user satisfaction. These demands are defined as intents (see Section 3), and the aim is to enable service operation on the basis of them. (We'll look at some additional intent use cases in Section 5.2.)

Figure 13 shows the technologies for achieving intent-based operation. Intents are not always given as specific requirements by users. For example, ambiguous demands for functional requirements, such as “enjoying watching sports”, or ambiguous demands with no index or value for the quality or performance of certain functions, such as “feeling of being there” can be assumed.

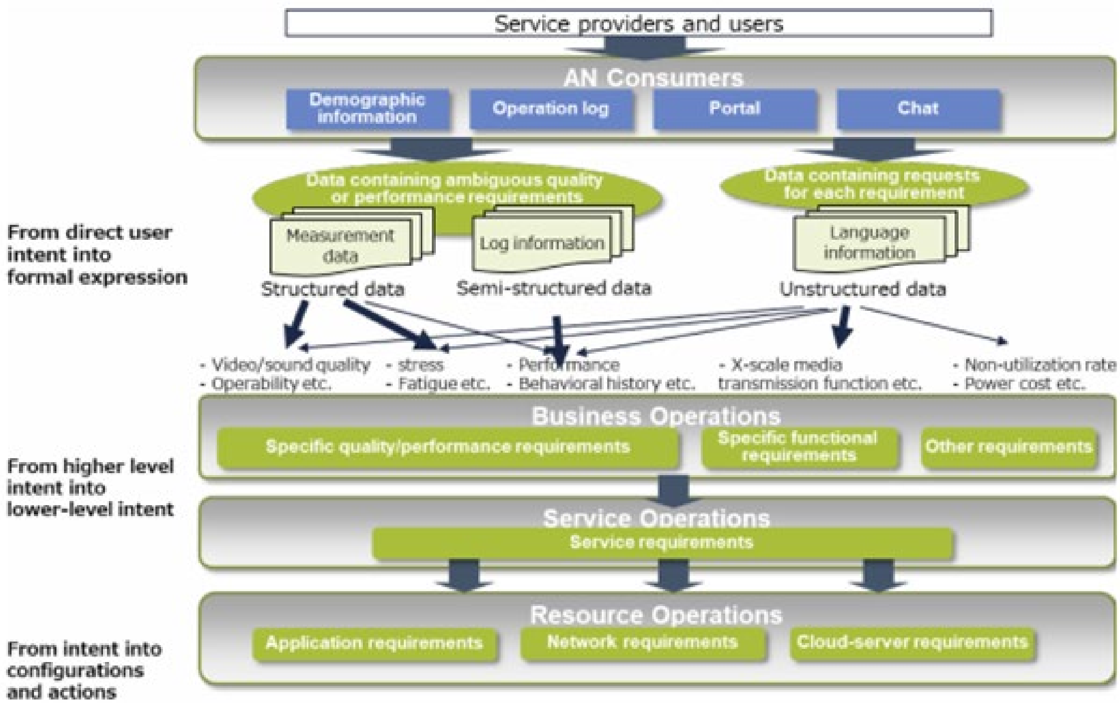

Figure 13*: Fundamental technologies of intent-based operation*

To apply these ambiguous intents in service operation, the team needs to break them down and define a set of requirements (intent definition) – see Figure 14. To express quantitative values of non-functional requirements related to quality or performance, the Catalyst is studying the definition of general indices for various intents and quantitative values for each index.

A set of intents of service providers and users	Specific requirements	
Good video/sound quality	quality/ performance	Media quality index（MOS）
Excellent operability		Operability index
Task-processing accuracy greater than that of humans		Performance index
Audio/ Visual support for operation		Biologic index
Identification of suspicious persons	function	Video distribution function
Games can be played anywhere, anytime		Image analysis function
Holding events at many remote locations	Others	RPO(recovery point objective)
Accelerating fault detection and recovery		RTO(recovery time objective)
Reduce power consumption		Power consumption

Figure 14*: Intent definition*

Intent-extraction technology

This technology collects information related to users' intents and extracts a set of specific requirements. Intent-related information is 1) language information through the input interface for users and 2) information obtained in-service related to these users. The Catalyst aims to extract a set of specific requirements that users have by using various types of information.

Resource-requirement-conversion technology

Specific requirements extracted with intent-extraction technology need to be converted into indicators that can be controlled by the resource controller. A two-step function, 1) quantitative intent -> high/low-level intent 2) high/low-level intent -> configuration, is required. The technology to achieve quantitative intent can be developed not only by conventional machine learning, but also by the hierarchical KPI structure and implications of KPIs for intents.

Implementation architecture of AN hyperloops

By combining Self-X capabilities with intent study, the Catalyst is exploring much new ground, and new component areas need to be introduced in reference to AN reference architecture. Intent extraction as part of knowledge and intelligence plays a major role in during the journey to usable intent-driven orchestration (see Figure 15).

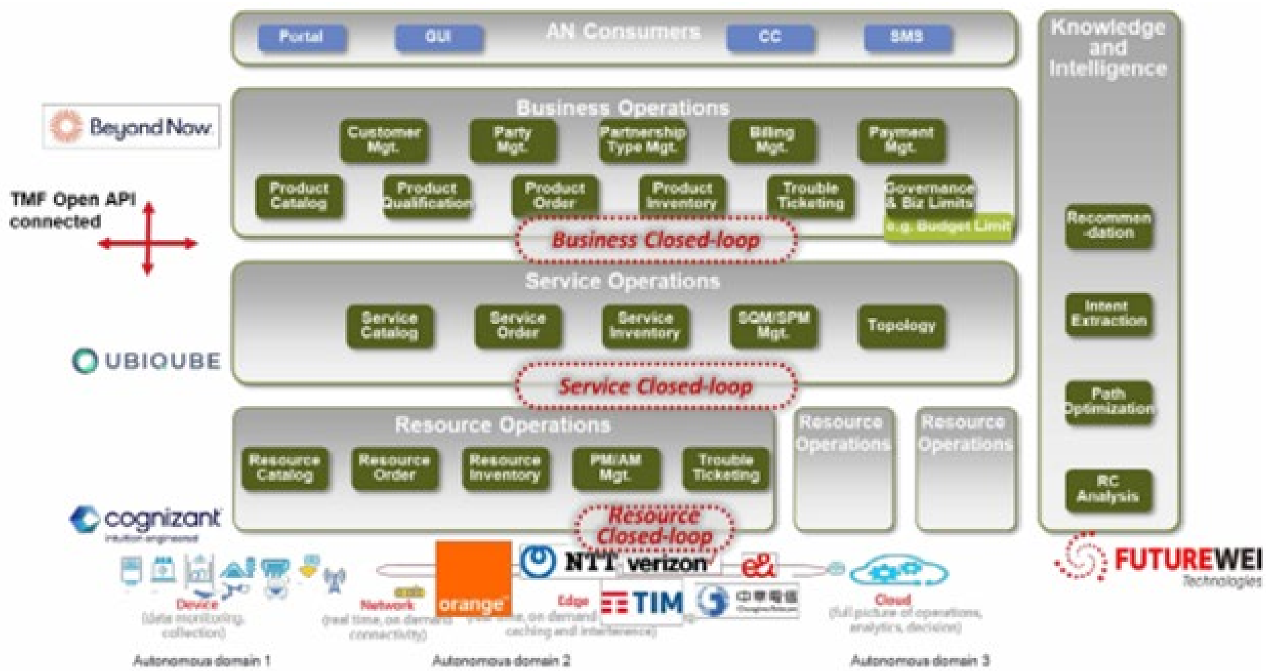

Figure 15***: Implementation architecture***

1. **Scalability and elasticity with energy efficiency**

The Covid-19 crisis is accelerating digital transformation across industries. Digitalization dramatically changes customer behavior. Driven by the new demand for contactless self-service ordering, many companies have seen on-demand services as a critical priority for the upcoming years, and continuously automate processes to improve efficiency, respond to fast-changing customers' needs and so on.

Using AI to make energy use more efficient

The change in energy consumption over time brings time series data that can be used to understand patterns and predict future patterns. Machine learning can be used to achieve the best energy efficiency and AI can be used for solving the time series forecasting problem. In the implementation, various data such as configuration, network traffic and performance indicators can be collected from the live network. Deep learning can further predict future network traffic and energy utilization. Based on AI prediction, some interfaces and functions of the device can be turned off without affecting the service experience to achieve the purpose of energy saving.

On-demand self-service networks make eco easy

Network-on-demand not only provides business agility, but also cost-effective energy efficiency. ANs keep network services performing smoothly and fulfill the SLA target. Moreover, the Catalyst introduces the capability to dynamically onboard network functions depending on the specific connectivity requirements whenever needed and to promptly eliminate those functions once the requirements are fulfilled, so as not to consume more energy.

4.1.5. Autonomous Networks Hyper Loops for disruptive digital services Phase II - Smart Agriculture

New, disruptive and innovative digital services that are completely autonomous and designed for zero-touch and zero-fault operations could revolutionize the future of how we do business and interact with society. These new digital services offer a great opportunity for service providers to increase their revenue through new services they can offer to their customers. To be able to offer many of these digital services such as smart industry, cities or health, CSPs need to automate their operations and gain efficiencies so that they can be delivered at a cost point the market requires.

Autonomous Networks with zero-wait, zero-touch and zero-trouble capabilities empower CSPs to monetize & support the diverse set of vertical use case requirements. Once Autonomous Networks are in place service providers, B2C customers, digital service providers (DSPs) and telecom service providers will benefit from better, seamless experiences and improved operational efficiencies. In addition, the end-to-end lifecycle complexity will be hidden away from the user and self-assurance will be inbuilt.

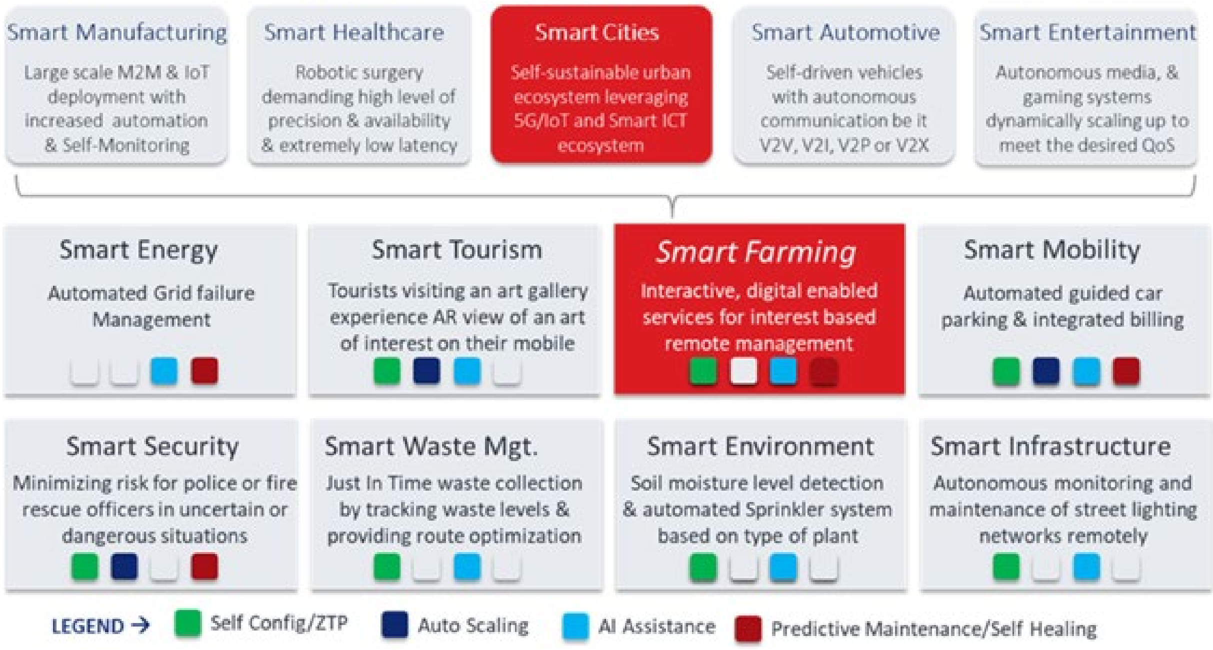

Figure 16*: Examples of vertical use cases that benefit from Autonomous Networks*

From the vertical examples listed above, smart agriculture is a paradigmatic use case where Autonomous Networks are key for CSPs to deploy smart agriculture solutions and services that can help farmers become more efficient and increase their profitability by managing crops and livestock in real-time. These solutions will require the connection of many IoT devices spread over large and complex areas gathering lots of information such as tractor location, weather forecasts, soil moisture levels etc.

A good example of smart agriculture being currently explored by one CSP is how they can improve rice planting with autonomous drones, to optimize seed use, avoid planting during unfavorable weather as well as improve worker efficiency. The drones will be connected to a wireless access network and collect lots of data from sensors and sources such as weather reports and then collate all of this data as well as stream back live video feeds to the farmers via an app on their smartphone. Machine learning and AI will use all of this information to recommend the best time to plant the seeds as well as to pick out the most favorable locations to increase yield and reduce the risk of disease by spotting the disease signs early and recommending immediate actions.

Solution Architecture powering Autonomous Networks

To achieve Autonomous Networks for vertical use cases (as described above), maturity is required across the Resource Loop, Service Loop, Business Loop and User Loop. The simplified architecture to achieve this maturity is as shown below

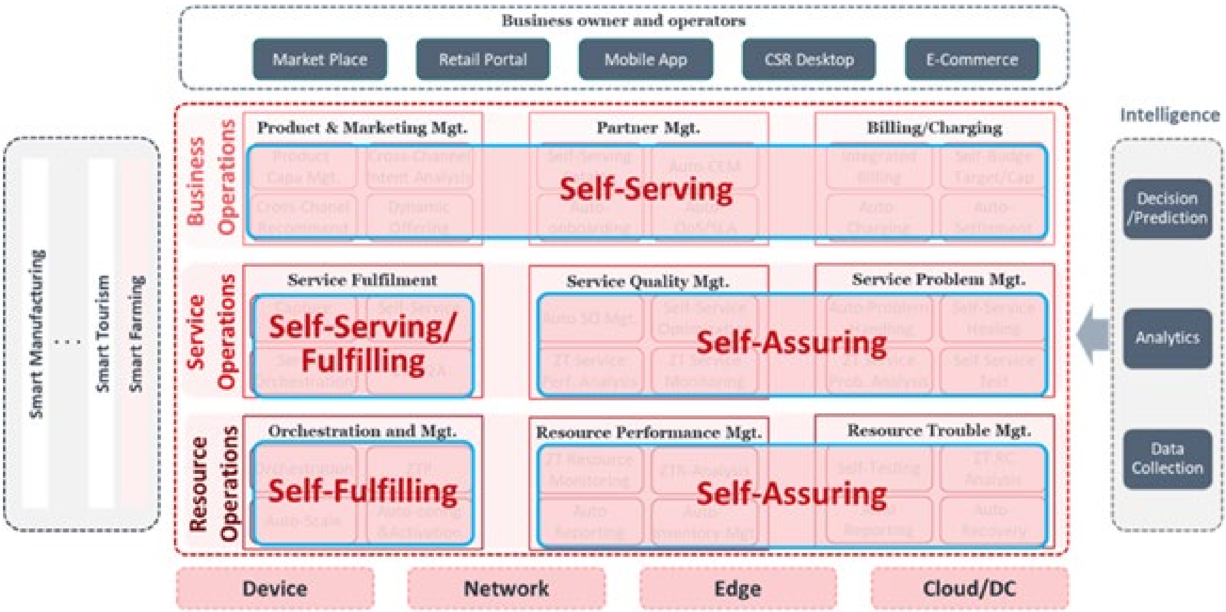

Figure 17*: Simplified Solution architecture of Autonomous Networks*

- **Business Operations (BO)**– This layer presents the Business rules and Business Intent for enabling Self-planning & Self-marketing capabilities to facilitate zero-friction products towards their end-users and business partners. It defines the master product catalog, which will drive the business intent decomposition into service intent and to centrally manage the autonomous order management process i.e., Self-ordering, including autonomous order-2-activation.
- **Service Operations (SO)**– This layer represents autonomous service life cycle management comprising Self-ordering, Self-organizing and Self-managing capabilities in addition to Self-Assuring. It captures business intent and provides autonomous service orchestration, self-service assurance, etc. to govern the accurate translation of service intents to resource intents.
- **Resource Operations (RO)**- This layer represents autonomous resource management functions to Self-organize, Self-manage and Self-Assure the physical, virtual and logical resources in order to fulfill the resource intents and address the customer requirements. RO defines and governs the resource instantiation, configuration, resource life cycle management (LCM) and performance metrics.

CSPs can monetize and support Smart-X industries like – Smart Cities (Smart Tourism, Smart Farming, Smart Energy), Smart Manufacturing, Smart Healthcare by leveraging the above vertical/domain agnostic technical architecture.

Scope of the PoC

Our approach to realize this technical architecture with Self-X capabilities based on AN Framework is by pivoting few key use cases. In our catalyst we defined Self-Serving, Self-Healing & Self-Optimizing use cases for Smart Farming vertical. While defining these use cases we considered several constraints and service quality parameters like Budget cap of a farmer, intent driven SLAs & SLOs, KPIs like throughput, capacity and so on.

We are bringing in the 3 dimensions – Intents, the technical architecture & AN framework within and across the loops to achieve these use cases and to extend seamless experience.

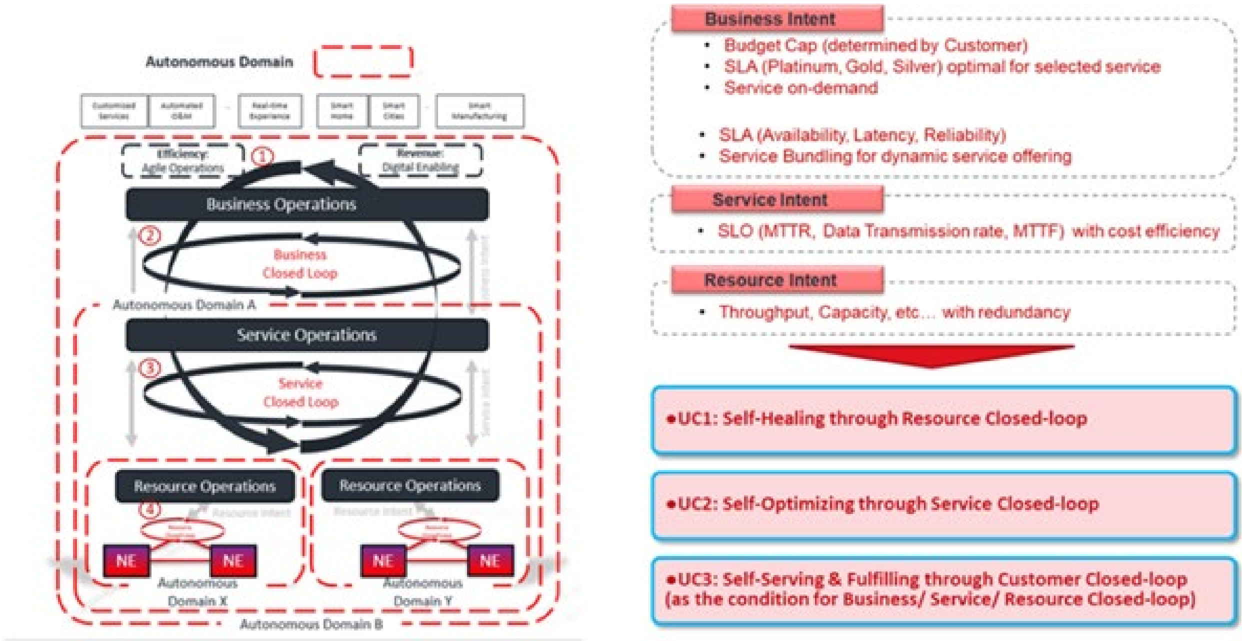

Figure 18***: Autonomous Networks Hyperloops Use cases with Intent***

High Level Technical Architecture (with processes)

As we zoom into each of these layers, each Self-X capability translates to multiple Self-X components.

Self-Serving functions in the Business Operations layer facilitate Zero-X experience in Product Marketing & Ordering, Partner Management, Seamless Billing & Charging to their subscribers and business partners. It presents the master product catalog, which will drive the business intent decomposition into service intent and to ensure zero touch ordering, Self-fulfillment and autonomous order-2-activation.

Self-Serving & Self-Assuring functions in Service Operations layer aims at Autonomous Service Lifecycle Management comprising policy driven service instantiation, Autonomous service orchestration, zero touch service chaining, Closed loop service assurance, self-healing etc. to govern the accurate translation of service intents to resource intents.

Resource Operations layer represents autonomous resource management functions to self-monitor, self-optimize and self-heal the cross domain physical, virtual and logical resources to fulfil the resource intents and to address the customer requirements. RO defines and governs the resource instantiation, configuration, resource LCM and performance metrics.

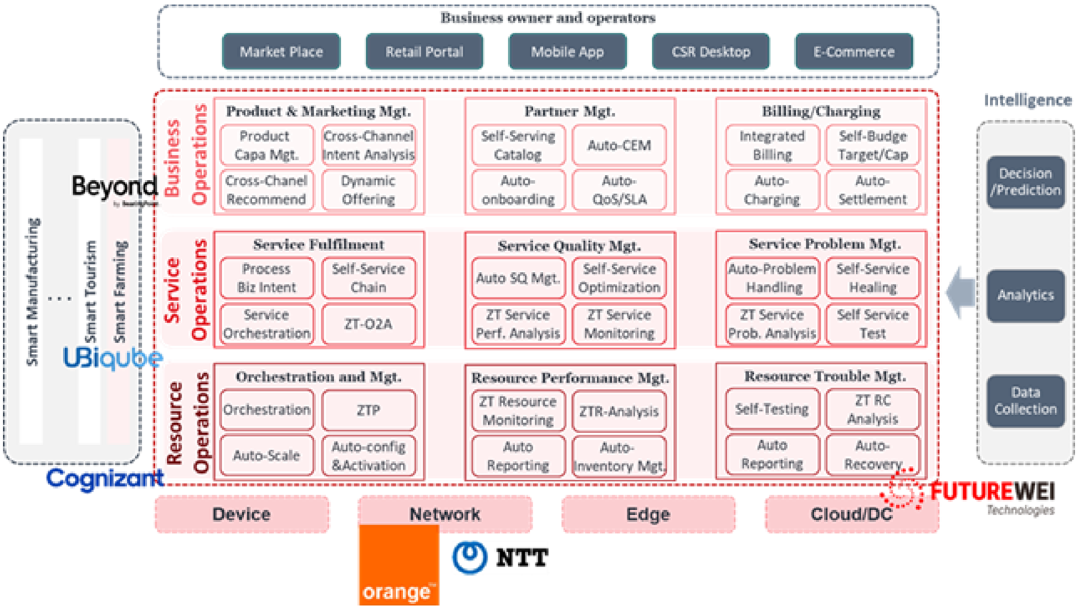

Figure 19*: Solution architecture of Autonomous Networks Hyperloops*

High Level Solution Architecture of Autonomous Networks Hyper Loops

In reference to TM Forum Open Digital Architecture, several new grounds are being explored in this catalyst, and new component areas need to be introduced. Intent Extraction as part of Intelligence management plays a major role on the way to arrive at usable intent-driven orchestration. Targets&Caps Management, which we have seen to be much more than just an extension of real-time billing, are needed to put limits on the possible activities of autonomous operations, who no one wants to run unchecked.

CSP enabling Smart Farming

CSPs can monetize the Smart Farming use case to empower farmers with cost & time efficient management of farms leveraging Zero-X experience based on AN business and technical architecture across the layers including the edge at Turtlebot/Drone with Video capability, edge container, virtualization, automated to autonomous, AI & insights analytics, 5G. The reference architecture to achieve AN for Smart Farming is depicted below:

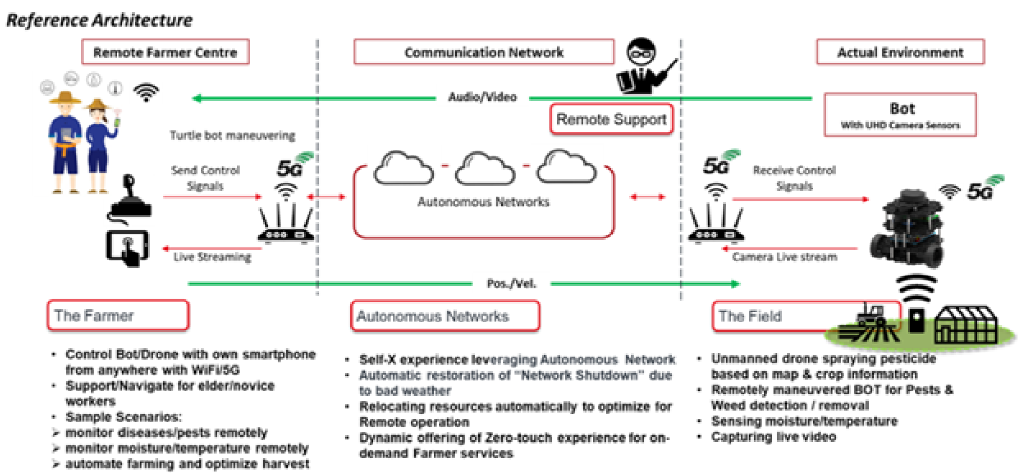

Figure 20*: Smart farming use case*

This Smart Farming use case described above aims to demonstrate autonomous behavior across all 4 loops as describe in chapter three (Resource, Service, Business & User) with 5G network as the connectivity backbone and video analytics capabilities at the edge. Autonomous self-service assurance is depicted below as an example of usage of Autonomous Networks capabilities, the detailed information can be found at TMF catalyst project - Autonomous Networks Hyper Loops and related whitepaper.

Autonomous Self-Service Assurance

One of the key elements of providing seamless autonomous services to farmers is zero trouble service assurance. It's a leapfrog transformation in the quality of service from manual and reactive troubleshooting to resolve workflows to autonomous predictive/preventive self-optimizing and self-healing networks. Autonomous self-service assurance workflow aims at zero impact to services extended to farmers and optimizing the total cost of ownership (TCO) for the service provider in managing the promise of zero-trouble/zero-impact services.

The autonomous workflow depicted below aims at zero-friction services to farmers. The key elements of autonomous service assurance workflow are:

- Service & Resource usage monitoring (QoS/QoE/SLA)
- Autonomous Service instance (PM & FM) Analysis
- Zero-touch service incident reporting and LCM
- Autonomous Root cause analysis
- Dynamic Resource Scale In/Out & Optimization
- Closed-loop remediation with Intent
- Automated temporary / permanent fix

Assumption: Service operations layer interacts with resource operations layer based on Resource Intent which is decomposed from Business & Service Intent.

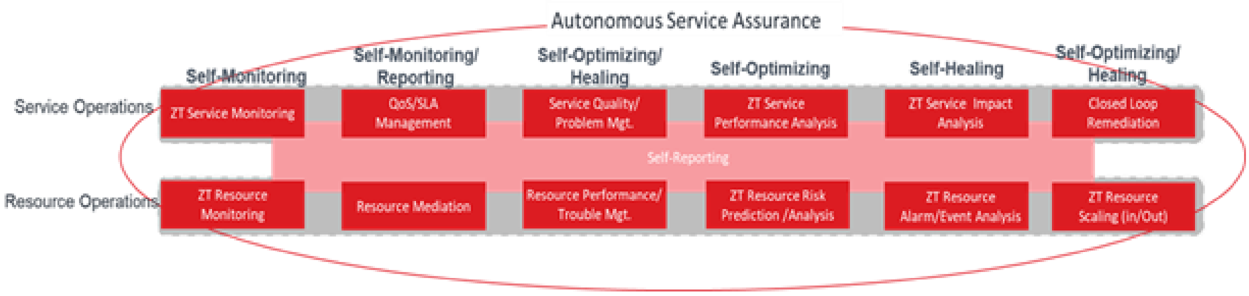

Figure 21*: Autonomous Service Assurance workflow*

- **Self-Monitoring – Zero Touch Service/Resource Monitoring**: Leverages Service/Resource performance and availability Management, Pro-active service/resource monitoring capabilities to monitor the services against defined Quality of Service & SLA and predictive reporting of the service/resource status for preventive actions.
- **Self-Monitoring/Reporting – QoS/SLA Management**: Leverages Self-Monitoring capabilities to manage the service & resources of the network against defined SLA and report the service/network resource status through automated incident management & its lifecycle management (LCM) using intent driven interaction, which will be handled by resource operations layer and service operations layer accordingly.
- **Self-Optimizing/Healing – Service Quality/Problem Management**: Leverages automated hidden risk prediction & automated fault identification capabilities to autonomously manage the Service quality, Service/Network problem.
- **Self-Optimizing – Zero Touch Service Performance Analysis**: Based on the service performance trend and risk predictions, the system leverages AI/ML capabilities to assess the efficiency of resource/service allocation and to autonomously suggest preventive optimization actions.
- **Self-Healing – Zero Touch Service Alarm Event Analysis**: Based on the generated incidents & the predicted service instance problems, the system leverages AI/ML capabilities to predict/depict resource impacts, service impacts & to autonomously arrive at Root Cause Analysis to enable further actions.
- **Self-Optimizing/Healing – Closed Loop Remediation**: Based on the Service Performance Analysis and/or Service Alarm Event analysis, the system leverages Self-Optimizing and Self-Healing capabilities with Self-testing to relocate or assign resources (e.g., Scale-in or Scale-out) autonomously to provide intent-driven service assurance.

4.1.6. China Telecom: Smart Manufacturing – Multi-Cloud and Multi-Base Autonomous and Flexible Interconnection

Large manufacturers typically own multiple R&D bases, manufacturing campuses, test sites and offices. To leverage digital transformation in many areas of the business including R&D, manufacturing, office buildings and marketing departments, manufacturers require a network to suit the needs of manufacturing, research, quality inspection and marketing. Such a network featuring "multi-branch collaboration and one-point access to multiple clouds" is described in Figure 22.

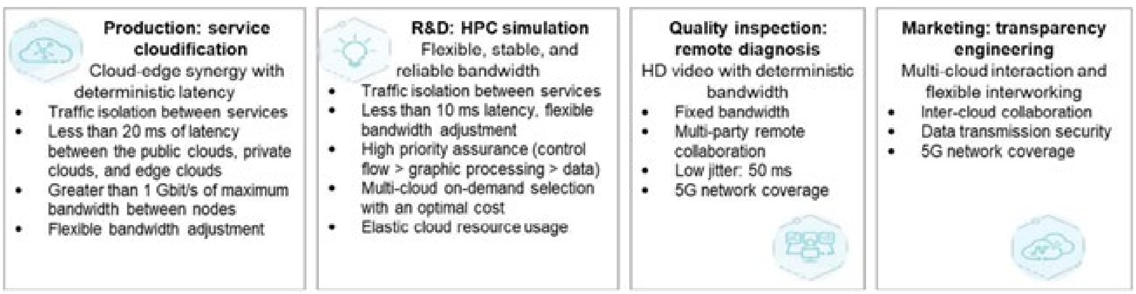

Figure 22*: Manufacturers' network needs*

To meet the requirements of manufacturers, China Telecom integrates the cloud network and operations system combining with the three-layer AN architecture. This allows the company to introduce new technologies and ideas, build the cloud private network solution, and implement AN cloud network operations.

On one hand, the business and service operations layers deliver cloud network management and control capabilities to enterprises. Customized and lightweight operations applications and self-service options, such as service self-subscription, traffic control self-adjustment, network self-monitoring and fault self-maintenance are available for enterprise network management personnel. On the other hand, automatic and intelligent service orchestration and cloud network resource orchestration and scheduling are applied to build service-level slices in private networks for various production scenarios in the manufacturing industry.

For example, dedicated slice and deterministic capability assurance are provided for production services. IP MANs are used to provide office and outbound services. Intelligent slices are used to flexibly plan bandwidth and priorities on demand for broadband scheduling services (such as design solution, video conference and finance). With a complete network topology, the traffic direction and link status on the private network are monitored in real time.

At the resource operations layer, exclusive access devices are deployed in enterprise campuses. These devices are pre-connected to multiple clouds and networks to implement integration-free and one-stop access. Technologies such as slicing, SRv6, and in-band detection are introduced, improving the precision and accuracy of automatic network performance detection and the flexibility of intelligent service path optimization, and providing differentiated and deterministic SLA assurance for different applications.

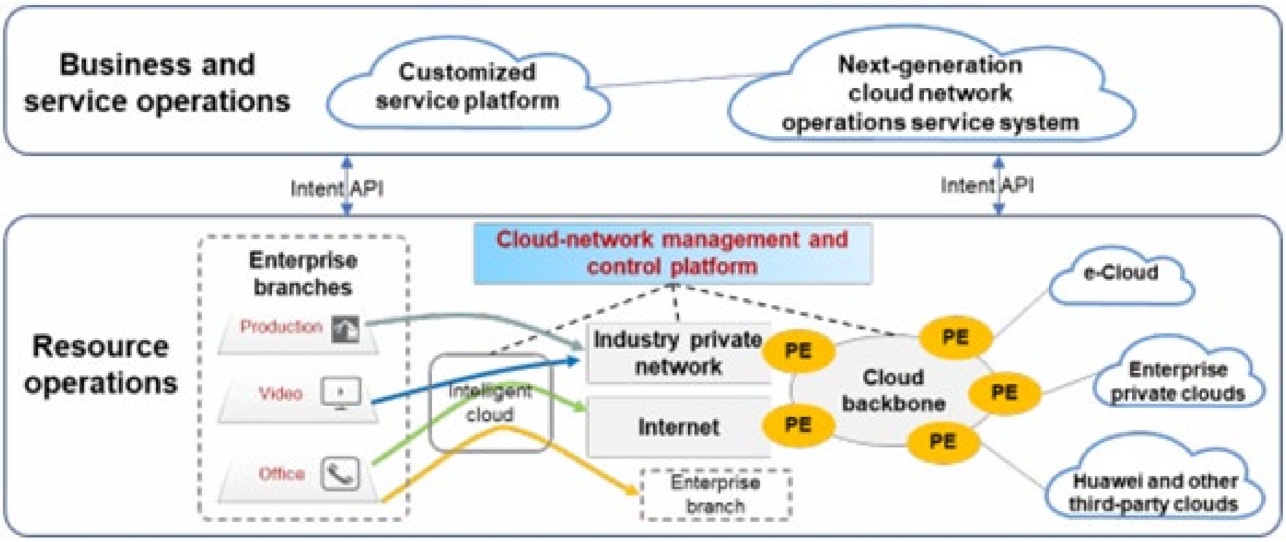

Figure 23*: Overall architecture of the cloud private network solution*

China Telecom's cloud private network solution has been widely applied to thousands of large manufacturers, helping them achieve multi-location autonomous interconnection, intelligent traffic control, independent and visualized management control, and improved SLAs. The solution deploys private line services into overall connected services, consolidates the capability of one network connection to multiple clouds, and provides a better multi-cloud access experience for enterprises. Some of the positive results include:

- Multi-location autonomous interconnection – shortens the private line provisioning time on both the cloud and network from one to two weeks to a few minutes. On-demand and flexible networking is supported, meeting enterprises' requirements for cloud access through any network, one line to multiple clouds, and high-quality mutual access between multiple bases.
- Intelligent traffic control – reduces IT personnel's workload by 20%.
- Independent and visualized management control – provisions new connections within minutes and changes SLA levels such as bandwidth and latency.
- Improved SLAs – reduces the maximum one-way latency from 15ms to 3ms, the maximum jitter from 60ms to 150ms, and brings down the average packet loss rate from 1% to 0.001%, providing high-quality network services for enterprises.

4.1.7. China Unicom: Agile Service Provisioning – Intent-Based Automatic Provisioning of Enterprise Private Lines

Legacy enterprise private line service provisioning was mainly performed manually, including networking solution design, resource scheduling and resource allocation, and the workflow of service provisioning had breakpoints for automation. When resources were available, the service provisioning still required one week.

China Unicom is committed to providing customers with zero-wait and self-provisioning agile service experience and proposes an intent-based automatic provisioning solution for private line services. The solution adopts the three-layer architecture of AN and uses intention-conversion technology to convert the customers' business intention into the specific service, sending the request to the orchestration module through the intent execution interface. Figure 24 on the next page shows how autonomous service provisioning works, and an explanation of what happens at each layer follows.

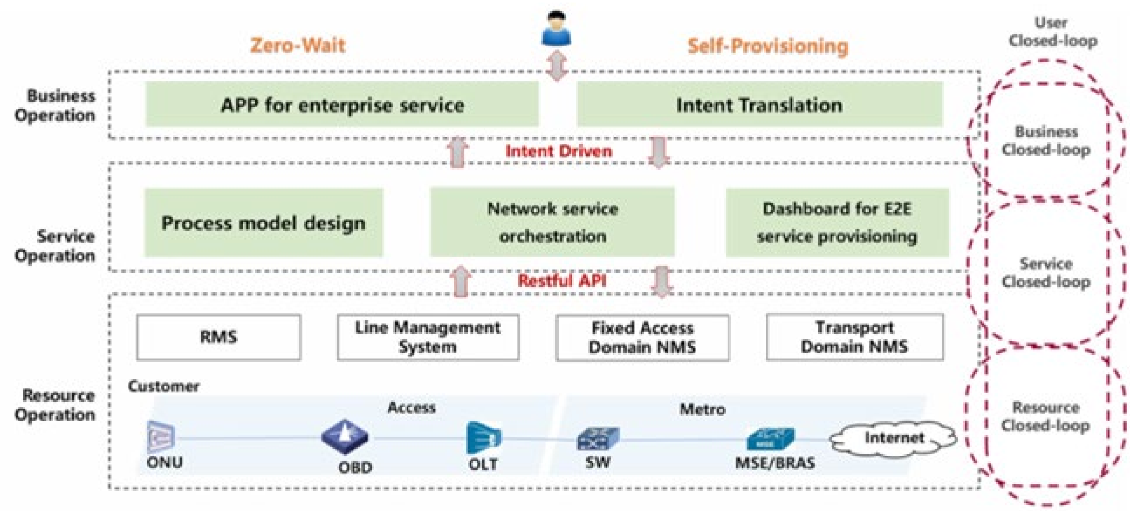

Figure 24***: Autonomous service provisioning***

Business operation-intent handler – converts a customer's business intention into a service intention. The handler receives the customer's intention, determines the specific service through intent matching, and invokes the service through the intent execution interface. Take internet private line provisioning as an example. It is a business intention, and through intention matching decides to provision an internet private line service, such as PON.

Service operation-service orchestration – this refers to the Open Digital Architecture (ODA) Product, Service, Resource (PSR) model. The network service is orchestrated into resource- and customer-facing services (RFS and CFS) through a graphical user interface based on the service provisioning action flow. The designed and compiled CFS model is deployed to the running state and uses an Open API to provide services. For example, the Internet private line can be orchestrated as PON access CFS, IP RAN access CFS, and fiber direct connection CFS.

Resource operation – the provisioning platform is connected to the fixed access domain network management system (NMS), transport domain NMS, line management system, and public customer system, thus realizing end-to-end automatic provisioning of private lines.

The intent-based enterprise private line automatic provisioning solution hides the complexity of the operations and reduces seven manual processes. The provisioning duration is shortened from days to minutes. This effectively improves customer experience and improves the autonomous network level from L1+ to L3+ in service provisioning scenarios.

4.2. Customer Experience and Business Growth

4.2.1. AIS: Customer Complaint Prevention

To improve customer experience (CX), AIS will leverage a new solution called CCP (Customer Complaint Prevention), which captures real-time CX data, network events and process information based on an AI model to proactively identify poor experiences. Then, using resource operations intelligent analysis and a decision engine, AIS can identify customers' problems and through optimization automation solve them to deliver a "wow" experience. Figure 25 shows the CCP architecture.

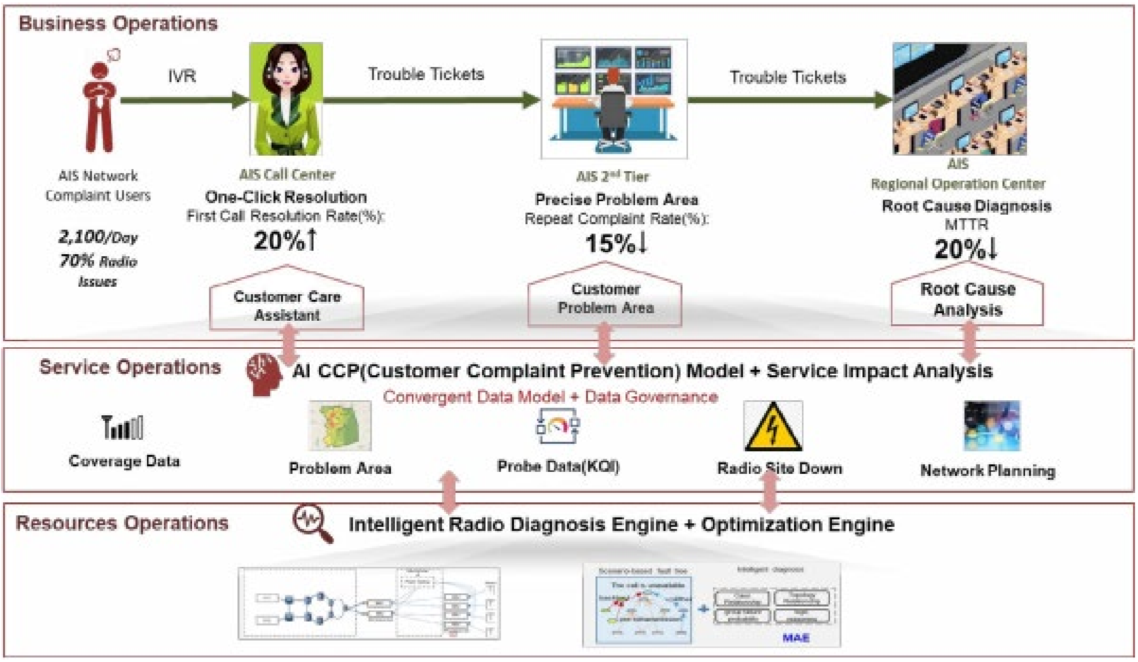

Figure 25: ***shows the CCP architecture***

1. **Know customers' problem before complaints**

- **Service impact analysis** – AIS captures "site down" events from fault management systems and from customers' probe data to identify customer-impacting events. It integrates the impacted-customers list to an interactive voice response system and through SMS proactively notifies customers, intercepting complaints with proactive/ reactive notification.
- **CCP model** – using historical complaint data (for example, KPIs, KQIs and radio measurement reports) and an AI engine, machines are trained to learn poor-experience patterns and output the knowledge to the CCP model. The model will deploy to real-time environments and based on KPI/ KQI/radio events identify in near real time other customers who have similar problem patterns.

   a. **Self-X capabilities by Intelligent diagnosis**

- **Intelligent Diagnosis Engine** – once AIS has identified customers with poor experience, the company uses integrated coverage and signaling data, known problem areas, customers' probe data, network planning data and network fault event data to build an integrated root-cause analysis engine to quickly analyze the root cause of customers' problems and suggest next best decisions.
- **Network Optimization Engine**: around 70% of network complaints are radio issues, such as weak coverage, congestion and interference. Once radio issues are discovered, the intelligent diagnosis engine can also find problem cells. Since radio network optimization involves lots of factors and expert experiences, AIS is trying to build a rules-based engine to consolidate the original human knowledge base and best practices in order to automatically suggest to next best action to improve network optimization and customer experience.

Benefits

Using its AN framework, CCP, intelligent diagnosis and a network optimization decision engine, AIS can proactively identify customers with poor experience and determine the root cause. Then through the service operations closed loop, the company is able to provide distinctive customer experiences. AIS expects the following results:

- Reduction of complaints from mobile customers through proactively informing them
- Increase in first call resolution in the customer care center
- Reduction of repeated complaints
- Reduction of average handling time for customers' complaints.

4.2.2. HKT：Zero-X Customer Experience on Health Tech Apps (Dr. Go)

The Covid-19 pandemic created a market need for remote medical consultation. HKT (Hong Kong Telecom) launched a health tech platform called Dr. Go, the objective of which is to build an intelligent B2B2X platform to link up Health Care partners (hospitals, doctors, pharmaceutical companies, etc.) and patient and health products consumers. The Dr. Go apps (see Figure 28) connect patients and doctors through high-definition video calls. HKT, joining with Huawei technology, deploys the autonomous operation concept to enable Zero-X experience.

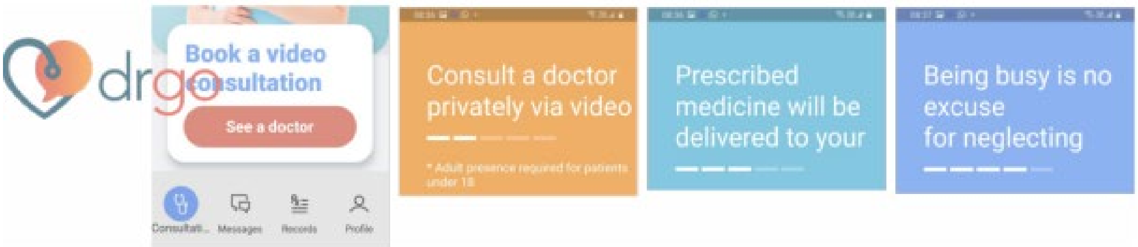

Figure 26*: Dr. Go apps functions*

Dr. Go apps eliminate human support in booking appointments with doctors, to achieve zero-touch. The appointment bookings are made through self-selection, and calls to talk to doctors are also established within seconds, achieving zero-wait. To achieve zero- trouble, an Autonomous Operation approach focuses on the service closed loop and the resource closed loop.

To ensure quality video calls, Autonomous Operation with AI modelling and Customer Experience Index+ (CEI+) digital metrics are being used for service guarantee of all video calls. Figure 27 shows the autonomous framework concept used in the use case.

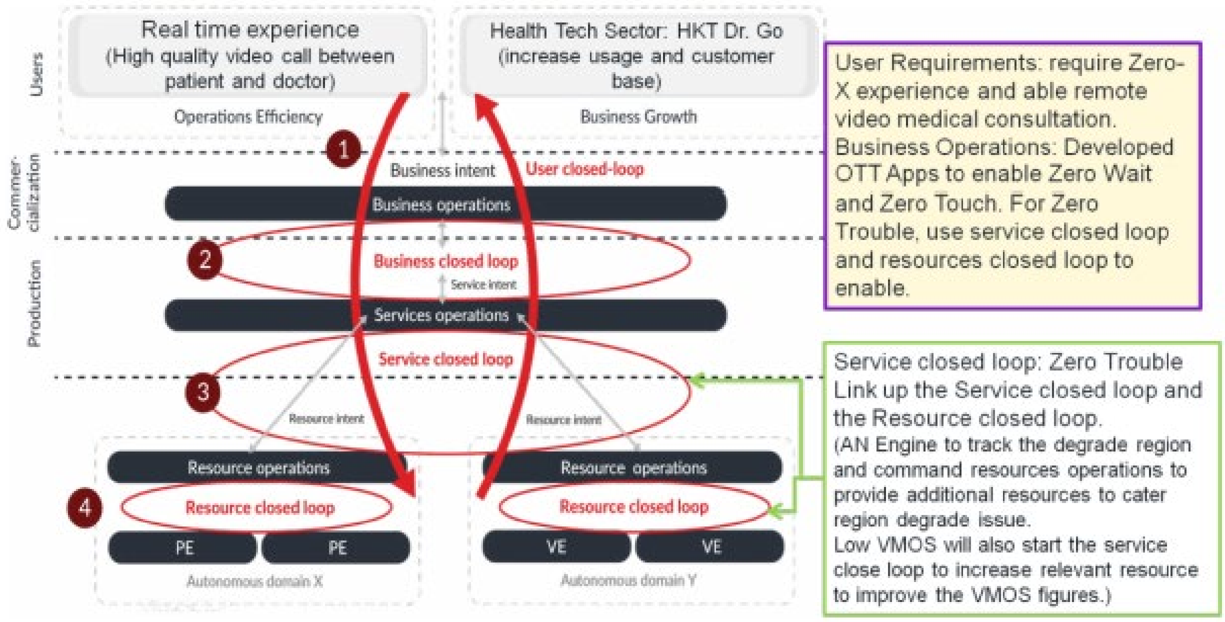

Figure 27*: Dr. Go with superior CX to support Health Tech Platform*

Figure 28 on the next page shows a high-level diagram on the AN approach using the Intelligent Engine. When the CEI is low, the Intelligent Engine will look at the quality of experience (QoE) and the KPI/KQI responsible for changing VMOS (Video Mean Opinion Score) figures. Identifying the problem set of figures, the Intelligent Engine will command the relevant resources cluster to provide additional resources to improve the VMOS figures.

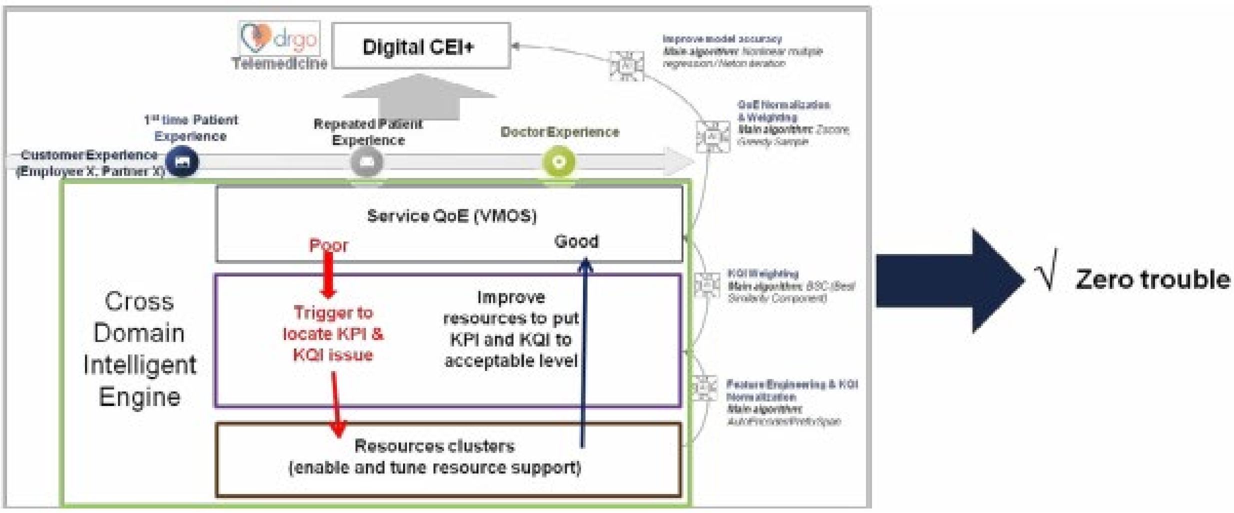

Figure 28*: Intelligent Engine to support Zero-X*

Business benefits and outcomes

With the advance in Autonomous Operation, HKT is able to provide zero-trouble connections to Dr. Go apps. Patient and Doctor are able to experience high-quality video connections during medical consultation. With good experience and word of mouth, the customer base increased by 214% year over year. Dr. Go also won "Asia Smart Apps Award 2021 – Public Sector and Social Innovation" and "The Global Economics Award 2022 – Technology: Best Telemedicine Mobile Apps".

Next steps

- Health Tech platform (all-in-one): with its immense success, Dr. Go is building an all-in-one healthcare platform that includes vitamins, electronic medical wearables, organic food, etc.
- Autonomous operation on mobile slicing platform: HKT and Huawei are working towards a medical mobile slicing platform supported by AN.

4.2.3. Telkomsel Indonesia: AI for Crowdsourced User Experience

User experience is replacing network performance as a main criteria for assessing CSPs' network operation and maintenance. As a core strategy of Telkomsel, its AN efforts are focusing on user centricity. Traditional service experience optimization methods rely on engaging significant manpower in test-driving and analysis, but while these costly activities consume lot of time, the impact to overall users' experience remains uncertain.

To overcome this challenge, Telkomsel has worked with ZTE and other partners to develop a solution that uses crowdsourced data as additional user experience assessment criteria and enables a network optimization closed-loop automation for improving application-level experience. With this solution, the service layer manages experience-to-network mapping, network assessment and proactive assurance. The resource layer manages the crowdsourced experience monitoring, network fault detection and wireless optimization.

Architecture and solution

This solution includes four major innovations: baseline self-study, user experience-network KPI correlation, intelligent root-cause-analysis (RCA) and AI-based network tuning. With its implementation, the level of network automation is enhanced further as shown in Figure 29.

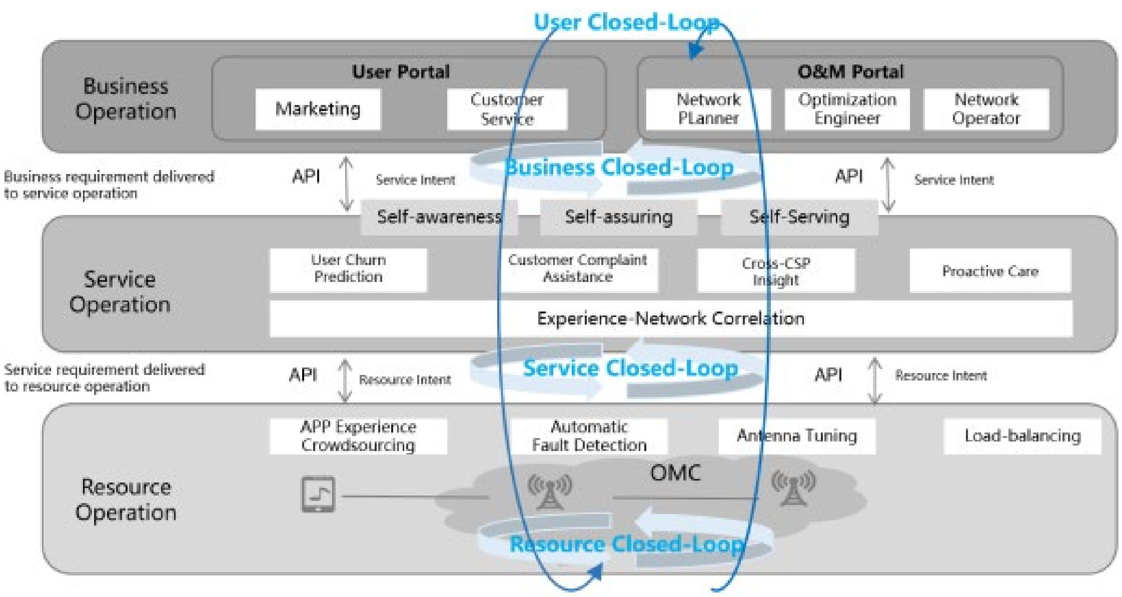

Figure 29*: AI for crowdsourced user experience solution*

Resource closed loop

- **App experience crowdsourcing** – assess app-level experience captured from various mobile applications and numerous users
- **Fault detection** – prevent, improve, or accelerate resolution of network element (NE) hardware faults thanks to RCA and historical alarms correlations
- **Antenna tuning** – optimize coverage and reduce interference issues through AI-based and machine learning configuration management of antenna parameters
- **Load-balancing** – optimize network resources allocation with AI-based automatic load balancing control to NE.

Service closed loop

- **Experience-network correlation** – correlate user experience KPIs and network KPIs, identifying the most impactful network parameters on user experience.
- **User churn prediction** – identify at-risk users and prevent churn based on historical user behavioral data and experience assessment data
- **Customer complaint assistance** – minute-level trace back to user complaints on poor service experience
- **Cross-CSP insight** – assess/benchmark current service experience vs. competitors and find the gap areas for improvement
- **Proactive care** – proactively detect and optimize cells with low service experience score.

Business closed loop

Through coordination of the resource layer and the service layer, the business layer assures service experience with an automatic closed-loop of network problems, realizing one-click complaint handling and real-time service experience management for improving user satisfaction.

Benefits

After one month of operation in an observed area, the following benefits were identified:

- **App experience** – the average game latency reduced from 37ms to 35ms (5.7% improvement), and the average video stall frequency reduced from 0.1 times/play to 0.08 times/play (20% improvement).
- **User satisfaction** – NPS increased from 51 to 59, and churn rate dropped from 6.2% to 5.5% (to one month before).
- **Efficiency** – the optimization cycle has been shortened from one to two weeks to just one to two days.
- **Revenue** – cost saving, churn reduction, and higher productivity is estimated to bring an annual revenue gain of $62.33 million for a nationwide deployment.

As this solution is implemented in more regions, the user-centric planning, optimization, O&M and marketing will become more visible, manageable and automated, moving forward a higher-level network autonomy.

4.2.4. China Mobile：Intelligent Diagnosis of Network Quality for Home Broadband Services

After the epidemic in 2020, rigid demands for home offices and online education have been activated. The rapid popularity of new applications such as video live broadcast, XR games, and smart home has further promoted the development and popularization of home broadband services, especially gigabit broadband. The diversity of requirements and services raises higher requirements on broadband rates, latency, availability, and fault rectification. Therefore, how to comprehensively and accurately perceive the service experience of each home broadband user, provide certain service assurance, and obtain greater business value through precision marketing of value-added services are the key issues that CSPs need to address in the operation of home broadband services.

- **Experience assurance:** Existing problems such as insensitive perception, inaccurate positioning and untimely processing could greatly affect the user experience of home broadband services.
- **Value improvement:** Users' requirements for value improvement services such as quality improvement (different SLA assurance), home networking, and smart home cannot be accurately identified.

China Mobile fully absorbs the concept of "single-domain autonomy and cross-domain collaboration" of autonomous networks and introduces technologies such as Xgboost algorithm, edge computing, telemetry second-level collection, big data analysis, and network topology restoration. Focus on improving Self-X capabilities, such as self-marketing for target customers, self-monitoring/reporting of service quality, self-orchestration of network resources, self-healing of faults, and self-optimization of performance, to achieve precise value improvement and proactive service experience assurance.

- **Self-guaranteed service experience, self-healing and self-optimization:** The service operation layer monitors and reports user experience in real time, proactively identifies users with a poor experience, predicts complaints and prevents mass faults, drives user marketing or retention, and improves service and network quality. The service operation layer automatically analyzes the various code streams of video and games traffic in real time, finely identifies traffic types, and perceives the quality problem of different traffic according to the preset differential threshold. It orchestrates and schedules resources in real time to ensure service quality. It also drives the expansion or optimization of associated networks such as transmission and content distribution and drives content introduction. Based on distributed OLT edge computing and cloud platform AI, the resource operation layer automatically identifies the top 50+ applications with poor quality and reports service or network faults. For the link diagnosed with poor quality, the spectral clustering algorithm is used to analyze the performance index such as optical current, power, bit error rate, quickly locating the end-to-end network problems.
- **Self-marketing for target customers and precise value improvement:** The service operation layer automatically recommends marketing based on user preferences and tariffs and provides self-subscription services. Customers can subscribe to services on demand and flexibly combine services. The service operation layer comprehensively analyzes user services, tariffs, experience,

and network information to identify value-added service target customers. The resource operation layer provides the network and resource information of subscribers' locations and provides customer service preference and service experience perception.

After the solution being applied in China Mobile Henan's existing network, 450,000 cases of poor-quality problems, 8,000 poor quality lines and 150 poor quality content sources were actively identified. The diagnostic rate reached 90%. The network problems were dealt with ahead of customer complaints, which effectively improved the satisfaction with home broadband services. The ANL is increased from L2 to L3.

- **Zero interruption and proactive experience assurance:** The accuracy of proactive identification of poor-quality home broadband services is 95%, the user experience is significantly improved by 83%, and the average fault locating duration is reduced from 2.1 hours to 10 minutes. The system accurately identifies network bottlenecks and drives capacity expansion planning, improving the average user rate by 45%.
- **Self-marketing improves quality and revenue:** The target customer identification rate of value-added services reaches 95%. The success rate of smart home networking packages increases by 30%.

4.2.5. MTN：Build a Mobile Bearer Network with The Best Experience, Enabling Self-Optimization and Self-Closed-Loop Management

MTN has 19 mobile transport networks that are mainly operated in the African continent. Most of the subnets face insufficient transport resources and uneven traffic, resulting in traffic suppression on the mobile network. However, due to the lack of effective analysis tools, precise investment cannot be implemented to maximize value. Traffic distribution changes caused by the Covid-19 pandemic and site visit difficulties exacerbate this situation.

Solution

To give full play to network values and ensure user experience, MTN adapted the A-A-D-E (Awareness-Analysis-Decision-Execution) cognitive closed-loop into the transport network as “awareness- demarcation-locating, relief-recovery” to build a self-optimization and self-healing, congestion-free mobile transport network.

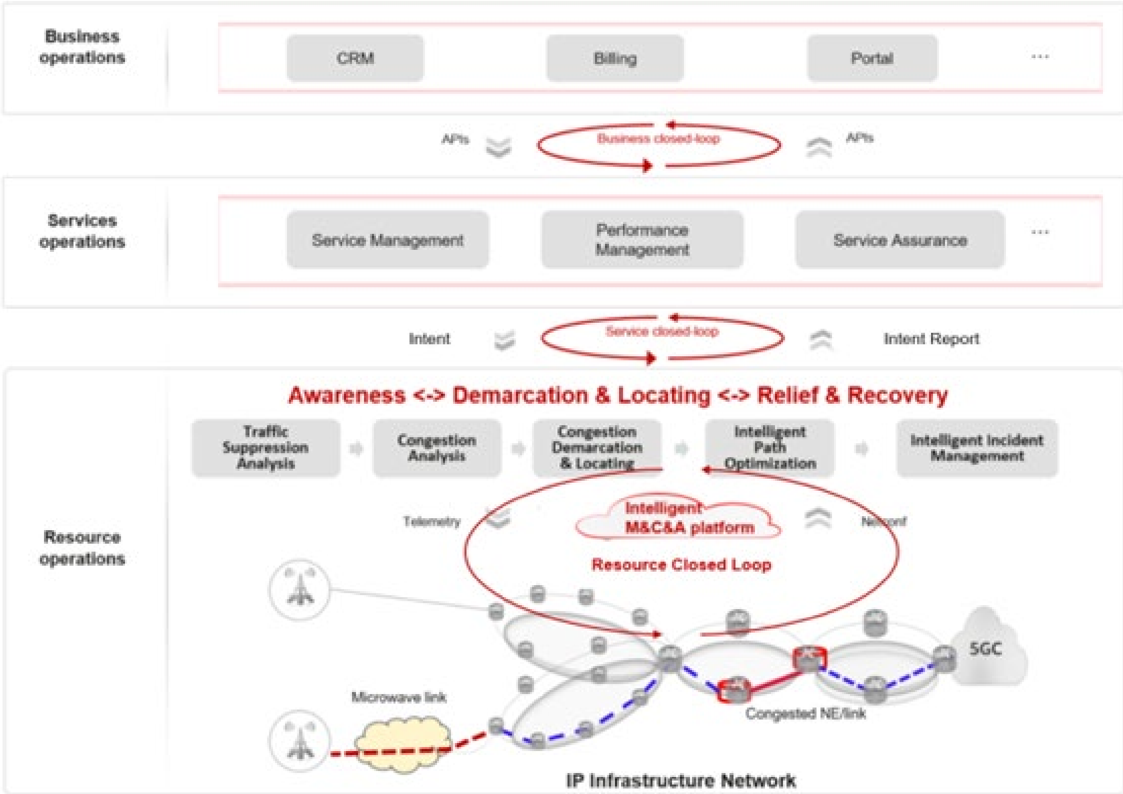

Figure 30*: IP Autonomous Network with congestion-free mobile transport*

With the implementation of the congestion-free solution, IP Autonomous Network is achieved through:

Resource closed loop

Awareness

- **Microwave and congested link identification** – end-to-end two-way active measurement protocol (TWAMP) detection is used to identify poor-QoE microwave segments and bearer network congestion points.
- **Online wireless traffic suppression detection** – visualized wireless traffic suppression on the entire network, such as ranking of suppressed areas by proportion and digitalization of suppressed traffic, guides customers to invest in network optimization and helps verify the investment effect.

Analysis (demarcation and locating)

- **Transport network congestion analysis** – if wireless traffic is suppressed due to insufficient bandwidth on the transport network, Network Cloud Engine (NCE) uses quality measurement solutions for service flows and network paths, such as TWAMP, to restore the forwarding paths of wireless service traffic on the transport network, identify congestion bottlenecks on the transport network and provide guidance for capacity expansion planning. If the wireless traffic is suppressed due to instantaneous traffic surge, NCE automatically starts the real-time, high-precision, hop-by-hop measurement solution to identify poor-QoS services and restore the end-to-end service topology. Service SLA deterioration can be clearly identified and located within three minutes.

Decision and Execution (relief and recovery)

- **Intelligent path optimization –** combined with the SRv6 intelligent path optimization capability, NCE supports intelligent path computation with 15+ factors and minute-level traffic scheduling, accurately adjusts network paths, balances network traffic distribution, and implements minute-level self-optimization for congestion problems.

Intent Report

- **Intelligent incident management** – in the next phase, for unexpected congestion caused by network faults such as device forwarding, link, and interface capability failure, downgrade, and path failure, NCE uses AI-based intelligent incident management to automatically correlate root-cause faults and services. Faults can be quickly rectified based on the fault troubleshooting plan, and congestion problems caused by faults can be automatically rectified.

Service closed loop

With the congestion-free solution, SLAs of mobile bearer services are visible, manageable and committed, providing users with deterministic service experience.

Business closed loop

Based on continuous traffic suppression analysis and high-value area analysis, operator can quickly identify investment priorities and make precise investments based on capacity expansion and rectification suggestions, to continuously improve service experience on the bearer network.

Benefits

MTN South Africa continues to use the traffic suppression model to analyze congestion on the live network and provide guidance for precise capacity expansion.

The average daily traffic suppression data decreases by 28%. MTN Nigeria uses intelligent optimization to reduce the average recovery time of fiber cuts from three hours to minutes, improving bandwidth utilization by 30% on average, and ensuring user experience.

4.2.6. MTN：NFVO Enable Network Auto-deployment, Auto-adaptation and Intelligent Anomalies Awareness

Recently, MTN has been accelerating its telecom cloud strategy: MUNIC. In particular, automation is the key component of the MUNIC 2.0 strategy and is under planning and deployment. With the application of cloud-native architecture and the introduction of slicing and MEC scenarios, the cloud-based core network has been becoming increasingly complex. There are one hundred times more maintenance objects and the change operations occur more frequently. In such complex O&M scenarios, traditional methods are no longer fit for purpose.

NFVO functions as an orchestration system providing network function virtualization services. It is used to orchestrate and schedule NFV network services and resources, implement automatic network deployment and unified O&M, and accelerate the automatic transformation based on MTN's MUNIC 2.0 strategy. In addition, NFVO is also an indispensable component facilitating the evolution from level 3 and level 4 of the ADN. By managing, controlling, and analyzing network resources, NFVO can complete closed-loop handling of resources and achieve the vision of "self-configuration".

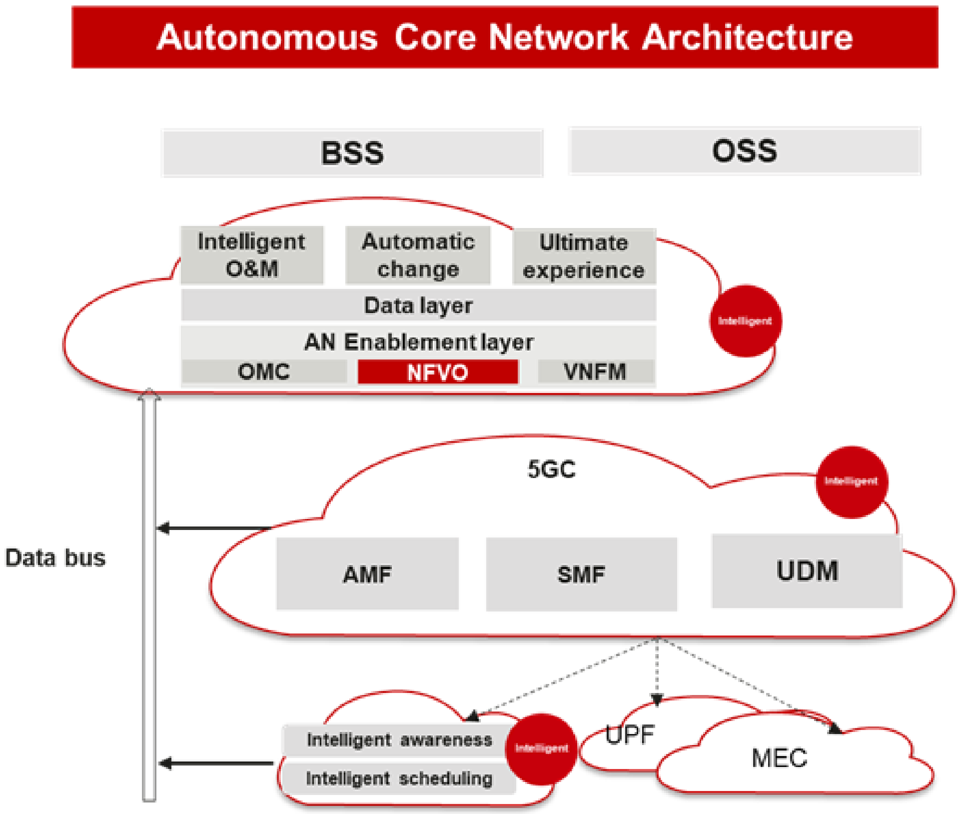

Figure 31*: Autonomous Core Network Architecture*

Solution Introduction:

Automatic network deployment. The architecture of the core network is rather complex. As a result, traditional methods of network configuration can be seriously inefficient. Configuration scripts are sent to switches or routers manually, taking more than two weeks to compile the network configuration and more than one week to configure the network. This has severe impacts on delivery efficiency.

NFVO provides the automatic DCN configuration capabilities and automatically generates NSD and VNFD files. Afterwards, NFVO delivers commands to complete network configuration and VNF deployment. By automating the previously manual operations, the network generation time is shortened from several weeks to a couple of days, significantly improving network configuration and deployment efficiency.

Network automatic adaptation. Traditionally, the capacity expansion of VNFs is manually performed. Moreover, there is little collaboration between manual network configuration and VNF capacity expansion. As a result, VM networks are disconnected after the capacity expansion. In migration scenarios, related network configurations and security policies cannot be migrated at the same time as VMs. NFVO supports automatic network adjustment, online visualized network editing, and real-time detection of NE changes. During capacity expansion and service migration, network configurations can be automatically streamlined, and security and QoS policies can be migrated.

Network anomalies awareness. Thousands of counters exist in the core network. As such, distinguishing the key counters from others is a daunting task. With NFVO, the network performance can be monitored, and the correlated counters and counter reports can be customized so that any issues regarding these counters can be analyzed, regardless of their types. In order to facilitate performance analysis, the KPI insight feature of NFVO has two major functions: network quality monitoring and root cause analysis expert. KPI insight monitors the counters by classifying them into six categories: accessibility, retainability, mobility, capacity, coverage, and service quality. Counter exceptions can be detected within 5 minutes. Additionally, KPI insight provides flexible drilling and correlation functions to locate the root cause of issues related to the aforementioned counters and enables users to customize counter thresholds when the functions are being used. KPI insight is a fast, precise, and powerful feature.

Future Outlook

In the future, we will continue our efforts in the field of NFVO to build network management, control, and analysis capabilities, raise the automation and intelligence levels of E2E management throughout the core-network life cycle, and keep improving network deployment and O&M efficiency in multiple scenarios, such as the centralized cloud and MEC.

4.2.7. MTN：Business Intent Close Loop

Like all global CSPs MTN needs to address a number of key challenges including managing the huge traffic growth driven by OTT and video streaming, increase ARPU and shutdown legacy networks such as 3G to re-farm the frequencies to deliver CAPEX and OPEX efficiencies.

To increase data usage, MTN launched a Double Data initiative and promoting and migrating users from existing 2G and 3G networks to 4G was a key priority. To ensure success, MTN developed a framework that supports automation in most aspects of this initiative to address the following challenges:

- Difficulty in identifying potential 4G users – dynamic profiling of subscribers that have the highest propensity to accept migration proposals e.g., a user generating more than 30MB using a 2G device
- Low migration efficiency and low marketing success rate – additional metrics to support campaign initiatives such as recent user behavior on the network and offer acceptance rate
- High fallback of 4G users due to poor 4G network quality

To overcome these challenges an end-to-end cross-functional 2/3G to 4G User Migration use-case was implemented. At the technology layer and to automate identification of potential users, an advanced analytical capability was implemented powered by Huawei's SmartCare solution in some of the MTN operating markets.

A joint operation team with MTN was put in place to accelerate the development of the 4G users. It utilized the MAN (Market, Area, Network) model to maximize the value of the user migration lifecycle based on the 4G user journey. MAN provided a 360 degrees holistic view through AI based modeling by leveraging on data from OSS, BSS and social media. The model provides insights such as subscriber location distribution with key behaviors, network readiness index distribution, marketing readiness index distribution and target area/city.

Intent Driven Interactions

For this particular use case the business intent is to migrate 2G and 3G users to 4G. Intent is one of the key components that make up the TM Forum Autonomous Network framework. The role of intent in autonomous network is to clearly communicate requirements and goals.

For this use case data is collected from various sources such as OSS and BSS to identify the potential 4G users. An intent report is produced to show the marketing success of the campaign. The intent report will show the status and success of the intent handling.

Architecture and Solution

Figure 32*: Architecture and Solution*

The diagram above shows the 4 steps of the user migration solution which are described below:

- **Step 1- Accurate Identification of Potential 4G Users:** AI/ML model is used to develop smart insights. Algorithms such as Random Forest, XGBoost, and GDBT (Gradient Boosting Decision Tree) are used for 4G user identification by leveraging on OSS, BSS, service and user segment analysis data. It analyzes users who do terminal switch, SIM card replacement and 4G terminal replacement and will output user value, service behavior, geographical location and user group classification.
- **Step 2- Package Tariff Design and Promotion Scheme:** Data from the previous analysis is used to ensure precise marketing by designing subscriber package tariffs based on subscriber ARPU and migration bonus.
- **Step 3- Marketing Campaign Execution:** The lists of potential users are provided to the MTN marketing system from SmartCare and the campaign is executed. To maximize success, we have clear campaign rules, methodology for scheduling and prioritization of subscribers, tailored rewards and SMS execution.
- **Step 4- Post-migration Evaluation:** We monitor the migrated users looking at the trend and traffic and service behavior. A weekly report is produced to show the marketing campaign success and the effect of the reward scheme.

Impact of 2/3G to 4G User Migration Use Case

Typical improvements we have seen includes: Support Double Data initiative through increased DOU, User migration efficiency improves by 80%, 4G user retention rate increases from 79% to 92%.

4.2.8. XL Axiata: Market Expansion Through Outcome-Based Decision, Intent-Driven System

XL Axiata is focusing on creating customer segments to ensure availability and affordability of its products and realize the marketing strategy called “right product, right segment”. The idea is to improve customer lifetime value (CLV) and deliver sustainable business value.

The traditional siloed and disjointed analysis and decision-making processes with rules relying on human experiences usually lead to low efficiency and inaccuracy. Powered by an outcome-based decision intent-driven system under the autonomous framework, the customized marketing recommendation can be generated automatically, which improves efficiency and accuracy and finally increases revenue.

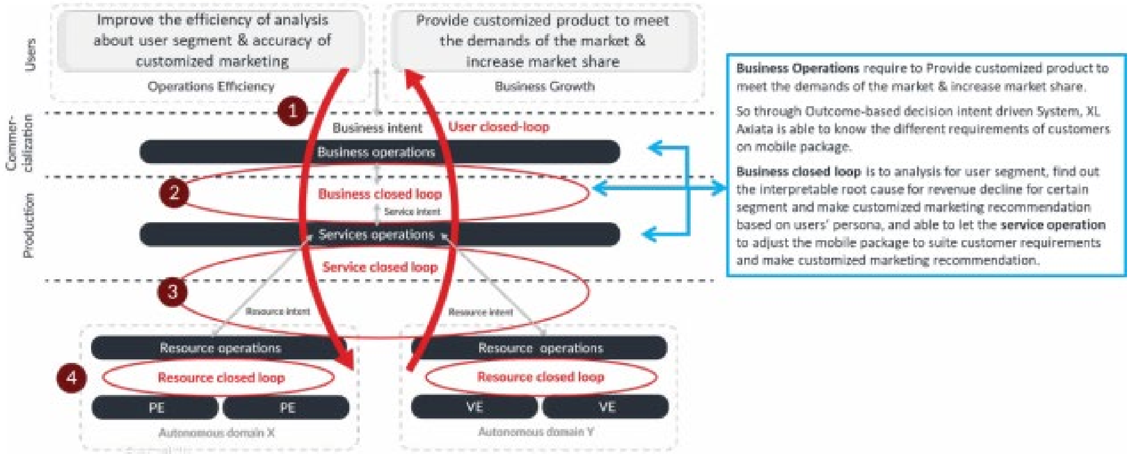

Figure 33*: Outcome-based decision, intent-driven system*

Figure 33 on the previous page shows that self-marketing is achieved through business closed loop with the introduction of the autonomous outcome-based decision intent-driven system:

- **Business growth objective** – provide customized products to meet the demand of the market and to increase market share. It is achieved through data analytics to understand the needs of the customers and develop a business closed loop linking up the market business operation and service operation in the sales offering.
- **Operations efficiencies objective** – improve the efficiency of analysis about user segments and accuracy of customized marketing. With the business closed loop, the service operation is able to change faster and map according to the package that the system thinks the customers require. Service offering can be implemented through autonomous operation and does not require human intervention. The results will be feedback to the intent-driven system, and continuous improvement is achieved through AI modelling over data analytics.

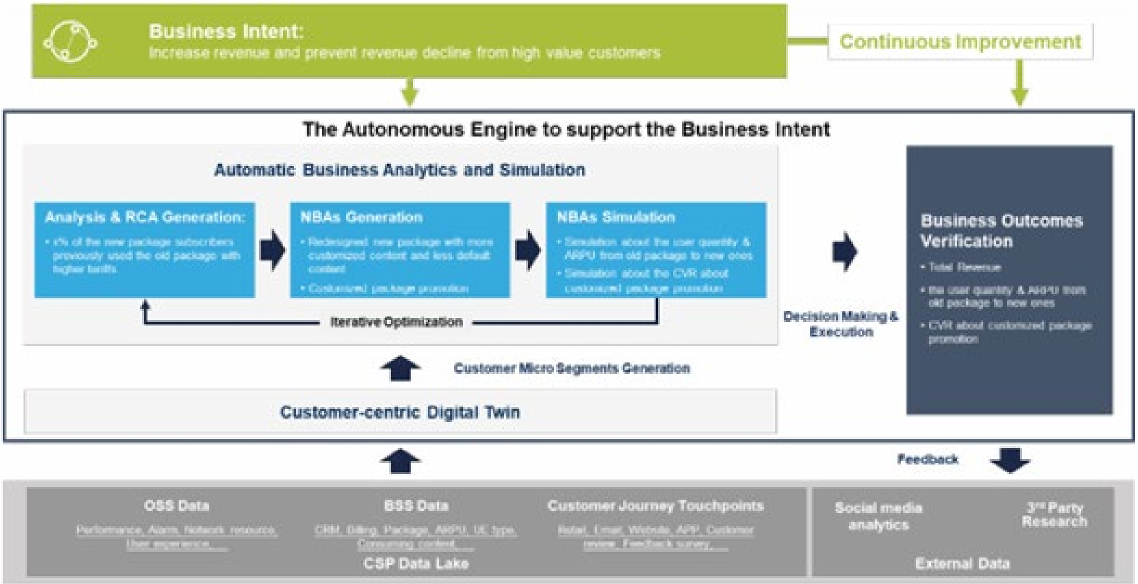

Figure 34*: Technical architecture for outcome-based decision intent-driven system*

Figure 34 above shows a technical architecture for the AN approach through the outcome-based decision intent-driven system. The autonomous system developed a special digital twin for decision intelligence, which includes a detailed description of the objects and their relationship in the telecom marketing scenario. After the execution of a decision generated by the system, business outcomes verification as well as the continuous improvement is done after the market feedback data is integrated into the digital twin.

Business impacts

Based on current co-innovation, efficiency of marketing analysis and decision-making is significantly improved, and the direct revenue of the target value region is expected to increase over the next year. In addition, XL Axiata is planning to explore more business opportunities in the fixed-mobile convergence (FMC) market during the next year.

4.2.9. Cloud-Network Low-Latency AN Solution

Cloud access has become a primary need in the course of enterprises' digital transformation. However, carriers face the following problems in providing services:

- Traditional networks provide non-differentiated connection services, which cannot guarantee the experience of services that have special requirements on latency, such as videos and games.
- Dozens of links are deployed between backbone nodes on an IP network. Due to limited resources, traffic is forwarded in load balancing mode, causing unstable latency for high-value services. To ensure a low latency, the traffic processing mode needs to be manually adjusted, which takes a long time and involves complicated error-prone configurations.

To improve the poor tenant experience due to a long latency on cloud private lines, a long service optimization period, and other issues, carrier A and Huawei jointly deployed the first commercial E2E cloud-network low-latency plane for Internet services. The SDN+SRv6 policy-based IP AN solution and digital and service-oriented capabilities on the network resource layer are used to enable service and business operations and achieve three-layer collaborative closed-loop management, implementing a highly autonomous network with ultra-low latency.

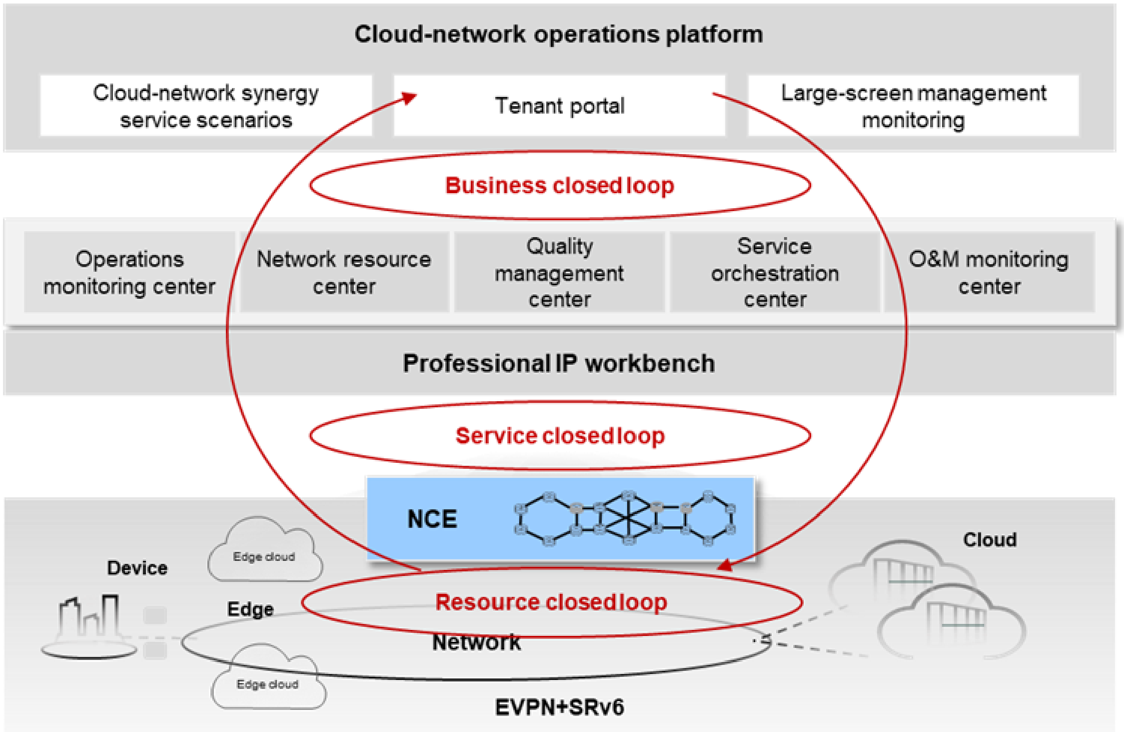

Figure 35*: Cloud-Network Low-Latency AN Solution architecture*

- **Business operations: Flexible service self-orchestration enables tenant self-service.** A real-time digital network map is developed to display the latency of the entire network and form a service-oriented latency circle. Service subscription pre-evaluation is supported to ensure that the latency meets service requirements. Tenants can subscribe to service SLA changes. Network capabilities are provided as a series of e-commerce products for tenants.
- **Service operations: Service self-healing enables deterministic network services.** The digital network map features more than 15 built-in path computation factors, which can be used to automatically plan network paths that meet service SLA requirements, providing a low latency and real-time monitoring assurance for VIP services. Faults can be located within just a few minutes, and poor-QoE services can be automatically optimized, delivering a low-latency for VIP users.
- **Resource operations: Network autonomy, intelligent scheduling of network-wide tunnels, and automatic optimization upon congestion.** The SRv6 tunnel optimization solution uses technologies such as TWAMP and telemetry to detect the service SLA status in real time. If the latency increases, intelligent tunnel optimization is triggered to optimize network traffic distribution and ensure that the SLA is met for VIP services, improving O&M efficiency by more than 30% when compared with the traditional adjustment method.

Traffic has been optimized for approximately 100 links between more than 20 core routers in Fujian province. The service latency from Ningde to Quanzhou is reduced by 53.4%, and that from Ningde to Xiamen is reduced by 44.7%, significantly improving tenant service experience and accelerating the evolution towards AN. Huawei will continue to work with carriers to further explore innovative network autonomy solutions to tackle major concerns about cloud-network services, in order to provide on-demand intelligent scheduling of computing power and networks, lower the O&M cost, and conserve energy.

4.2.10. Intent-Driven AN (IDAN) Use Cases

Business, service and network operations are becoming increasingly complex as they encompass multiple domains using multiple partners' solutions. This means that manual and static processes must give way to model- and knowledge-driven approaches that are based on business intent. By adopting a knowledge-centric approach, services can adapt and evolve autonomously as network conditions, business goals and customers' requirements shift over time.

Customers can have a better experience if their needs are captured and translated into intent without revealing any implementation details. Autonomous systems are governed according to intents, which are standardized by using an open interface. The multi-phased Intent-driven Autonomous Networks for Smart Mobility Catalyst developed an initial intent interface and model that works at all three operational layers – intents at the business layer, which will "cascade" (not decompose!) down to the service and resource layers.

Use case 1: Intent-driven Autonomous Networks for smart mobility

This use case is a cellular vehicle-to-everything (C-V2X) scenario that demonstrates how true intent implementations decouple layers and allow for better optimization of services and resources based on the business objectives defined by the CSP. CSPs want to apply autonomous network technologies and principles to the problem space of toll road operations/transportation.

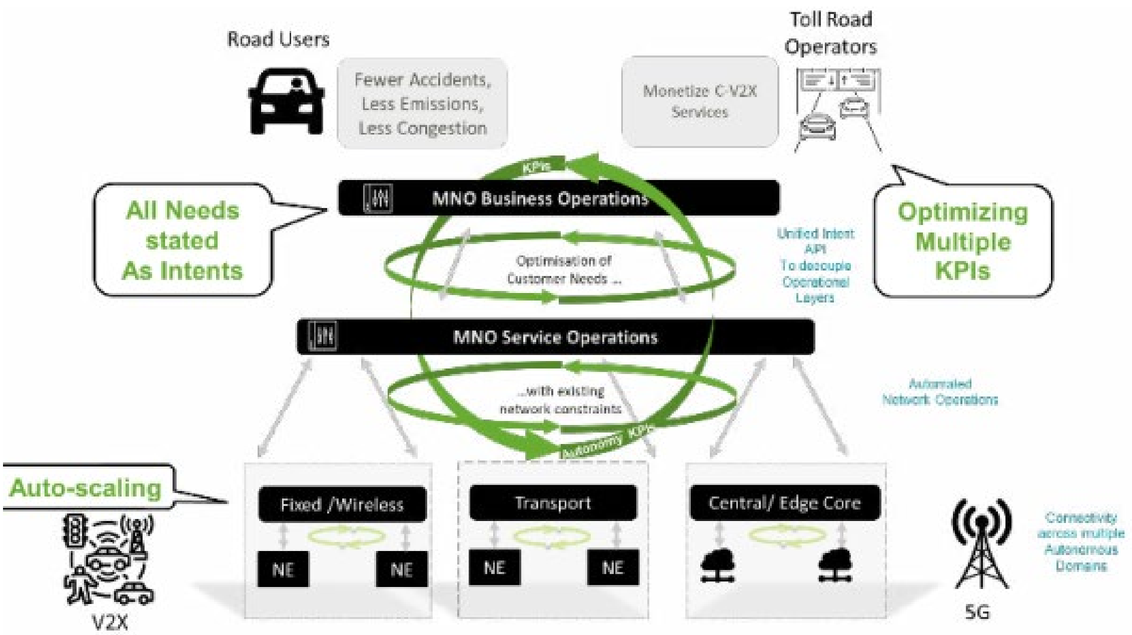

Figure 36: ***illustrates IDAN phase I***

In this case, the autonomous network uses Intent APIs to automatically convert user requirements at the application layer into network languages, implementing agile service provisioning and simplified operation. At the same time, networks are automatically optimized based on user requirements and network status to implement intelligent O&M.

Road users communicate their requirements at the application layer.

The autonomous network automatically divides user requirements layer by layer (Intent API at business layer -> service layer -> resource layer), translates requirements into system instructions and executes them.

The AN feedback the instruction execution result to the user or upper-layer system layer by layer.

Each autonomous layer of the overall system architecture leverages an intent approach and this, in turn, changes the focus to each system to be more self-contained, autonomous systems that focus on their respective closed loops.

Use case 2: Intent-driven Autonomous Networks for dynamic pricing connectivity service

This use case demonstrates a dynamic pricing scenario that provides zero-touch customer experience, self-healing and self-optimization capabilities leveraging intent. The scenario applies to customers needing non-real-time connectivity, such as large research institutions or hospitals, which need to periodically synchronize a large amount of data with a data center or cloud. In this mode, customers can obtain higher-experience services with lower tariffs, and carriers can better utilize idle bandwidth resources to obtain more value without disrupting existing business. Figure 37 on the next page illustrates *IDAN phase II.*

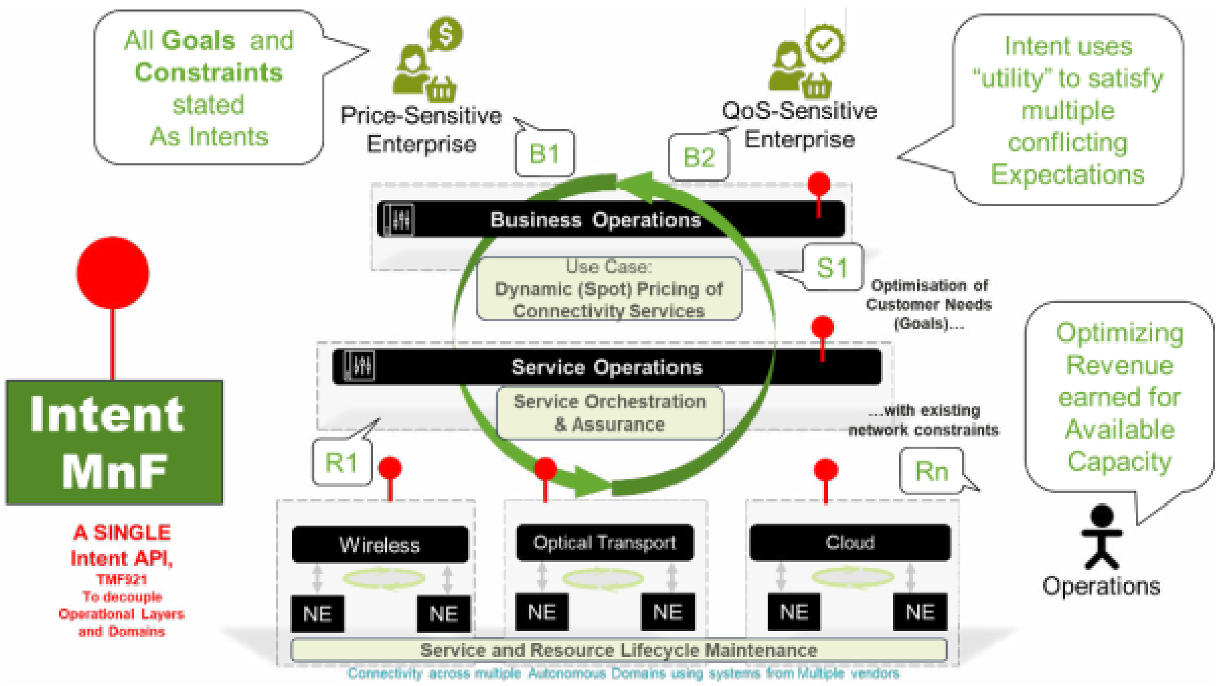

Figure 37*: IDAN-Phase 2 – TMF921 Intent "red lollipop" for AN*

- **Business layer** – refers to the "spot pricing" business model to enable users to obtain services with a higher user experience at lower tariffs.
- **Service layer** – translates the service intent through the Intent Management Function (IMF), creates the service order for cross-domain and cross-vendor service orchestration and works with service-based assurance to close the assurance loop.
- **Resource layer** – uses intent-based interfaces to drive fast service provisioning and network slicing at the network layer, and triggers agile and intelligent fault diagnosis and rectification based on alarms.

The Catalyst developed a complete intent interface (from swagger to user guide to fully working reference implementation) as a formal contribution to TMF921 Intent management API and the associated intent ontology (Turtle) to make the intent approach more concrete and real. Figure 38 shows how the Catalyst uses multiple innovations to create a uniform yet flexible interface that allows the intent-driven approach to be applied to not only dynamic pricing but to any use case of scale across AN.

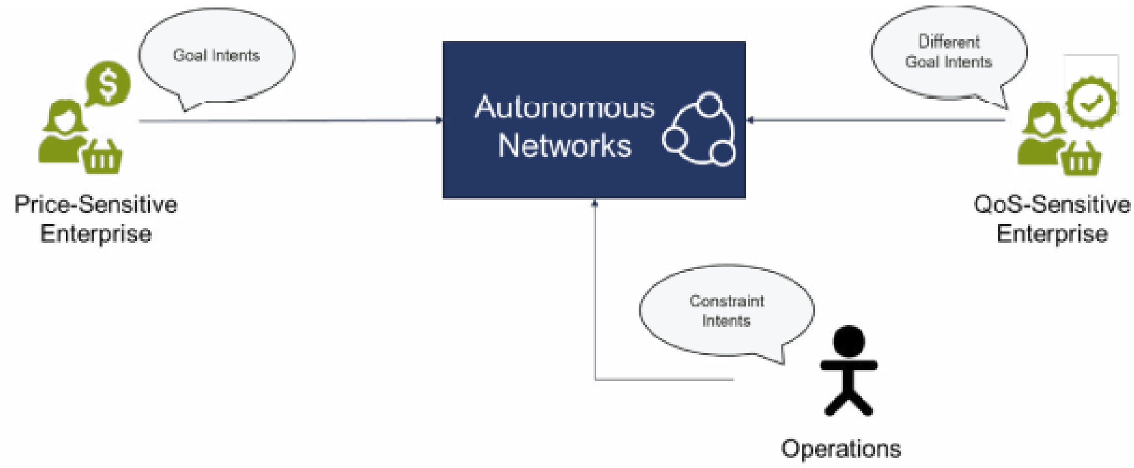

Figure 38***: Intent can be applied to any AN use case***

4.2.11. Intent-driven Service Grading Experience Assurance

As is known to all, the communications industry, as the basic industry of national economy and people's livelihood, shoulders the mission of ensuring national construction and the normal operation of various industries, and is the cornerstone of social development. In daily life, communication assurance is the most common scenario, ranging from important meetings, earthquake relief, entertainment, and sporting games. CSPs often need to guarantee the proper implementation of communication activities and avoid communication faults caused by unexpected problems, which has a great negative impact on the entire major event.

Traditional service assurance has the following disadvantages:

- High technical requirements and high requirements for guaranty personnel.
- It is difficult to respond to service changes and emergencies in a timely manner.
- The guaranteed effect is not obvious, and user experience cannot be guaranteed.

- It is difficult to support continuous assurance, and the assurance strategy cannot be flexibly adjusted with the changes of network conditions.

With the wide introduction and application of intelligent technologies in the 5G era, the requirements for intelligent, simple, and de-risky communication assurance are increasingly urgent. In this context, the time has come to integrate Intent Network into the mainstream business scenarios in the communications field.

Functions

The Intent-Driven Service Grading Experience Guarantee Project changes the O&M mode from "How to do" to "What to do" for the first time in the industry to guarantee the top-speed service experience guarantee driven by natural language and zero-process intervention.

- The network intelligently translates the intent entered by a user with a natural language.
- The network provides self-adaptive assurance for a type of specific services based on translation, and the assurance is divided into multiple levels as required.
- The network automatically perceives the scenario of service assurance, and dynamically adjusts the assurance policy to ensure that the effect continuously meets the standard.

These functions ensure that the user experience of services in specific scenarios reaches the desired level, and thus provide real network assurance with good understanding.

Benefits

This case verified the commercial use of Tencent video playing, live streaming, Minzhengtong QR scanning and WeChat video conferencing services. In the actual verification, each guaranteed level of different applications has been verified many times. The highest throughput can be increased by 760.55%, and the lowest delay can be reduced by 88.70%. Compared with the traditional assurance mode, the assurance efficiency is increased by five times. The economic benefits of this case are mainly to save and assurance human and material costs, and to assure the benefits of new traffic on sites.

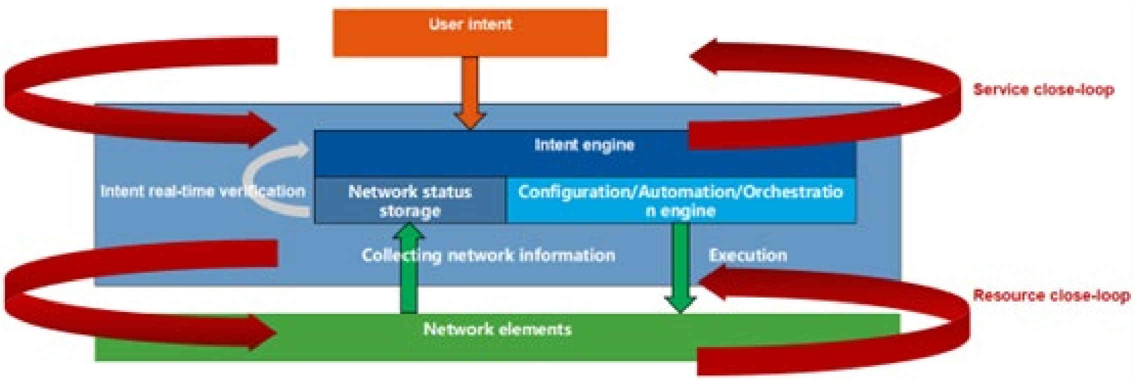

Figure 39*: Architecture of Intent-driven service grading experience assurance solution*

4.3. Efficient O&M

4.3.1. China Mobile: New Radio (NR) Network Coverage Optimization

Massive MIMO is an evolved form of multiple-antenna technology, which is widely regarded as a key 5G network technology. This technology integrates more radio frequency (RF) channels and antennas to implement three-dimensional precise beam forming and multi-stream multi-user multiplexing. Massive MIMO achieves better coverage and larger capacity than traditional technologies. In contrast with 4G massive MIMO that supports more than 200 broadcast beam combinations, 5G massive MIMO supports thousands of broadcast beam combinations. The pattern adjustment scope varies according to AAU types. Pure manual configuration and adjustment of broadcast beam combinations cannot achieve the optimal performance of massive MIMO due to its complexity. When massive MIMO modules are deployed on a large scale, the adjustment workload is heavy, and it is challenging to complete the adjustment manually.

According to the test results of multiple CSPs on the live network, massive MIMO intelligent optimization can improve the reference signal received power (RSRP) and user equipment (UE) throughput while maximizing CSPs' ROI.

To meet the challenges brought by large-scale commercial rollout of 5G networks, the online massive MIMO intelligent optimization solution can automatically collect basic network data, automatically analyze and generate optimization solutions based on drive tests data, and directly evaluate online KPIs in real time. This solution effectively resolves weak coverage, interference, and co- coverage problems, improves coverage gains, and ensures user throughput.

- **Optimization Intent Delivery:** Obtains coverage optimization areas and objectives, such as the proportion of weak coverage areas from the service management layer.
- **Data Self-awareness:** Through the scenario-oriented API obtains drive test data, performance counters, traffic statistics, engineering parameters, configuration parameters and other basic information including electronic maps, antenna patterns, frequency bands, and AAU types.
- **Policy Self-generation and Self-execution:** Performs iterative reinforcement AI learning based on the preset optimization objectives to obtain the optimal optimization advice. It automatically delivers the massive MIMO pattern parameter combination, down tilt, and azimuth parameters of problematic cells and their neighboring cells based on the Massive MIMO pattern common AI model.
- **Data Self-analysis:** Creates grids for DT/MR data, identifies problematic grids, and merges them into problematic areas. The RAN Manager selects the best scenario-based beam, azimuth, and down tilt configurations for problematic cells. In this step, antenna hardware must meet the corresponding configuration requirements.

In a typical operator application scenario, the RAN Manager (wireless resource management layer) interconnects with the network management system (NMS) (service management layer) through an open API. The NMS delivers the network coverage optimization objectives and areas to be optimized to the RAN Manager. The RAN manager sends the final optimization result and optimization advice of each round to the NMS of the operator.

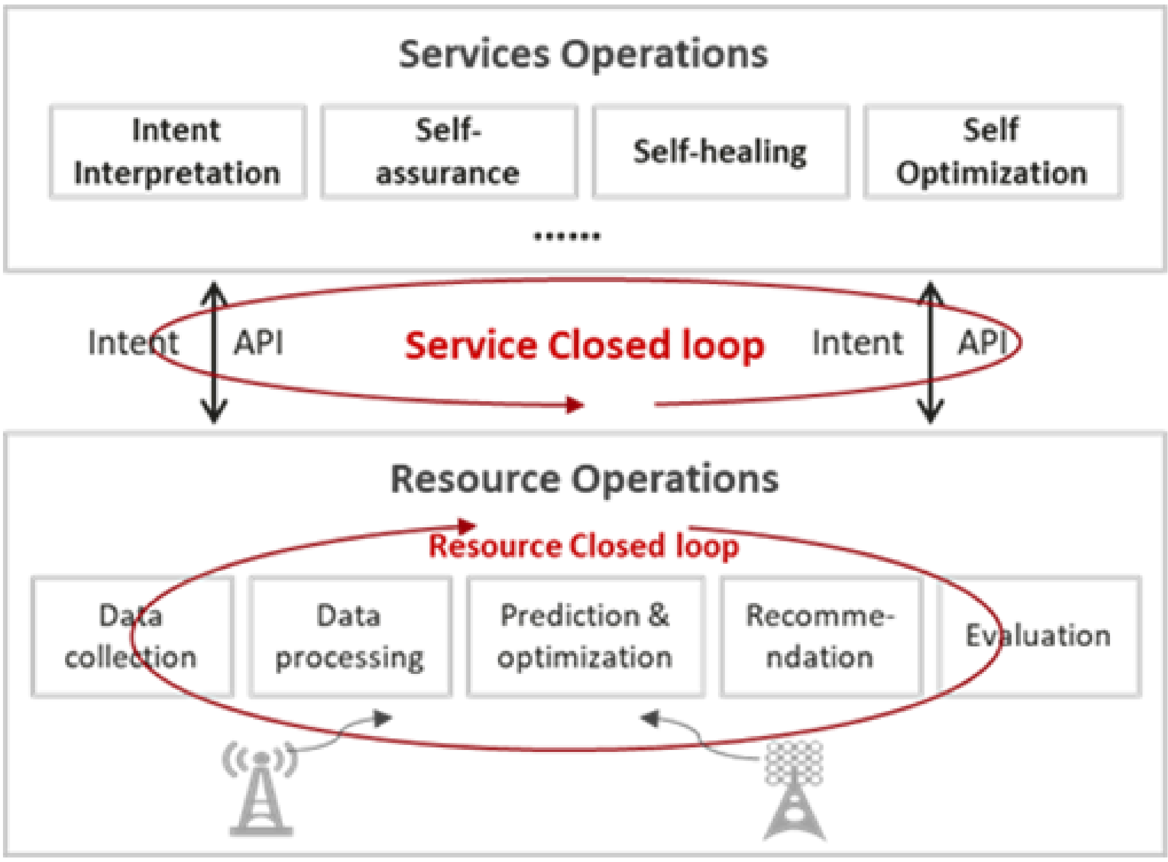

Figure 40: ***NR network coverage optimization solution***

This solution increases the average coverage of 5G massive MIMO cells by 15.8% and the road coverage by 91%. After the application in China Mobile Jiangsu, wireless parameters are automatically configured more than 50 million times a month, with outdoor download rate increased by 13%, indoor download rate increased by 30%.

4.3.2. China Mobile: "Zero-touch" Reliability guarantee of 5G network (automated faults handling)

With the rapid growth of 5G networks the average daily network alarms from provincial subsidiaries exceed 10 million, involving multiple network domains, long collaborative chain and complex dependency relationships. With the development of 5G to B services, enterprise customers have higher requirements for network fault detection and processing efficiency. They therefore urgently need to transform to the predictive and preventive maintenance mode that integrates human-machine and data-driven services to improve fault self-guaranteed and self-healing capabilities.

The Zero-touch Reliability guarantee of 5G network business solution uses single-domain autonomy and cross-domain collaboration as the core principle to build a fault management framework with comprehensive real-time sensing, automatic anomaly diagnosis, and intelligent decision-making.

- **Single-domain autonomy:** The resource operation layer improves the self-guaranteed capabilities of wireless, transmission, and core network domains, including the large-capacity alarm processing capability of 2000 alarms per second, the 1000:1 alarm compression capability, and the network configuration capability of 800 atomic networks for the service operation layer to support fault self-healing.

- **Cross-domain collaborative autonomy:** The service operation layer implements visualized network quality monitoring through network topology restoration. Through centralized cross-domain big data analysis and flexible orchestration of atomized configuration capabilities at the resource layer, automatic diagnosis and automatic decision-making for 300 types of fault scenarios are implemented.

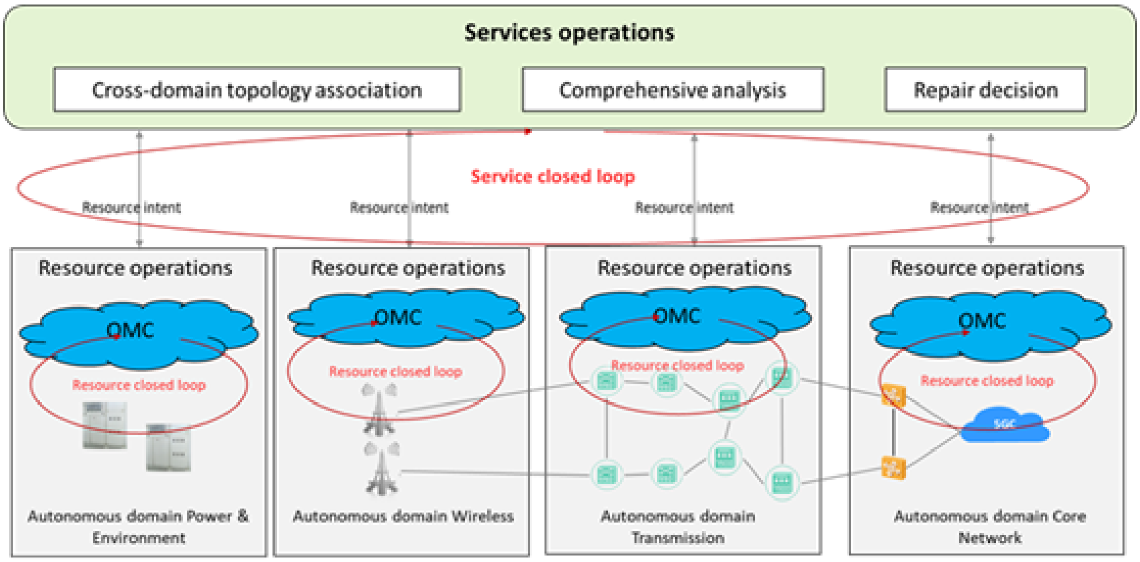

Figure 41*: "Zero-touch" Reliability guarantee of 5G network*

This solution has been deployed in multiple provincial and municipal subnets of China Mobile. After applying in the network, main faults such as batch base station out of service can be cleared within 30 minutes, with average processing efficiency increased by 40%. The number of invalid work orders is reduced by more than 20%. The fault handling efficiency of frontline maintenance personnel is improved by 80%, and that of second-line maintenance personnel is improved by 25%. The autonomous network level has increased from L2 to L3.

4.3.3. China Telecom: Agile Provisioning of 5G Customized Network

As a key cloud-network convergence product, China Telecom's 5G customized network is a comprehensive solution featuring "network customization, edge intelligence, cloud collaboration, and X on-demand". The company aims to build integrated, customized and converged services for customers and implement "cloud-network convergence and on-demand customization".

However, the 5G customized network solution involves many professional networks, systems and service industries. In addition, due to the short commercial use time, obstacles such as too many handling steps, difficult requirement translation, slow resource survey, and high proportion of manual orchestration and configuration still exist during service provisioning. It will take a long time to realize ultra-premium services.

Solution

China Telecom has developed the agile provisioning for 5G customized network solution. Combined with the three-layer architecture of ANs, this solution focuses on the autonomous capability of cloud network operations.

The resource operations layer aims to achieve single-domain autonomy and enables upper-layer applications, improving network situation self-awareness and facilitating network self-configuration. On the business and service operations layers, China Telecom first aims to improve customer experience and build capabilities such as e-commerce service and intent-based requirement translation. To improve resource utilization and ensure service quality, China Telecom is attempting is to generate end-to-end autonomous capabilities, including online resource survey, automatic orchestration and scheduling, and automatic generation of a configuration solution. Figure 42 depicts the solution architecture, and a more detailed description follows.

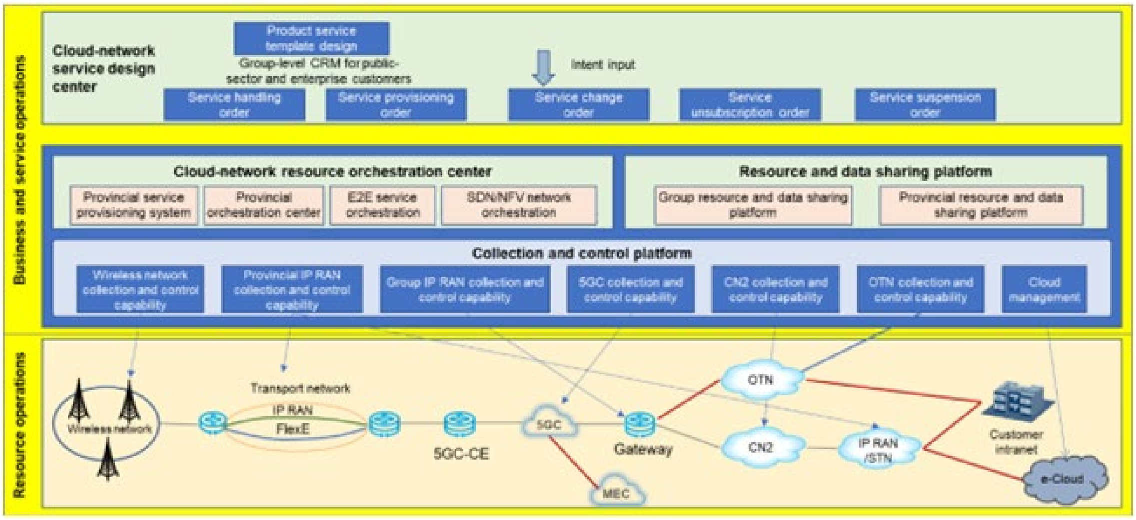

Figure 42*: Agile provisioning of 5G customized network solution*

Equipped with the intelligent functions of China Telecom's next-generation cloud network operation service system, the solution integrates autonomous capabilities of the cloud network operations and implements the following, greatly shortening the service provisioning time and improving user experience.

- Template-based product design – the cloud network service design center builds the product template product structure tree (PST) to implement one-point product design and network-wide loading.
- Intent-based requirement translation and end-to-end collaborative orchestration – the service orchestration center translates customer intents into SLA parameters, implementing orchestration of various types of configurations such as end-to-end slice/ sub-slice, multi-domain collaborative private line, and number subscription configuration.
- Integrated solution design – the resource and data sharing platform realizes the unified allocation and management of line resources and slice resources.
- Automatic configuration and provisioning – the collection and control platform implements slice management configuration and end-to-end cloud network configuration.

Benefits

The solution has been deployed on a large scale. Most of China Telecom's provincial subsidiaries have launched function modules including automatic provisioning, automatic change, automatic un-subscription, and troubleshooting in their production systems. These modules support agile service provisioning, including 5G slice private lines and super number cards, shortening the provisioning time from two to four weeks to instant availability and greatly improving customer experience. By the end of 2021, China Telecom had provisioned nearly 500 5G slice private lines, generating total revenue of 270 million Yuan ($39.6 million).

4.3.4. China Unicom：Smart Operation of 5G Bearer Network- Zero Waiting Provisioning and Confirmatory SLA Guarantee

With the rapid deployment of 5G networks, the provisioning efficiency and SLA assurance capability of 5G bearer networks are one of the key areas of concern for CSPs. There are challenges to automating this capability:

	Challenges	Reasons
Service provisioning	Provisioning is mainly dependent on manual operations. The workload varies greatly between peaks and valleys, making it difficult to balance the staffing and utilization benefits.	Offline resource allocation, conflict-prone, and difficult resource recycling. Many manual configurations are prone to errors. Work order record input involves data synchronization in multiple systems.
SLA assurance	The legacy quality test cannot ensure consistency with actual service SLA. Across the technology domain fault locating takes days or weeks. Long fault recovery time	The insufficient capability of automatically monitoring service SLAs Hop-by-hop fault locating cannot be implemented and difficult. The switchover is lack of automatic and intelligent optimization methods.

Table 10: Challenges to autonomous bearer networks

To address these challenges, the 5G intelligent operation solution follows the concept of "single-domain autonomy and cross-domain collaboration" and introduces technologies such as AI, on-demand detection, and telemetry to build Self-x capabilities:

- **Service provisioning:** Self-orchestration of resources at the service operation layer and self-configuration of engineering parameters at the resource operation layer implements closed-loop service provisioning.

- **SLA assurance:** Automatic fault reporting at the network resource operation layer + Cross-domain fault locating and service self-recovery at the service operation layer; implementing SLA self-guaranteeing.

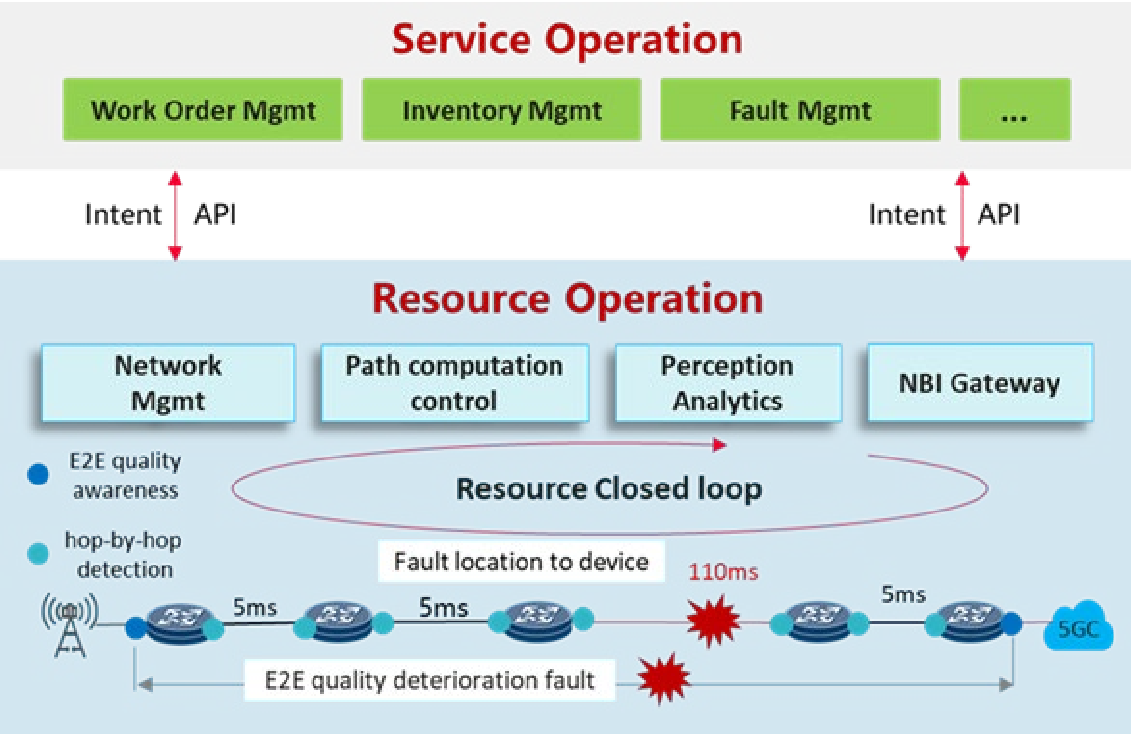

Figure 43*: Smart Operation of 5G bearer Network*

This solution has been widely deployed in China, greatly improving the provisioning efficiency and SLA guarantee.

Benefits

- **Zero wait and minute-level provisioning of bearer network:** The activation efficiency of a single line is reduced from 45 minutes to 2 minutes, and the activation accuracy reaches 99.999% without manual intervention. The autonomous network level reaches L3.
- **Real-time service SLA control**: Real-time visibility of 5G bearer service SLAs, supporting multi-dimensional and multi-period statistical analysis of service SLAs.
- **Zero interruption and minute-level service recovery:** Services are automatically repaired within minutes. The time for locating cross-domain poor-quality faults is reduced from hours to 5 minutes. The efficiency for handling base station mass faults is improved by over 60%.

4.3.5. MTN：Building an All-Optical Automated Network to Enable Agile Business and Intelligent O&M

The digital economy and digital transformation of industries pose new requirements for CSPs' network capabilities and operations. An intelligent, native, efficient and reliable network with deterministic experience is now the development direction for future networks. MTN is actively carrying out network digital transformation in line with its

Ambition 2025 strategy, MTN promotes the exploration, practice and application innovation of autonomous networks based on optical network automation scenarios.

Challenges

With the deployment of optical infrastructure networks and the rapid development of optical services, MTN is facing challenges in terms of time to market (TTM) and O&M efficiency. Table 9 describes the challenges.

Challenge	Root Cause Description
Long TTM for services	The offline route design and service provisioning need to be manually performed, which is time- and effort-consuming and leads to low efficiency.
	The offline system resource check is time- and effort-consuming, and the data is inaccurate.
Inefficient O&M	Fiber and OCh faults frequently occur, and most of them are slow-change faults, which are difficult to detect in advance.
	Fiber cuts have a great impact on services, but there is no reliable O&M method available to reduce the impact and prevent future fiber cuts.

Table 9*: Optical network challenges*

Solutions and benefits

With the intelligent management and control system as the core, the all-optical AN solution introduces AI to the NE, network and service layers to implement efficient O&M of all-optical networks and provide industry customers with zero-touch, zero-wait and zero-fault premium private line service experience. Figure 44 shows the approach, and a more detailed explanation follows.

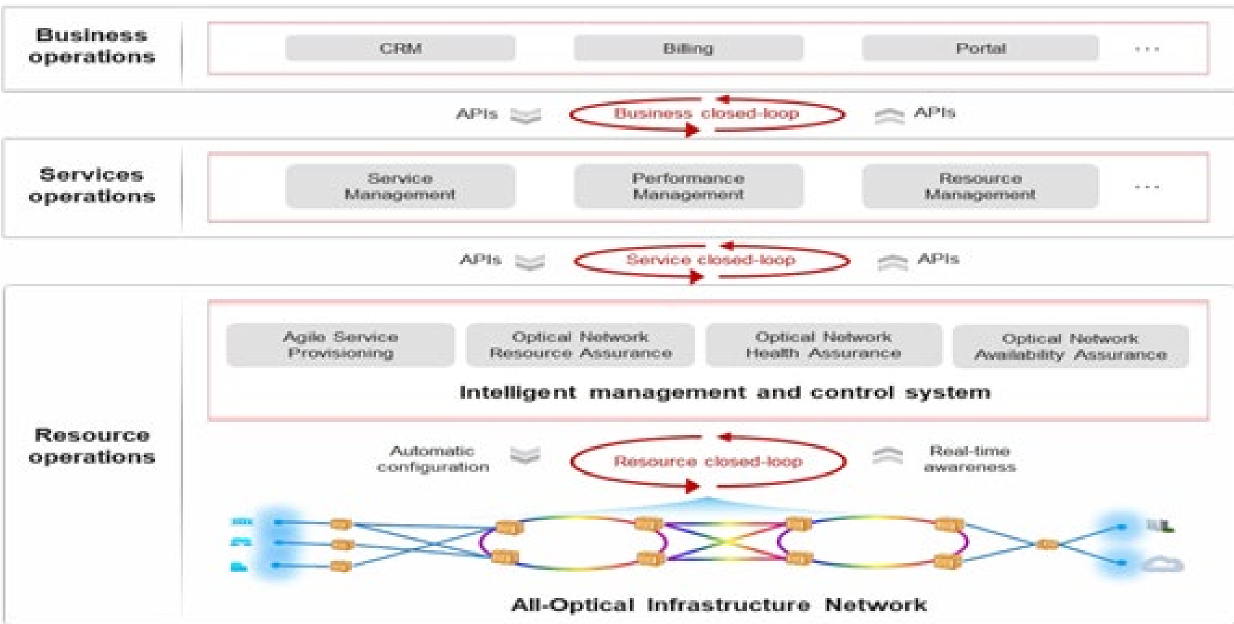

Figure 44*: All-optical AN with intelligent management and control system*

Resource closed loop

- **Agile service provisioning** – to shorten the service TTM, improve the service go-to-market pace and accelerate business monetization, automatic service provisioning is provided for MTN in South Africa. The simplified model of automatic service provisioning and multi-factor route calculation policies (the most comprehensive routing policies in the industry, meeting differentiated market requirements) greatly improve the one-time service provisioning success rate, shortening the TTM from weeks to minutes and providing the ultimate service experience with zero-wait time.
- **Optical network resource assurance** – in the resource check phase before service provisioning, the resource visualization function of the optical network resource assurance solution is utilized to implement minutes-level resource check, improving service provisioning efficiency. Additionally, based on historical data, AI algorithms can be used to predict resource requirements in the next 12 months, facilitating capacity expansion in advance and eliminating the need for frequent emergency capacity expansion.
- **Optical network health assurance** – in terms of O&M efficiency improvement, the focus is on tackling frequent fiber and OCH deterioration faults that cannot be detected in advance. For this purpose, the optical network health assurance solution has been introduced in the MTN project in South Africa. Based on rich optical sensors, big data collection and analysis, and AI algorithm-based prediction capabilities, this solution helps analyze the health status of each fiber and OCH on the entire network in real time, predicts fiber fault risks and fault locations in advance, and provides handling suggestions, realizing proactive O&M. The solution helps MTN identify more than 95% of fiber and OCH deterioration faults in advance, reducing the fault-locating duration by 83% and reducing fiber cuts by 30%.
- **Optical Availability Assurance** – high availability is the lifeline of networks and services. However, MTN lacks a method to measure the service availability for long periods of time. The lack of monitoring, risk identification and proactive optimization suggestions for availability severely restricts service development. Now, the optical availability assurance solution has been applied to the MTN project in Nigeria. Through the multi-dimensional evaluation and analysis for fiber and service availability, fiber cut impact and service protection risks, this solution proactively identifies potential risks of fiber service availability, monitors service availability in real time, automatically generates warnings when threshold-crossing occurs and provides optimization suggestions. In this way, rectification can be performed in advance to realize a highly reliable network with zero-fault.

Service closed loop

Based on the internal collaboration of service, performance, and resource management systems, the multi-domain decision-making capability is enhanced, and AI is introduced to drive multi-domain closed-loop management and support automated service operations.

Business closed loop

With the network capabilities provided by the intelligent management and control system at the resource operations and the operation support capabilities provided by the service operations, the business operations provide customers with e-commerce and self-service experience, including online service subscription, bandwidth on demand and real-time service SLA performance query, customers can enjoy self-service network management services anytime and anywhere.

Prospects

Based on the vision of future L4 ANs, MTN Group will accelerate all-optical infrastructure network coverage and build interconnected infrastructures. In addition, the MTN Group will continue to work with industry partners to innovate in the direction of network intelligence, build smart self-healing networks featuring self-configuration, self-recovery and self-optimization, accelerate the development of the digital economy, and achieve business success.

4.3.6. MTN：Fault Management-Closed Loop Automation

A key challenge in operation was resolving complicated cross-domain faults where the problem could be in the RAN, Core, TRX or IPRAN. When such problems are detected, the staff has to collect data manually from various sources and need experts in various fields to do the analysis. Demarcating the fault can take hours and finding the root cause can take days depending on the complexity of the problem.

To overcome this challenge, a Closed Loop Automation use case was implemented in the Intelligent Fault Management (iFM) module of the OSS platform called AUTIN. As shown in the diagram below the idea is to take people out of the loop and let the platform leveraging on AI resolve the issue through self-healing.

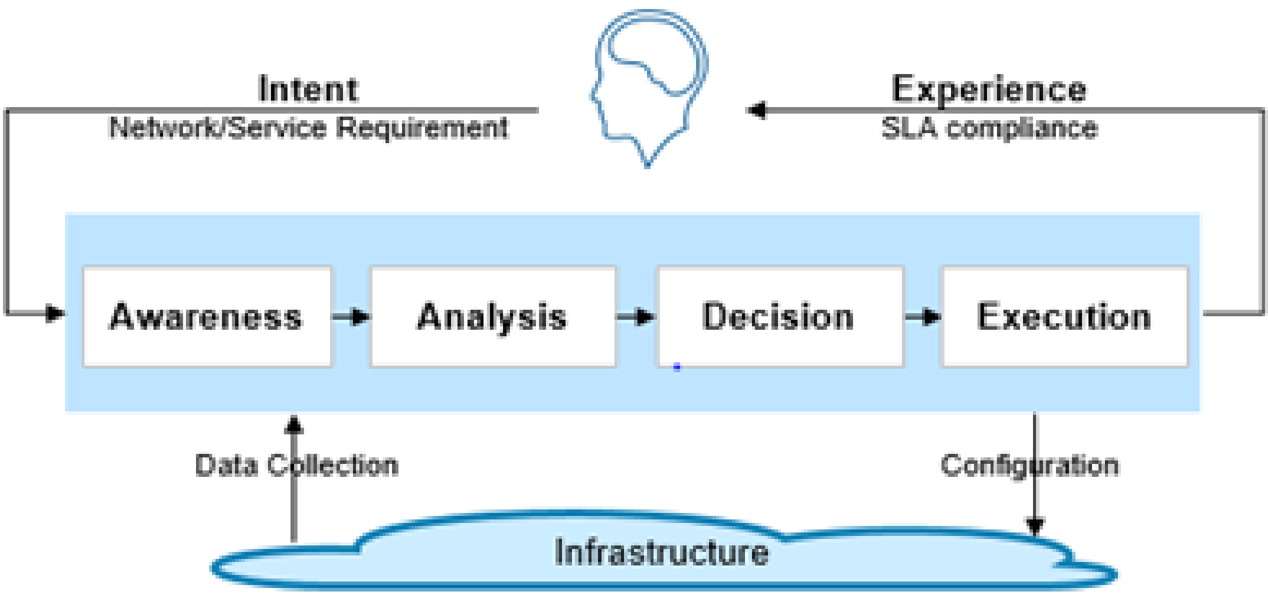

Figure 45*: Cognitive closed loop*

Architecture and Solution

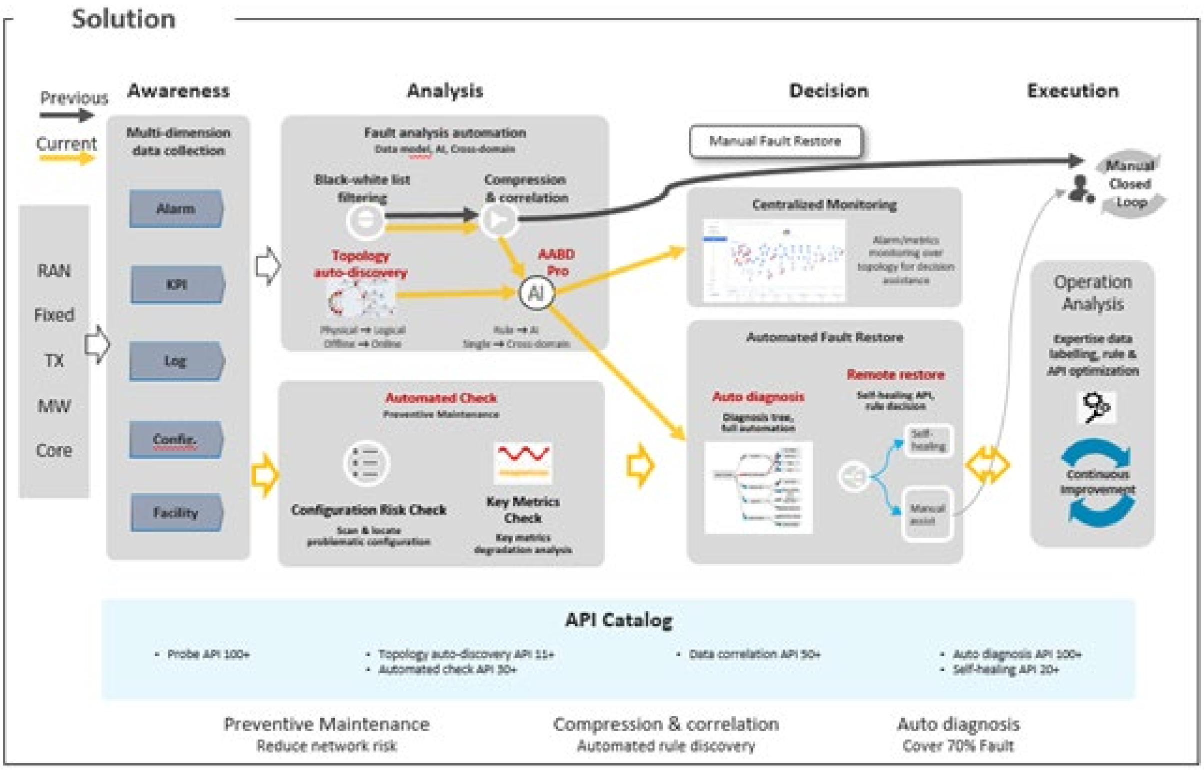

Figure 46*: Architecture and Solution*

The diagram above shows the 4 stages of the cognitive closed loop automation which are described below:

- **Awareness:** The group of tasks that monitor and understands what happened or about to happen in quality/state of network/services. It collects multi-dimensional data from all domains such as RAN, Core, TRX, MW etc. and can detect network quality degradation based on dynamic threshold monitoring model.
- **Analysis:** The group of tasks which analyze information generated in the awareness phase using technologies such as AI inference for topology generation and cross-domain alarm correlation to demarcate where the problem lies. For analysis it has various capabilities such as single domain fault identification and cross-domain (power and environment) fault identification models. Topology can be generated for both mobile and fixed networks and reduces problem demarcation from hours to less than 5 mins.
- **Decision:** The group of tasks that decide the necessary management operation for execution e.g., network configuration or adjustment. Here it leverages on various diagnosis trees such as fault root cause diagnosis model and performance degradation diagnosis model for RCA (Root Cause Analysis). Currently these diagnosis trees cover 70% of network problems with an RCA accuracy of 90%.
- **Execution:** The group of tasks which executes the management operations and feedback the result. Where configuration changes are required to resolve the problem, the platform can make many of the changes by itself without people intervention. This means self-healing or zero touch for these scenarios.

Impact of Closed Loop Automation

For MTN this use case improved its network availability by between 0.05% and 0.1%. It also reduced MTTR and revenue loss. The topology generation with its auto-discovery feature enabled visual trouble shooting and faster fault demarcation. The AABD (Automatic Alarm Behavior Discovery) functionality supports root cause alarm identification for cross-domain and complicated faults, and the open APIs supports MTN's Autonomous Network journey.

An example of a value for MTN was in RAN sleeping cell detection. Previously MTN had to do manual inspection to identify sleeping cells which can take more than 3 days. When the use case was implemented in one of the Opcos which had over 100,000 logical cells covering 2G/3G/4G the faulty cells were detected immediately and resolved remotely through self-healing which reduced the annual revenue loss. By 2023 MTN is expected to implement this use case in all 20 Opcos covering over 300 million subscribers.

4.3.7. MTN：Digital Quick Optical Distribution Network

Autonomous Networks is core for the Fiber To The x (FTTx) business strategy, and Optical Distribution Network (ODN) is the foundation of FTTx solutions. The Digital Quick ODN (DQ ODN) automation solution enables infrastructure resource digitalization, operation efficiency and service experience improvement. For traditional ODN solutions, the ODN network is manually managed, and the CSPs have no visibility of the resources and topological information. With the DQ ODN solution, the resource layer managed the digitalized resource and topology, and the service layer managed the online provisioning, capacity expansion, and fault management service

Architecture and Solution

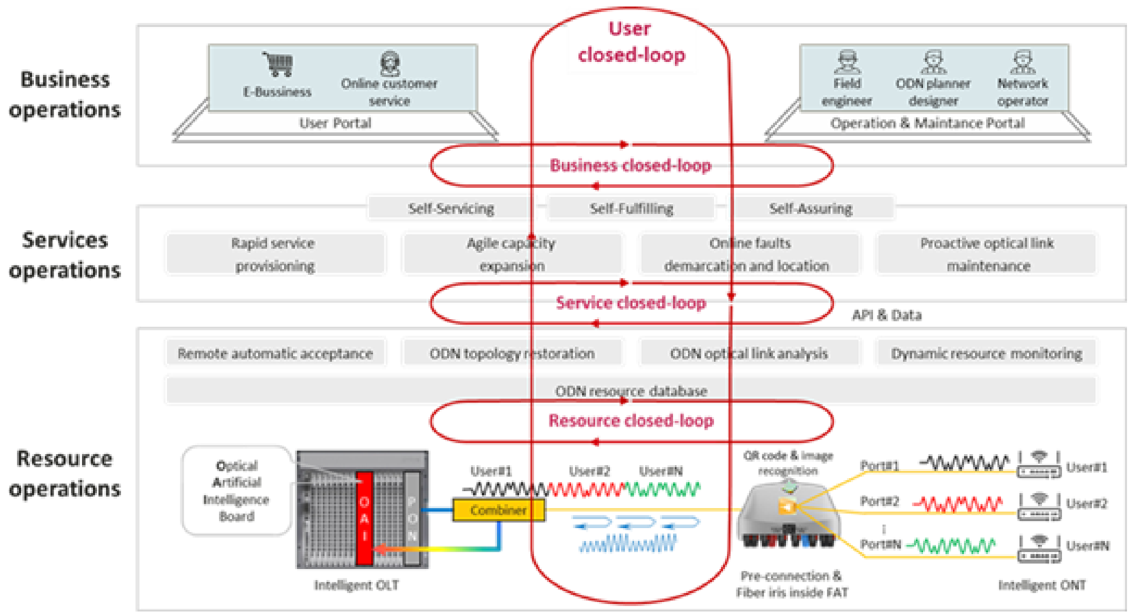

Figure 47*: FTTx Autonomous Network with Digital Quick ODN*

The Digital Quick ODN solution is implemented based on three innovations: pre-connected optical cable design, Innovative image algorithm and Optical Iris technology.

With the implementation of the DQ ODN solution, FTTx Autonomous Network is achieved through:

Resource closed loop:

- **Remote Automatic Acceptance**: The FAT port insertion loss data can be remotely detected and automatically recorded in the ODN management system.
- **ODN topology restoration**: Based on the ODN resource database, the End-to-End topology can be displayed, restored and updated automatically, including PON ports, feeder fiber, FAT ports, distribution fiber and ONT connection.
- **ODN optical link analysis:** Monitoring and analyzing end-to-end optical link insertion loss data.
- **Dynamic resource monitoring:** The FAT ports utilization can be monitored remotely and automatically.

Service closed loop:

- **Rapid service provisioning:** Online checking of the FAT port resource availability and provisioning the service in one site visit.
- **Agile capacity expansion**: Accurately identify areas where FAT ports need to be expanded, preventing invalid expansion, and improving resource utilization.
- **Online faults demarcation and location**: Avoid segment by segment onsite fault demarcation and location, shorten the average fault handling duration.
- **Proactive optical link maintenance**: Accurately identify areas that require rectification, and proactively dispatch maintenance tasks.

Business closed loop: With 100% accurate inventory information from the resource layer and service layer, the business layer is able to provide dynamic online services including: providing a provisioning map, checking resource readiness for new subscribers in real time, analyzing marketing data, and improving customers take-up rate.

Conclusion

With the implementation of the DQ ODN solution, the FTTx network planning, construction, operation, maintenance, and marketing processes and activities are more visual, manageable, and autonomous to enable a network with self-x capabilities. This moves us a step closer to evolving to a higher-level of autonomous network operations.

4.3.8. Hitless Automatic Upgrade of 5G Core Network NEs

In the 5G era, various industries are undergoing rapid digital transformation and posing numerous requirements, which in turn is triggering more frequent version upgrades. Traditionally, these upgrades are performed frequently at the NE level, which interrupts services, affects user stability, and hinders innovation and service development. During NE upgrades, users are re-registered or re-activated, and data and voice services are interrupted, affecting user experience. The following are key challenges:

- **Complex upgrade process** – an upgrade involves complex preparations and procedures and many manual operations. Leading carriers usually have hundreds of sites, and upgrades can be performed only at night.
- **Long interruption during upgrades** – before an upgrade, users must be migrated (or pooled). Otherwise, services will be interrupted. It takes 15 to 20 minutes to activate and upload software and restore services.
- **All resources required for hitless upgrade** – all resources need to be reserved for hitless upgrade, resulting in wasted resources.

Solution and benefits

To overcome these challenges, Huawei proposed an innovative hitless automatic upgrade solution for 5G core network NEs. This solution leverages automatic orchestration, automatic rolling upgrade, and other capabilities to simplify the long and complex traditional upgrade process, achieving single-domain autonomy and closed-loop resource operations on core networks. The approach is shown in Figure 48 followed by an explanation of how it works.

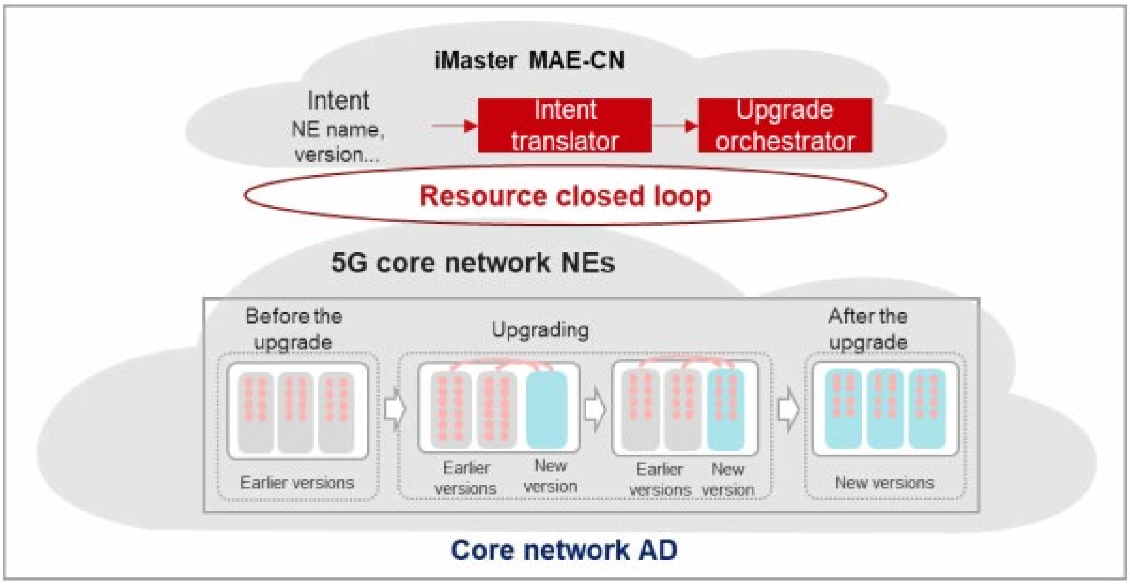

Figure 48*: Hitless automatic upgrade solution for core network NEs*

Automatic orchestration – a workflow orchestration engine performs flexible scheduling to remove manual breakpoints and automate the entire core network NE upgrade process. The core network software package can be downloaded on a centralized GUI in one-click mode. Risks can be automatically checked, and the upgrade can be automatically performed, significantly reducing risks caused by manual misoperations.

Automatic rolling upgrade – NEs are deployed based on the stateless design and microservice architecture to ensure compatibility with user data of multiple versions and allow instances of multiple versions to coexist. The internal network topology is shielded, and services on peripheral devices are not affected by the upgrade. 5G core NEs are divided into three modules from bottom to top: basic service platform, data and link service and business service. Each module is upgraded in rolling mode (migration > upgrade > migration), in batches.

The hitless automatic upgrade solution for 5G core network NEs ensures that users remain connected during the upgrade. Services are not interrupted, and peripheral devices are not affected by the upgrade. No additional resources are required, and service rollout is accelerated, laying a solid foundation for the rapid development of 5G

- **Zero service interruption** – services are hitlessly upgraded in batches for all users on the live network. User data is automatically synchronized, and the data formats of the earlier and new versions are automatically regenerated to meet new service requirements.
- **Zero manual operations** – the entire upgrade process is automated to deliver a zero-touch experience.

- **Zero additional resources** – NEs are deployed based on the distributed microservice architecture, and no additional resources are required for the upgrade.

Application and promotion

The hitless automatic upgrade solution for 5G core network NEs has been deployed in various provinces in China, including Zhejiang and Henan. In 2023, the solution will be replicated across China on a large scale. L4-oriented grayscale verification will be developed to implement daytime upgrades.

4.3.9. Intelligent Cloud Core Network O&M

The core network is the brain of the telecom network and is responsible for scheduling and managing global network resources. The core network serves a large number of users and has a wide impact scope in case of faults. Therefore, stability is a top priority for the core network. 5G all-cloud core networks are being rapidly deployed and are seeing large-scale commercial use. These networks have introduced NFV, slicing, and MEC technologies. Core networks are becoming increasingly complex and are witnessing a 100-fold increase in the number of maintenance objects, and increasingly frequent change operations. Traditional manual operations cannot meet new O&M requirements and face the following fault management challenges:

- **Pre-event:** Network anomalies are difficult to monitor, and faults are passively detected.
- **In-event:** Cross-layer and cross-NE fault demarcation is difficult. Faults continue to create more negative impacts.
- **Post-event:** No ground is provided for DR switchovers. Unnecessary DR switchovers may cause even more service failures.

To overcome these challenges, carrier A and Huawei jointly developed an intelligent core network O&M solution. Based on the intelligent engine and expertise, a complete fault management scheme is provided at the management and control layer to implement proactive fault prevention, quick fault handling, and lossless fault rectification, fully improving core network reliability.

- **Intelligent fault detection:** Various machine learning algorithms are used to infer the dynamic threshold ranges of KPIs for anomaly detection, shortening the detection time from several hours to just 5 minutes. The anomaly identification accuracy reaches over 85%. The troubleshooting mode is transformed from complaint-driven passive O&M to proactive prevention based on prediction.
- **Intelligent fault diagnosis:** Noise reduction, correlation, and aggregation are performed for abnormal KPIs, logs, and alarms in order to comprehensively analyze fault information in terms of space and time, and efficiently demarcate NFV cross-layer and horizontal issues. Faults can be demarcated at the minimum recoverable unit level within 10 minutes, significantly shortening the demarcation duration and saving time for DR operations, if any.
- **Intelligent DR assistance:** To tackle major core network faults, optimal parameter solving based on AI flow control and signaling impact simulation are used to quickly evaluate a DR switchover. Faults can be rectified within 15 minutes, ensuring a successful DR switchover at one stroke.

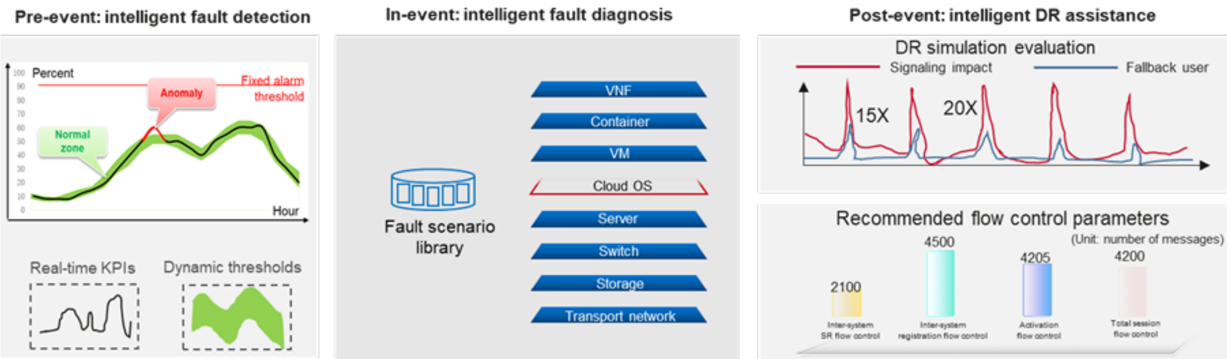

Figure 49*: Intelligent fault detection / diagnosis/ DR assistance*

The intelligent cloud core network O&M solution leverages the E2E intelligent fault capabilities, helping the carrier deploy a highly reliable core network. The solution has been piloted and verified in many provinces in China, including Henan, Jiangsu, and Zhejiang. The test results show that the solution can greatly improve the efficiency and intelligent level of core network troubleshooting, helping the carrier reach AN L3 and evolve towards L4.

4.3.10. Wireless Network – Intelligent Fault Management Based on Prediction

Intelligent wireless network fault management happens in three stages:

1. Automatic ticket processing, which significantly improves maintenance efficiency
2. Proactive maintenance based on prediction and prevention technologies
3. Providing a highly reliable self-sensing and self-healing mobile network featuring intelligent O&M based on advanced perception capabilities and various technologies, including intent-driven and level-based collaboration.

Most CSPs are at the first stage, but pioneering CSPs are developing automatic troubleshooting capabilities and shifting their focus to intelligent troubleshooting. In recent years, many have posed requirements on the scope of fault prediction capability in terms of many aspects, from strategic indicators to platform capability development. This is because wireless networks have always faced issues such as potential fault points, various fault symptoms and complex fault causes (hardware, software, external system, environment and human factors), and a combination of active and passive faults (such as passive fronthaul, power and environment, and device faults). They also use different fault-detection methods and granularities and have complex onsite troubleshooting and inspection operations. These issues create daunting challenges to the development of intelligent wireless fault capabilities, such as precise identification, demarcation and locating, troubleshooting and inspection and prediction.

Predictive and proactive O&M

Huawei has proposed a wide range of solutions based on the AN architecture with IntelligentRAN to overcome these challenges and facilitate the evolution towards Autonomous Networks. These solutions enhance the fault detection capability to maximize the fault management scope while also achieving the optimal automation result through upper-layer and lower-layer collaboration, cross-site collaboration and device-network collaboration.

Take the equipment high temperature prediction solution as an example. NEs self-detect the temperature data of each piece of equipment in real time, self-predict the temperature trend within a short period at the NE level and report the trend to MAE.

Based on long-term data of multiple sites, MAE uses the neural network deep learning algorithm to generate a baseline AI model. Next the model will be generalized and optimized for each site or region to perform single-site inference in order to obtain the optimal prediction result and identify risks of high temperature.

The prediction capability can also be used in other scenarios, such as identifying risks of optical modules and paths. Based on the long- and short-term perception data of MAE and NEs, the subhealth status of optical components and paths can be predicted and determined.

Intelligent AR inspection In the “last mile” practice based on device-network collaboration, augmented reality (AR) technology is applied to site devices. Image recognition technology and device-network collaboration enable automatic AR inspection, dumb resource modelling and real-time fault point identification. An intelligent wizard-based engine for troubleshooting is developed on MAE to communicate with site devices in real time to help site personnel perform efficient and accurate operations, greatly improving onsite troubleshooting efficiency.

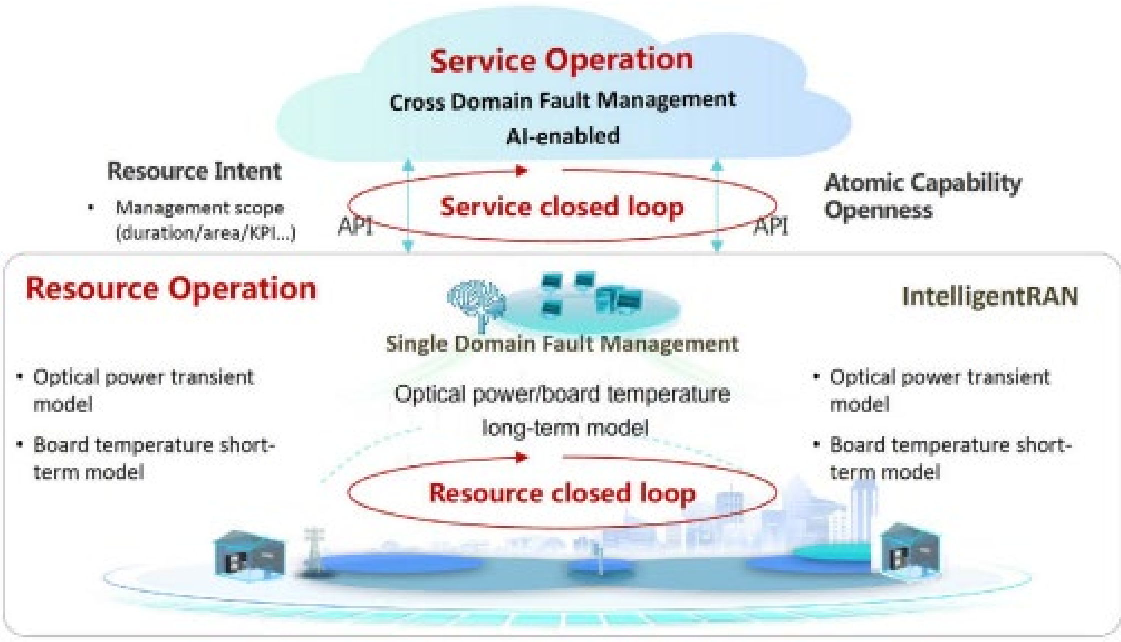

Figure 50*: Equipment high temperature/optical power prediction solution*

Figure 50 shows the solution, and a more detailed explanation follows.

- **Automatic equipment room self-inspection based on image recognition** – the inspection scope covers 11 types of items and 25 sub-scenarios (such as equipment room door locks, batteries and grounding surge protection), and 9 types of problems (such as battery rust and warranty period). Engineers can quickly take pictures and inspect equipment rooms, improving single-site inspection efficiency and ensuring that no inspection items are missed.
- **Proactive risk self-elimination assisted by knowledge library** – inspection personnel automatically check alarms and performance of devices based on inspection rules. Abnormal incidents can be handled by referring to the online

knowledge library of MAE. Alternatively, they can call experts for support in one-click mode, greatly improving the efficiency of equipment room inspection and troubleshooting.

Benefits

The equipment high temperature prediction solution has yielded satisfactory results in China and Thailand. The accuracy of predicting high board temperatures five days ahead reaches more than 90%. Possible causes and troubleshooting guidance are provided. Early troubleshooting significantly lowers the risk of base station being out-of-service due to high temperatures.

The AR site inspection solution has been verified in many provinces and cities in China. The solution can be used to read almost all dashboards and other items that need to be read by human eyes in wireless equipment rooms, reducing the inspection duration from 70 minutes to 30 minutes compared with traditional methods. The AR-assisted troubleshooting prototype solution reduces mean time to repair of fronthaul faults for onsite troubleshooting verification in typical scenarios.

4.3.11. Wireless Network - Dynamic Near-Real-Time Optimization

Wireless networks change with the passage of time. There are changes from many aspects, including the radio environment, traffic volume, network load, user locations, and service experience. The frequencies of these changes are different, for example, long-term monthly and weekly user growth, daily and hourly tidal traffic changes, minutes-level emergencies, and seconds-level and milliseconds-level service experience deterioration.

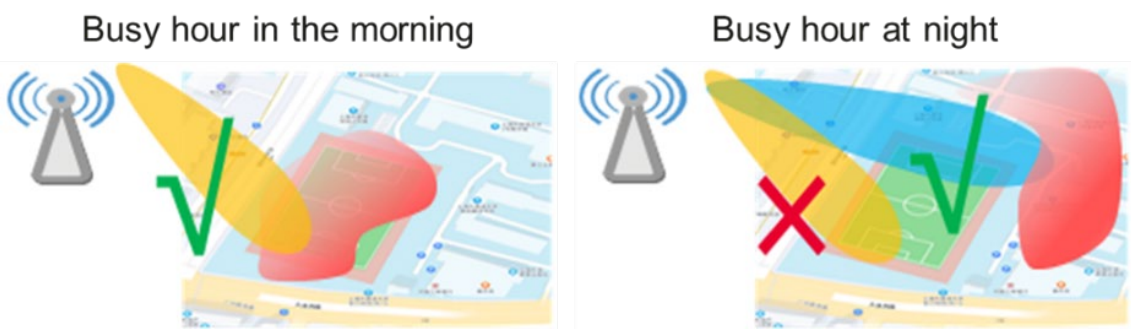

Figure 51***: Dynamic changes of wireless network traffic over time***

Dynamic network changes, especially those that happen within a few minutes or seconds, create tremendous challenges to network O&M. When an unexpected network event occurs, traffic converges quickly, and the usage of air interface resources increases rapidly, resulting in complaints from cell edge users due to the deterioration of user experience. If such an event occurs, the experience of specific users is reduced to a level lower than that specified in the SLA, affecting the experience of the entire service. It is difficult for O&M personnel to quickly monitor and respond to network or experience changes that occur within a few minutes or seconds. These frequent network changes are averaged in periodic and regional monitoring results. The impact of these changes on user experience cannot be quickly perceived. It may take one or two hours for data collection, root cause analysis, and closed-loop decision making after a complaint is received.

To address these issues caused by dynamic network changes, intelligent capabilities are introduced to mobile networks. Based on Huawei IntelligentRAN architecture, wireless NEs collaborate with MAE to quickly detect changes, and adaptively adjust and optimize networks.

Solution

To adapt to dynamic network changes, an intelligent network needs to provide quasi-real-time optimization capabilities, including:

- Network-level near-real-time perception and prediction of network performance or experience changes.
- Near-real-time optimization and closed loop for burst traffic or experience deterioration.

The solution consists of three parts: time modeling, network-level near-real-time perception and prediction, and near-real-time optimization and closed loop.

KPI change feature extraction and time series modeling: Network KPIs, such as traffic, resource usage, and throughput, of each cell change with the passage of time. Network data within a certain period can be collected to extract the features of long-term and short-term changes in order to develop a cell-specific time series model that can predict KPI changes.

Network-level near-real-time perception and prediction of network or experience changes: The time series model for network KPI changes and computing power can be leveraged to automatically identify burst traffic or experience deterioration on the entire network. The identification result can be immediately reported to the upper-layer management and control node. Collaborative intelligent identification at the network and NE levels in the intelligent architecture achieve minutes-level and seconds-level near-real-time prediction when compared with the traditional monitoring mode. Based on the short-term trend, KPI trends can be predicted to identify network or experience risks.

Near-real-time optimization and closed loop of burst traffic or experience deterioration: Problematic cells and correlated cells are quickly identified to provide optimization solutions (including MLB parameters, multi-frequency camping and mobility parameters, RF beam parameters, and power control scheduling parameters) based on the topology, scenario analysis, and model technologies.

Benefits

In Tianjin, shopping malls and pedestrian streets are located in business districts, and residential areas are located in adjacent districts. Traffic is concentrated in different areas in different time segments (shopping malls and pedestrian streets during the day, and residential areas at night). Based on the traffic changes predicted by the time series model, SSB beams of 5G cells are dynamically adjusted to increase the traffic volume and number of users by 5% to 10%, while ensuring that the KPIs remain normal.

In the university and industrial areas in Shandong province, traffic changes dynamically in industrial parks, urban villages, hospitals, residential areas, and secondary vocational colleges in different periods. After dynamic optimization of SSB beams in 5G cells, the traffic and number of users increase by 5% to 10%, while ensuring that the KPIs remain normal.

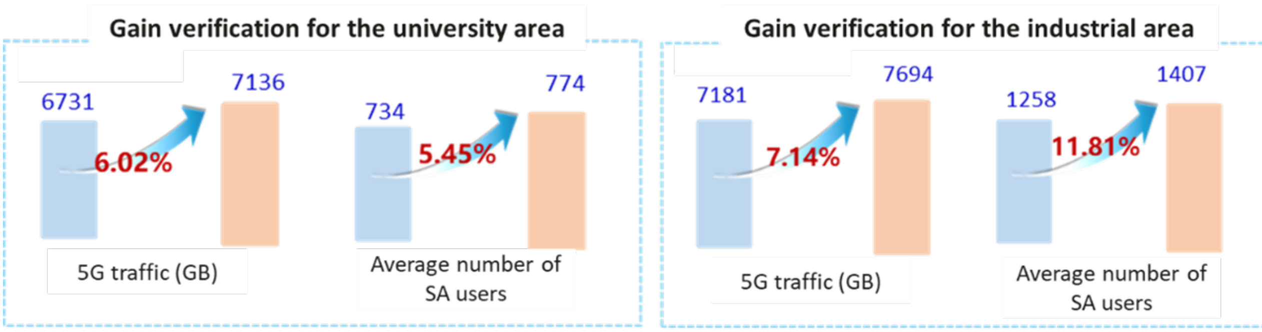

Figure 52*: Gain verification for the university/ industrial area*

4.3.12. Intelligent Locating of Optical Path Interruptions Within Milliseconds

Automatic and intelligent O&M for all-optical networks has always been an industry focus and a daunting challenge. The transport network is crucial to all-optical networks: Any fault with the transport network will affect numerous services and a large number of customers.

Line interruption is a common transport network fault. For example, a municipal subsidiary had 3,234 tickets for transport network faults in a month, among which about 50% were ETH_LOS optical path alarms. Rectifying line faults is expensive and time-consuming with a mean time to repair (MTTR) of about four hours.

Rectifying optical path faults involves three main challenges:

- It is difficult to perform fault demarcation and locating due to many potential fault points, including power and environment, equipment rooms, optical modules, optical fiber pigtails and optical cables.
- The traditional method for locating optical signal LOS alarms on a peer device cannot accurately identify the root cause (for example, power failure, optical cable interruption or connector disconnection).
- Precision must be compromised to improve the efficiency of centrally analyzing a large amount of KPI data (for example, optical power data).

Solution

To better predict optical path risks and accurately locate optical path interruptions, an unnamed CSP and Huawei jointly developed the millisecond-level intelligent optical path interruption locating solution. This solution provides millisecond-level optical power sensing capabilities for NEs, AI model optimization, and network topology-based end-to-end demarcation and locating capabilities. It can quickly detect and accurately locate optical path interruption faults, improving O&M efficiency. The solution architecture is shown below, and a description follows.

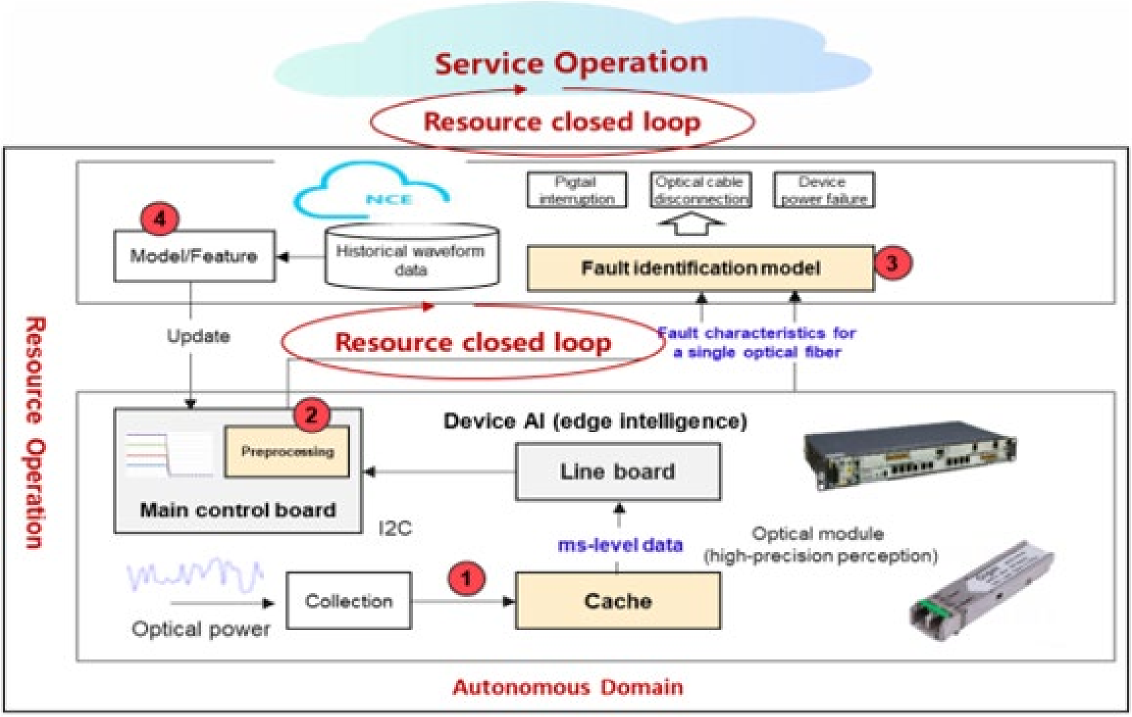

Figure 53*: Millisecond-level intelligent optical path interruption locating solution*

- **Native network intelligence** – the sensing capability of optical modules on NEs is upgraded to continuously collect real-time and fine-grained optical power data within milliseconds. Based on the AI capabilities of NE boards and the large data scale, the AI model for identifying optical path interruptions is continuously optimized to accurately identify optical path interruptions caused by power failures, pigtail disconnection and optical cable interruption.
- **Single-domain autonomy and cross-domain collaboration** – the optical module of an NE collects data and caches data within a short period. The edge AI module of the main control board of the device performs local analysis to demarcate and locate the causes of interruption at the NE level. The NMS identifies single-domain faults based on the network topology and automatically starts fault demarcation and locating, achieving single-domain autonomy. Key data in the demarcation and locating result is reported to the upper-layer system to enable cross-domain collaboration.

Benefits

This solution has been piloted and verified on networks in many provinces, including Henan and Guangdong. A full 77% of faults can be located within just a few minutes with an accuracy of 95%. The average troubleshooting efficiency is improved by 30%. The troubleshooting efficiency of frontline and second-line maintenance personnel is also significantly increased, reducing unnecessary site visits.

4.3.13. AI-Intellectualized O&M management

Traditional ways of handling O&M are facing many challenges including opaque system rules, inconsistent data management, fragmented business processes, slow demand response and high development costs. It is urgent to build an O&M capability platform and apply AI to realize full lifecycle management of business processes, automation processes, agile development and self-service.

Architecture and solution

The architecture for the AI-intellectualized O&M management solution, shown in Figure 51, has several goals:

- Extracting the common capabilities of electronic O&M systems, substitute maintenance systems and materials management systems
- Building an AI capability support system for O&M management with unified processes and users and data integration
- Realizing end-to-end penetration of O&M workflows Improving the efficiency and intelligence of O&M work scheduling
- Providing cross-layer and cross-domain process self-monitoring and self-service for all business systems in the OSS domain.

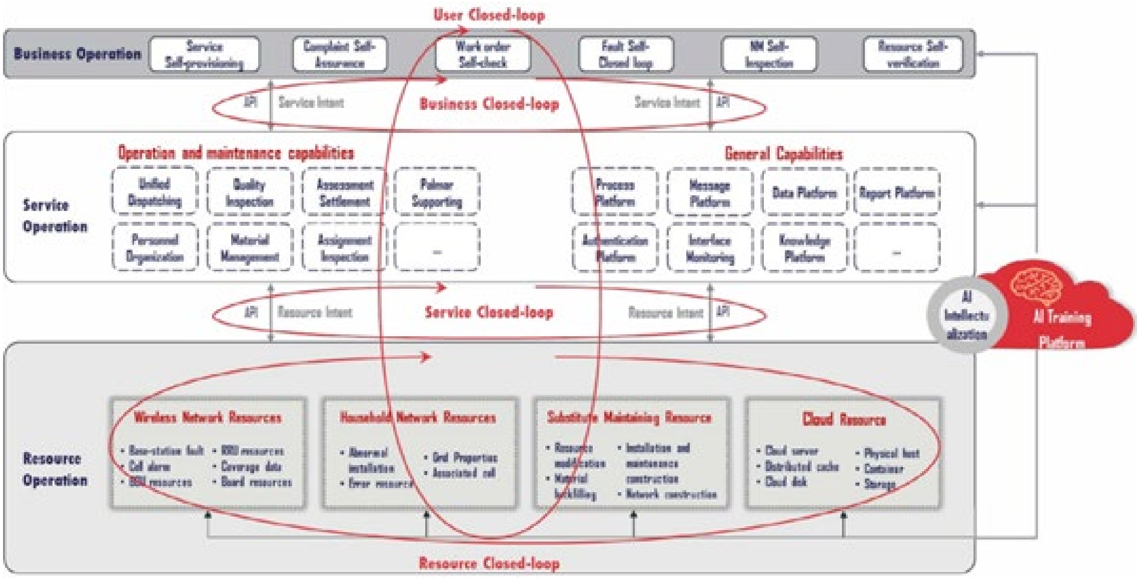

Figure 54*: AI Intellectualized O&M management solution*

The AI-intellectualized O&M management solution realizes automation and intelligence of O&M in the following ways:

- **Visualized fault closed loop** – when a fault event is triggered, the processing group/ personnel and all task lists to be executed are automatically matched according to the scheduling process configuration. The task can be presented quickly to realize the visual closed loop of the work order and fault self-monitoring.
- **Intelligent work order quality inspection** – analyzes the assessment intention of the manager and completes mass work order quality inspection through intelligent methods with AI training instead of manual. It promotes the standardization of fault handling process and improves the efficiency of O&M management from the perspective of the authenticity of fault recovery and the normalization of work order response.
- **Automatic patrol inspection of network management** – analyzes the intention of patrol inspection objectives and scenarios, automatically selects the corresponding operation plan and completes the distribution to realize the unified management and scheduling of cross-domain and cross-integrated network management intelligent patrol inspection.

- **Resources patrol inspection with AI** – completes a series of operations such as “scanning, target identification, photo uploading and compliance detection” through AI capabilities including video scanning and identification and helps O&M personnel conduct paperless and standardized patrol inspection during the work. The patrol inspection records can be uploaded to the server in real time for future reference, and the resource data can be automatically retrieved and verified according to the resource situation.

Application and outcome

This solution has been tested and verified in the O&M management of Anhui Mobile, Sichuan Mobile, Hunan Mobile, China Unicom Group and other provincial operator, where is has improved O&M efficiency and ANL.

- The intelligent quality inspection method has been deployed and applied in wireless, transmission, data, and other fields. The coverage rate of intelligent quality inspection is 99%, and the accuracy rate of intelligent quality inspection reached 95%.
- The quality inspection efficiency is reduced from 9 people per month to 1 person per month. The intelligent quality inspection capability of fault work orders has been deployed in AI mid-platform. The AN level of work order quality inspection reached L3 in Q4 2021. The demander can directly invoke it. Nowadays, the average number of invoking per month has reached 454,000.

4.3.14. Intelligent Automatic Verification of Dumb Resources Based on AI Technology

Dumb resource management is the vital and difficult task of resource operation and plays a decisive role in resource management. The dumb resources refer to the network element resources that cannot be automatically collected by the operation and maintenance system. In simple terms, they are resources which cannot ’speak’ and have no initiative. The amount of dumb resource data is huge and cannot be automatically collected, and the accuracy of dumb resources seriously affects the planning and construction, business scheduling, business monitoring and other service operations, and then affects the user's experience and business operation and maintenance procedure which penetrates the network domain, operation and maintenance domain and business domain.

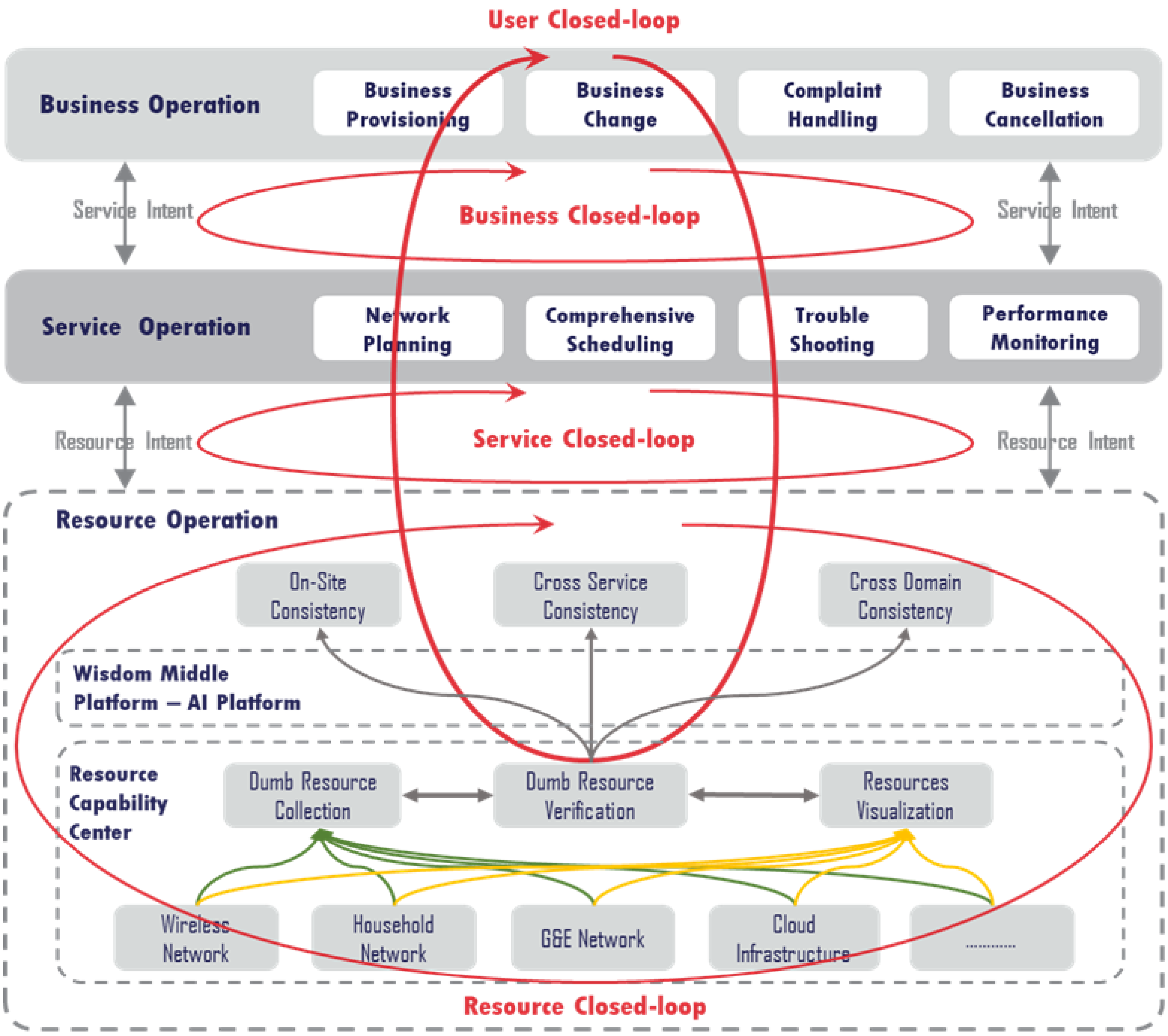

Figure 55*: Intelligent Automatic Verification of Dumb Resources Based on AI Technology*

In order to manage dumb resources and change the phenomenon that the input of resource data is inconsistent with the actual situation on the site, it is necessary to establish a centralized resource management system, which is relied on the production process of various resource management such as embedded network and inventory check, and collect immediate resource data and longitude and latitude dot photos on the site with the intelligent APP. The resource information will be stored into database and archived only after the audit by backend.

The resource audit has become a very important work in the current dumb resource management. There are many issues about the accuracy which is judged by manually comparing with the on-site photos and data in the current audit stage:

- **The Innumerable work orders make the audit pressure enormously**: the number of dumb resources in a certain province of China Mobile is nearly 150 million, the monthly average audit work orders is more than 10000, and the average monthly audit pictures are more than 100000. At the same time, the audit work should be embedded in production, and the audit time limit is short, so these factors result in enormous audit pressure.
- **Due to relying on manual audit, the audit standards are not unified**: dumb resources cannot be automatically collected, and their accuracy must be

checked by audit. However, the audit work is still conducted manually, lacking the intelligent methods.

- **Irregular on-site photographing procedure make great difficulty in review**: there are a large number of nonstandard or false photos in on-site photographing, which makes it more difficult for the backend review, resulting in a large number of invalid inputs and affecting accuracy.
- **Large demand for audit personnel and low audit coverage**: due to lack of automatic method to improve efficiency, and many ineffective inputs, the gap of audit personnel is large, so we can only spot check according to the proportion and cannot fully cover all dummy resources.

According to the current situation of dumb resource management, the steps of "establishing standard, intelligent audit, embedded production, automatic audit, analysis and optimization" dumb resource collection and verification are proposed, and a new dumb resource management system of intelligent and automatic verification shall be established.

Establishing on-site image collection specifications: according to the standard specifications of resource on-site image collection, add image acquisition verification in dumb resource on-site APP to effectively guide on-site construction personnel.

Building AI intelligent audit capability: composed the AI capability of the intelligent mid-platform and the self-built two-dimensional code identification capability and build up AI intelligent audit methods such as on-site resource type identification, name identification, location comparison and two-dimensional code identification.

Embedded AI capability in production & automatic audit: combined with AI capability and automatic audit model, audit and control the scenario processes of centralized resource creation, cutover, error correction and inventory inspection, it can effectively reduce the workload of manual audit.

Analysis and Optimization: provide statistical analysis report of collector portrait, work order automatic audit and picture AI intelligent audit. The personnel are assessed and analyzed through the portraits, and the on-site photographing problems are summarized through the analysis of the AI intelligent audit results. The photographing specifications are optimized according to the problems, forming positive closed loop.

The solution has been put into practice in China Mobile's branches in many provinces and achieved remarkable results. Taking a provincial branch as an example, after the intelligent automatic verification of dumb resources was launched, the audit efficiency was significantly improved, and the labor cost was reduced. The AN level can reach L4 in the related rating.

- There are 15,000 monthly audit work orders in this province, the automatic audit success rate can reach 90% + after deploying the Intelligent Automatic Verification System of Dumb Resources. There is an average of 1000 times per day for invoking AI identification capability of smart mid-platform, 3000 times per day for invoking OCR capability, and 2000 times per day for invoking QR code identification.
- The audit time of single work order is shortened from 180s to 60s, and the time consumption is reduced by 66.67%.
- 438 hours of labor hours can be saved every month, 5255 hours per year, and 93.33% of audit labor can be reduced.
- The coverage rate of resource verification is 100%.

4.3.15. End-to-end Cross-layer Network Fault Location Solution

Based on NFV(Network Function Virtualization), the core network is constructed on three layers (application layer, virtual layer and physical layer) and multiple VNFs share the resource pools. Service fault location is more complicated than that of traditional devices. In general, network faults have the maximum ratio, the greatest impact, and the greatest analysis difficulty among service faults. So rapid delimitation and location of network faults has become a key point for troubleshooting in the NFV architecture. Cross-layer diagnosis and analysis of network faults are very difficult, and have the following challenges:

- **Unclear Network Topology:** Complicated and dynamic network topology is caused by network virtualization, and visual network topology is not available.
- **More Potential Fault Points:** VM -> Virtual NIC -> Virtual switch -> Physical network interface ->TOR/EOR switch -> router. Longer traffic forwarding path increases fault points and it is more difficult to delimit the faults.
- **Difficult to Implement Traditional Packet-capturing:** Unclear topology and complicated types of faulty protocols, and packet-capturing is too difficult to implement.
- **Lack of End-to-End Location Method:** The existing network fault location tools only support single-layer fault location without inter-layer end-to-end fault location measures crossing application layer, virtual layer, and physical layer.

End-to-end cross-layer network fault location solution integrates the fault location capabilities of three layers under the NFV architecture. From the application layer top-down, it breaks through the capability barriers of each layer, and integrates the fault information of each layer, so as to realize fast cross-layer fault delimitation and location. This solution achieves closed loop at the resource layer in CN autonomous domain and supports the service layer to achieve closed loop of services. In this way, self-monitoring, self-reporting, and self-analysis capabilities are improved in an all-round way, and the core network can achieve self-intelligence network of L3. Figure 56 shows the architecture of the end-to-end cross-layer network fault location solution.

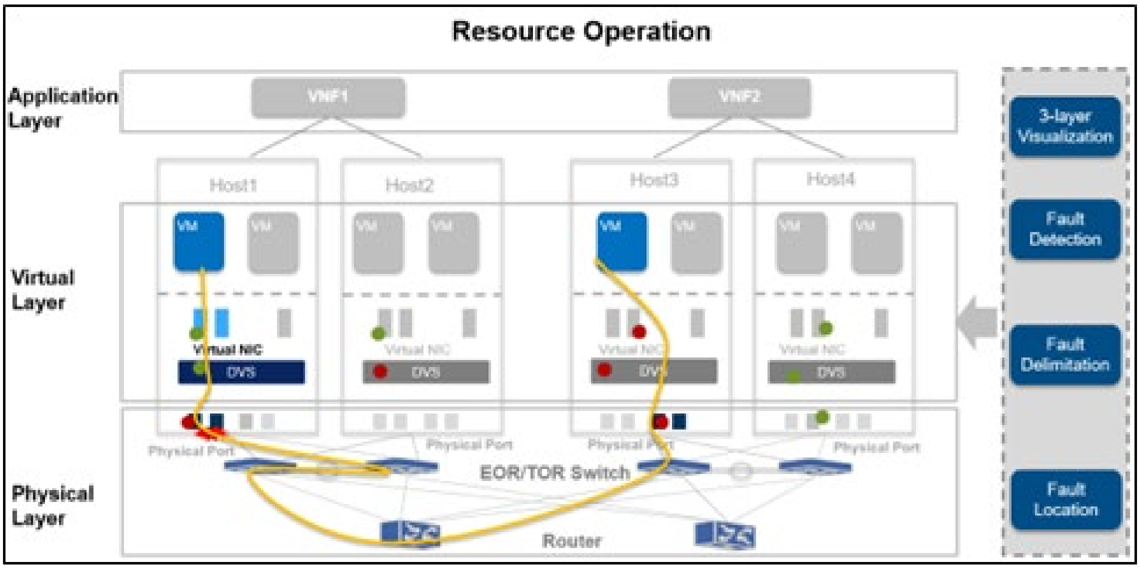

Figure 56*: Resource operation*

This solution comprehensively improves zero-touch and zero-fault from O&M dimension through four in-depth analysis methods of "three-layer network visualization, fault detection, fault delimitation, and fault location," and helps achieve zero-interruption of services.

- **Three-layer Network Visualization:** Visible network topology of three-layer and all the resources in the resource pool, and the layers are displayed together. By rendering alarms based on the topology graph, faulty nodes and possible network paths can be found rapidly to assist in locating network faults.
- **Fault Detection:** Ping addresses of network and application in real time to detect the disconnection, packet loss, and to detect potential network faults.
- **Fault Delimitation:** By tracing IP packets, the system can collect statistics on IP packets and render them, and then analyze the traffic in the resource pool at the minute -level granularity to help implement fast fault delimitation.
- **Fault Location:** Provides automatic and intelligent packet capture capabilities for troubleshooting. Through one-click generation of packet capture paths and one-click delivery of packet capture instructions, packet capture can be implemented efficiently and reliably, and faults can be rapidly located.

This solution has been verified in many networks (China mobile, China Unicom, China Telecom etc.) and has been used for commercial purpose. The verification results show this greatly improves O&M efficiency of network troubleshooting.
ü **Resource Panorama**: Displays distribution and connection relationships of VNFs, VMs, HOSTs, network devices and links in the resource pool.
ü **5-minute Fault Delimitation**: In the complex traffic model scenario, fault delimitation duration is shortened from 60 minutes to 5 minutes, covering above 90% of the cross-layer faults.
ü **10-minute Fault Location**: Efficient and intelligent packet capture, and efficiency is improved more than 90% as compared with traditional mode.
ü **Improve Self-intelligent Network Level**: Improve self-intelligent network level, and advance CN O&M towards L3.

4.3.16. 5G Preventive Maintenance of Ultra-high-pressure Dense Corridor

Anhui whole territory ultra-high-voltage line 2627 km is the only way to transport load center of East China with clean energy in the west. It is also the "big artery" and "highway" sent by East China Electricity in the west. The super-high-voltage dense power transmission channel (backbone layer) is formed by the "seven lines combined 1" operation and maintenance lines of Anhui Power Supply and Transformation Engineering Co., Ltd. Mei Jiechi Town, Guichi District, West Chizhou, and Xinhe Town, Qingyang County, Chizhou, is located in a mountainous area and remote suburb country. It is intended to integrate 5G with the ultra-high-voltage drone preventive maintenance service to achieve the integration of 5G and power services.

Traditional service guarantee has the following disadvantages:

- Ultra-high voltage (UHV) lines, remote areas in the field, and long line mileage.
- The safe environment of the tunnel corridor is harsh, and manual preventive maintenance is inconvenient.
- Substations and power distribution rooms are widely located, and the cost of preventive maintenance is high.
- The manual preventive maintenance of the power grid is low in efficiency and easy to be omitted.
- 24-hour preventive maintenance in special scenarios.

According to service characteristics, 5G slicing in the power industry is required to be highly reliable and secure, and private network slicing is required.

Case

Based on the atomic capability of BAF, the 5G private network + China Mobile A8 network design service is built for application and transport network design, to implement the three-dimensional patrol of the ultra-high voltage channel of Anhui Electric Power and fine management of service applications.

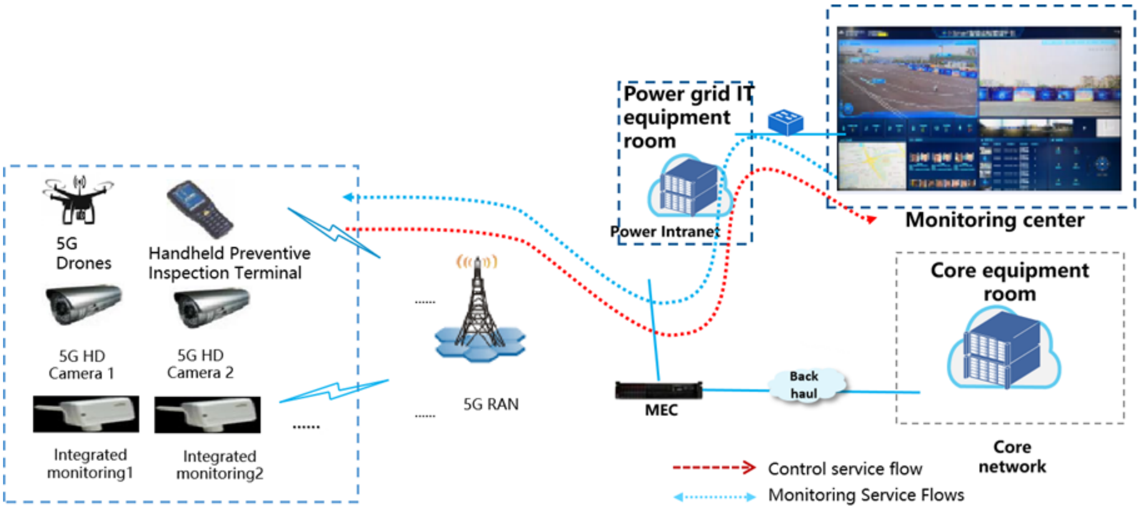

Figure 57: ***5G Private Network Architecture Of High-Voltage Dense Channel In Chizhou Jiuhua***

- 5G+MEC distributes local service data and ensures data security.
- 5G+ preventative maintenance, early warning, forest fire protection preventative maintenance, and real-time backhaul video content analysis and identification, thus improving the line preventative maintenance information construction and management efficiency.
- 5G large bandwidth, to meet the application requirements of real-time HD video and mountain fire prevention.
- 5G network slice plans dedicated service channel to ensure 5G service experience.

Case Results

The original manual preventive maintenance cost of this line is 2 million yuan/person · years. The subsequent manual preventive maintenance cost is 1.8 million yuan/person · years. With the sharing of power towers, the construction cost of iron can be saved by 1 million yuan/unit. The use of 5G slicing technology unique to CSPs can flexibly ensure 50% decrease in QoS compared with traditional private line, wired access, 4G network cost and deployment speed. The reliability is greatly improved and the establishment of BAF network service business mode is promoted.

4.4. Green Energy

4.4.1. China Mobile: Green and Intelligent Optical Cross-Connect (OXC) Network

Development of services such as 5G, cloud and "eastern data and western computing" , as well as customers' demands for green energy saving and zero-wait ANs, transmission network nodes face unparalleled challenges in capacity, energy saving, latency and autonomy. At the same time, the traditional optical switching solution occupies a large amount of cabinet resource, fiber patch cords between cabinets and much energy. Therefore, a new optical technology solution is badly needed. To meet the low-latency and intelligent O&M requirements of premium private lines, CSPs must greatly accelerate the deployment and expansion of optical paths to achieve single-day service provisioning and intelligent assurance.

Solution

OXC supports single-domain autonomy and enables resource closed loops. The company pioneered the adoption of multi-dimensional, all-optical OXC technology on intelligent transmission NEs to accelerate single-domain autonomy, save energy and enable intelligent O&M. In addition, network capabilities are open to enable agile business. OXC replaces the traditional optical-to-electrical conversion, thereby achieving high integration, low-energy consumption, zero fiber connection and simplified O&M. In addition, the network architecture is optimized (Meshnet), leading to a significant decrease in latency and increase in transmission network quality (see Figure 58).

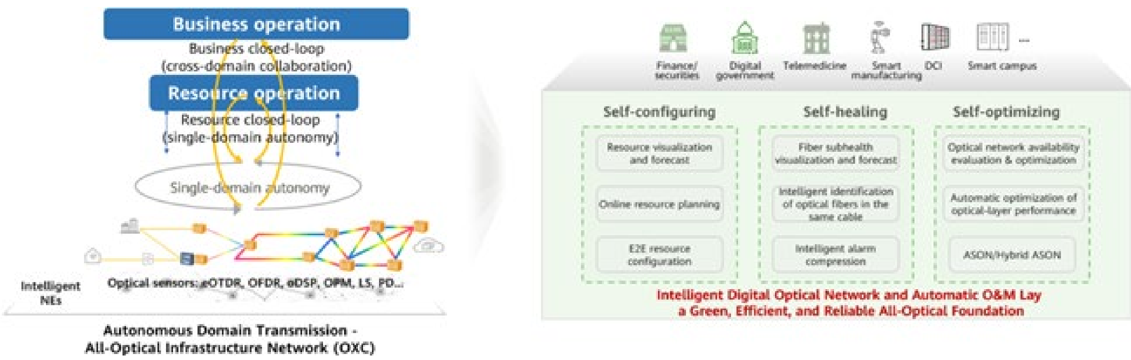

Figure 58*: Architecture of a green and intelligent OXC network*

Application and benefits

OXC lays a green, autonomous, all-optical foundation for the development of premium private lines. It reduces the space needed for transmission devices by up to 90% and cuts their energy consumption by 60%, respectively, with no fiber connection at sites. In terms of transmission latency, it forms a 10ms latency circle around cities, facilitating more efficient operations of premium private lines.

Provincial branches such as China Mobile Jiangsu have joined hands with Huawei to deploy the OXC technology. This move helps them save space amounting to 216 optical-layer and 42 electrical-layer standard transmission racks in their transmission backbone equipment rooms. For the 34 optimized nodes, China Mobile Jiangsu estimates its energy savings to be 1.3 million kilowatts a year, with a 45% reduction in energy consumption.

By adjusting the network structure, the operating company effectively reduced the transmission latency, with intra-province transmission latency cut by 33%. This ensures the quality and experience of 5G private networks and transmission private lines and builds a solid technical foundation for Autonomous Networks.

4.4.2. China Mobile: Dynamic Energy Saving With Slicing Packet Network(SPN)

In 2021, China Mobile's energy consumption costs were 36.878 billion Yuan ($5.4 billion), and the transmission network accounts for about 5%-10% of the total. China Mobile is developing the SPN for 5G slicing of the transport network, which will reduce energy consumption.

Service volume on the SPN transport network gradually increases with continuous development of enterprise private line services. Service traffic changes with time and shows an obvious tidal effect: there is a large difference in loads between peak and off-peak hours.

However, the energy consumption of network devices does not change when service loads vary. Instead, they always consume energy at full load, resulting in unnecessary waste. CSPs must find ways to formulate dynamic energy-saving policies and properly set energy-saving parameters in order to implement refined and dynamic adjustment of energy consumption while ensuring network experience. Service KPIs must not deteriorate in energy-saving mode, but the energy consumption of the entire network needs to be reduced.

Solution

Working with Huawei and ZTE, China Mobile built an AI system to accurately forecast link traffic trends based on historical traffic data, network topology, and service routes. This system collects network data in real time, models traffic-burst patterns, intelligently analyzes service load changes, and automatically generates multi-layer (chip/module/board) multi-mode energy saving solutions (see Figure 59). This makes dynamic energy saving a reality.

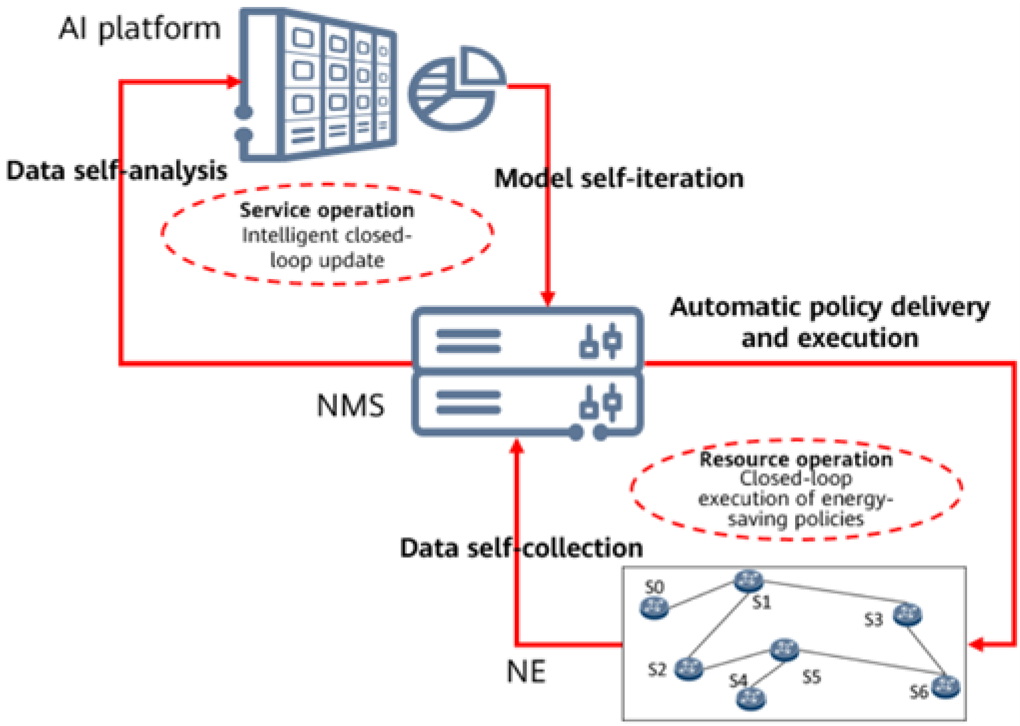

Figure 59*: AI platform for dynamic energy saving*

Application and benefits

The solution has been piloted in provincial subsidiaries such as China Mobile Guangdong. On the premise that service KPIs do not deteriorate, this solution achieves deeper shutdown and longer energy-saving periods. The average energy consumption is reduced by 15% to 18%. During the pilot application, the system has been proven efficient and reliable in various scenarios including Children's Day, Dragon Boat Festival, China National College Entrance examination and even natural disasters caused by huge floods.

4.4.3. China Mobile: Facilitating Low-Carbon Operations of State Grid Corporation of China

In Anhui, China, the ultra-high-voltage line covers 2,627km and is the only way to transport clean energy from western China to eastern China. Traditional inspection of the electricity transmission line has many disadvantages:

- Ultra-high voltage (UHV) lines, remote areas in the field, and long line mileage make it difficult to reach.
- Guaranteeing the security of inspection personnel is difficult, and manual maintenance is inconvenient.
- Substations and power distribution rooms are widely located, and the cost of operations, administration, and maintenance (OAM) is high.
- The manual OAM of the power grid is inefficient, and it is easy to make mistakes.
- 24-hour inspection is needed in some special scenarios.

Solution

Based on China Mobile's BAF atomic capability (the company's BAF business model is a multi-dimensional, 5G dedicated network business model based on "Basic network + Advanced value-added functions + Flexible personalized services"), China Mobile Anhui is building a 5G private network for the State Grid of China. The solution combines a dual-network integration mode for the 5G private network and the power grid communication network, applying the 2B Smartlink one-stop service solution from ZTE to provide precise network planning and 3D modelling and simulation of the 5G power distribution intelligent O&M service (see Figure 60).

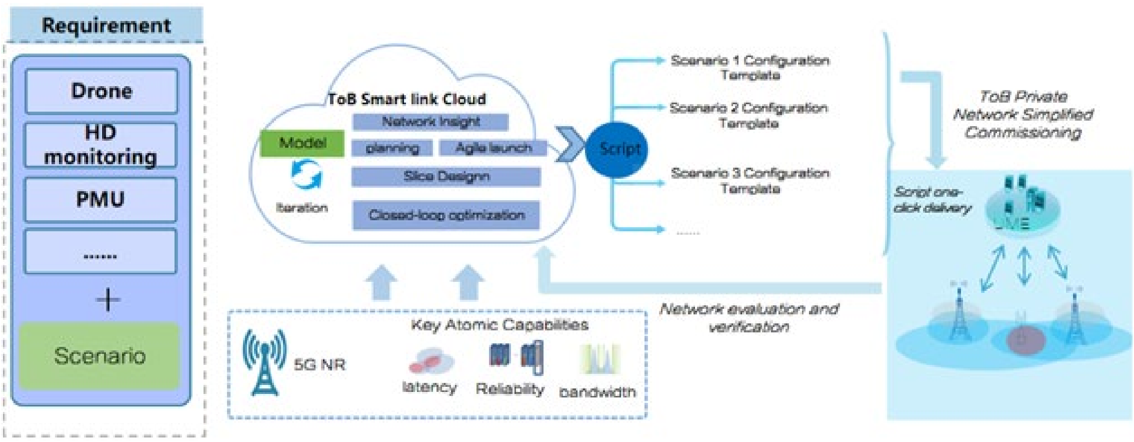

Figure 60*: 2B Smartlink 5G closed-loop management in the full lifecycle*

Through slice-dedicated configuration, China Mobile Anhui implements agile launch of the intelligent power distribution O&M service and guarantee of service indicators. The solution also provides closed-loop management throughout the full lifecycle of network planning, deployment, maintenance, optimization and operation to meet service requirements and implement 3D OAM of UHV line and fine management of services.

System data and public resource data such as meteorological and hydrology data are connected through the 5G private network. Various types of OAM and monitoring data are converged, and an intelligent OAM platform that monitors the full status of UHV lines is formulated, improving power scheduling efficiency and achieving accurate electricity power distribution.

Benefits

Manual OAM of the UHV line costs 2 million Yuan ($293,000)/person annually. The predicted cost saving will reach 1.8 million Yuan ($263 million)/person. With the sharing of power towers, 1 million Yuan ($146,000) per unit can be saved in construction cost of towers. CSPs’ 5G private network and unique 5G slicing technologies can be used to flexibly ensure QoS. Compared with traditional private lines, wired access, and 4G networks, the cost and deployment speed are reduced by 50%, and the reliability is greatly improved to promote establishment of BAF network service.

4.4.4. China Mobile： “Smart Cooling” Intelligent DC Cooling Solution

With the rapid development of the global digital economy and the continuous digital transformation of industries, the demand for and the construction scale of data centers in the world are increasing year-on-year. As a result, the energy consumption of data centers accounts for more than 1.3% of the global energy consumption. The energy consumption of the cooling facilities in the DC center is around 30%.
Therefore, effectively reducing the energy consumption of the cooling system and optimizing the power usage effectiveness (PUE) value is important for China Mobile to realize low-carbon innovation, reduce costs and increase efficiency.

The traditional PUE optimization mode of data centers mainly depends on O&M personnel. There are two limitations:

- **Limited expert optimization effect:** Whether O&M personnel has energy conservation optimization experience has a great impact on the final
- **Long optimization period:** Tens of device parameters are involved. It is difficult to find out the software optimization scheme quickly by manual statistical analysis methods due to more than 1,000 parameter combinations in IDC air conditioning systems.

The DC PUE Smart Energy Saving Solution adopts the architecture and concept of "autonomous optimization, Cloud-Premise collaboration, and continuous iteration". It introduces technologies and systems such as automation, AI intelligent platform, and RPA, which adopts multi-index time-space series prediction and deep neural network algorithms, actively predicts the subsequent operating conditions and air-conditioning energy consumption according to the historical data of outdoor temperature and humidity, which comprehensively improves the capability of "autonomous closed-loop energy-saving and self-evolving model". The DC cooling system is optimized and commissioned to achieve the effect of "fully automatic, short cycle, and more energy-saving".

- **Automatic closed loop of energy saving:** (1) The resource layer automatically collects the operating parameters and status data of cooling devices through the group control system. ② Energy-saving configurations are automatically delivered and executed. The DCIM at the service layer automatically performs energy-saving configuration reasoning. The RPA automatic robot implements seamless interconnection between systems of different vendors. The group control system automatically delivers and executes energy-saving configurations. ③ The energy -saving optimization is self-iterative, the policy updating period is set, and the parameters of the water cooling system are optimized quickly by multiple iterations, to achieve the optimal energy saving state. ④ Visualized energy-saving effect.

- **Automatic energy-saving model evolution:** Cloud- Premise collaboration implements automatic update and closed-loop of DC energy-saving models. ① Data samples are automatically collected and uploaded to the cloud-based AI platform, and models are automatically retrained. ② Automatically delivers the updated model to the local DCIM to implement continuous self-evolution of the energy-saving model.

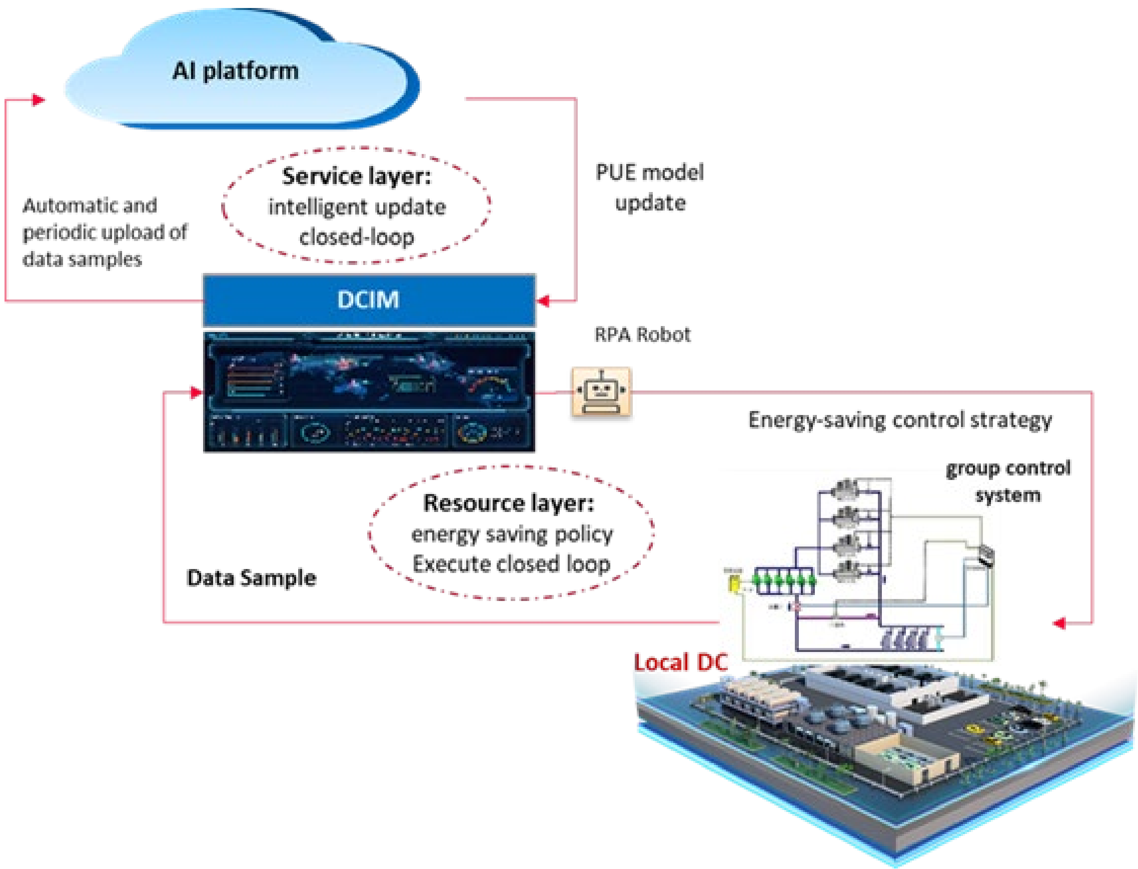

Figure 61*: The DC PUE Smart Energy Saving Solution*

Compared with the traditional expert mode, the DC PUE intelligent energy-saving solution has higher optimization efficiency and better energy-saving effect. After the pilot application in China Mobile Anhui, the energy consumption of data center refrigeration is further reduced by 8%-15%. An estimated electricity saving of 220 million kWh per year will be achieved after broader adoption.

4.4.5. Base Station Online Energy Saving

As CSPs' network energy consumption keeps increasing, reducing the energy consumption of the main equipment is key to delivering energy savings. Reducing the power consumption of the main equipment at wireless sites has become the top priority for all.

The network traffic volume varies greatly during peak and off-peak hours. Despite this, the equipment keeps running, and the power consumption is not dynamically adjusted based on the traffic volume, resulting in energy wastage. In a typical network, the features of different scenarios vary greatly. How we automatically identify different scenarios and formulate appropriate energy-saving policies becomes the key to energy saving.

The solution involves providing automation capabilities for the service management layer and resource management layer. Based on network-level AI-based intelligent energy saving policy management and site energy saving scheduling control, the mobile network energy saving solution implements network scene adaption, one site one policy, and multi-network collaboration for intelligent base station energy saving management. This maximizes network energy saving benefits while ensuring stable network performance and achieves the optimal balance between energy consumption and KPIs.

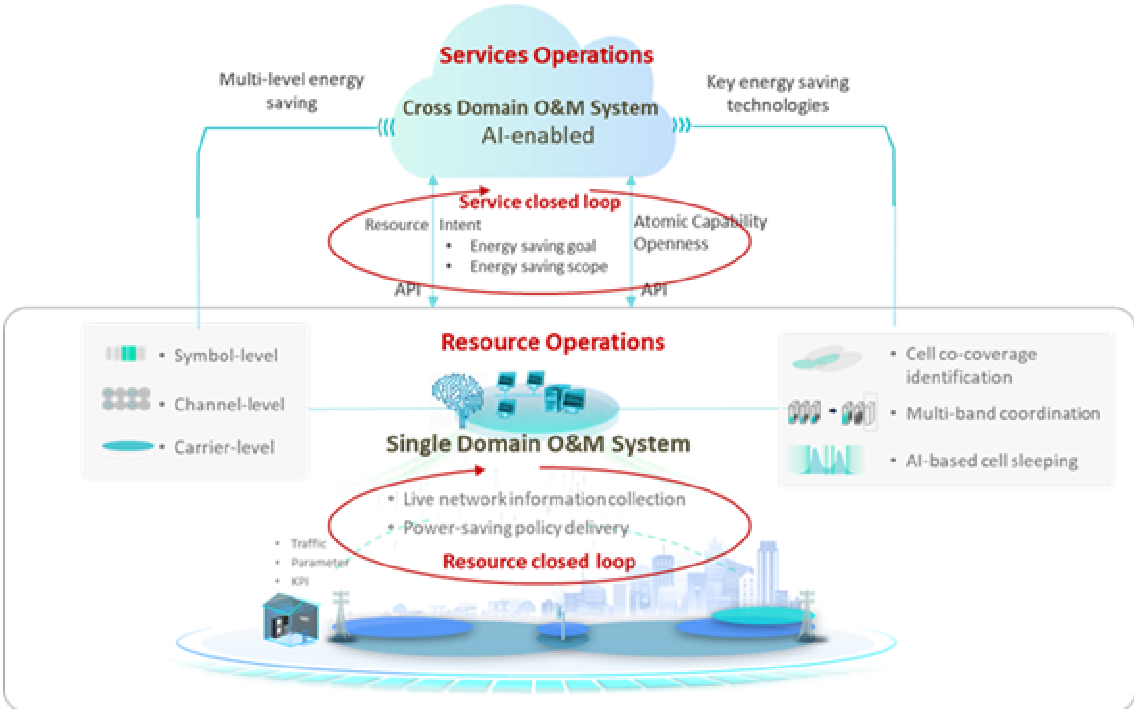

Figure 62*: Online energy saving solution*

The solution focuses on wireless single-domain and collaborative analysis of cross-domain data. The overall solution is as follows:

- **Data Self-awareness**: Automatically obtains network data from the resource management layer (radio domain) through scenario-based open APIs, including engineering parameters, MR measurement data, historical performance KPI data, and neighbor relationships. It automatically obtains other data that may affect energy consumption from the service operation domain, e.g., multidimensional data such as weather and specific events.
- **Data Self-analysis:**Based on big data analysis, AI technologies are adopted to automatically identify network energy saving scenarios, predict network traffic trends, such as traffic busy/idle hours and areas, traffic/energy consumption

trends, identify multi-cell co-coverage, and automatically generates energy saving policies.

- **Policy Self-adjustment:** real-time monitoring of impact on network KPIs and energy saving benefits is implemented to achieve human visualization and management of energy saving benefits on mobile networks.
- **Policy Self generation and Self-execution**: The system automatically delivers energy saving policies and implements network-level intelligent energy saving policy management and coordinated management and control of site energy saving scheduling.

Application and Performance

In typical network configurations, the power consumption of base stations can be reduced by 10%–15%, and the emission of about 2 million kg carbon dioxide can be avoided for every 1000 base stations in one year.

The RAN element management system (EMS) can automatically identify different scenarios and optimize energy saving policies for different networking modes and loads, maximizing network energy saving benefits while ensuring KPIs. The overall energy consumption is reduced by 13.59%. The average shutdown duration is 9.88 hours, which is a 57% improvement compared with that when the feature is manually enabled. The tidal effect is obvious in office buildings, business centers, large stadiums, suburban areas, and county-level areas. The average energy consumption is reduced by 16.88%. Globally, online energy saving solutions can help save CSPs 100 million kWh of power every year.

5. SUMMARY

We have seen more CSPs join the AN journey in the past year. SDOs make good progress in defining the business architecture, technical architecture/API, and best practice sharing. The AN realization methodology continues evolving and becoming more mature. The industry makes progress in defining AN levels and effective indicators from a business and user experience perspective. In all four categories (Enable Verticals, Customer Experiences, Business Growth, Efficient O&M, and Green Energy), many use cases are implemented in the operator's real networks. The methodology and practices from leading CSPs summarized in this document help accelerate the AN realization of other CSPs.

As leading CSPs will achieve L3 of AN in 2023 in specific domains, we expect more excellent use cases and best practices to emerge. We will continue to refine, summarize, and update relevant experience and reflect the key technologies, interoperability standards, and commercial cases of higher AN level.

6. REFERENCES

[1] https://www.ericsson.com/en/5g/forms/5gforbusiness-2019-report

[2]https://www.gsma.com/mobileeconomy/wp-content/uploads/2020/03/GSMA_MobileEconomy2020_Global.pdf

[3]https://www.idc.com/getdoc.jsp?containerId=US45599219

[4]https://mediabrief.com/45-of-repetitive-work-tasks-will-be-automated-by-2022-idc/

[5]https://www.networkworld.com/article/3325397/

[6]https://www.tmforum.org/Autonomous Networks whitepaper (Rel 1)

[7]https://www.tmforum.org/Autonomous Networks whitepaper (Rel 2)

[8]https://inform.tmforum.org/Autonmous Networks whitepaper(Rel 3)

[9] https://www.tmforum.org/resources/how-to-guide/ig1218a-autonomous-networks-case-studies-v1-0-0/

[10]Autonomous networks hyperloops - Enabling self-X digital services for smart-X verticals Phase II - TM Forum

[11]Whitepaper_AN_Enabling_Self_X_Digital_Services_for_Smart_X_Verticals.pdf (tmforum.org)

[12]IG1218 Autonomous Networks Business Requirements and Framework v2.1.0 - TM Forum

7. Administrative Appendix

7.1. Document History

7.1.1. Version History

Version Number	Date Modified	Modified by:	Description of changes
0.1	15-Nov-2021	Deng Lingli Liu Kaixi Min He Li Jiang Mohammad Rubbyat Akram Deng Delia Takayuki Nakamura	Initial Version, Based content from TMF White Paper "Autonomous Networks: Empowering Digital Transformation Third Release" With modification and additional contributions.
1.0.0	26-Nov-2021	Alan Pope	Final edits prior to publication
0.2	15-Nov-2022	Deng Lingli Liu Kaixi Min He Li Jiang	Based content from v1.0.0 and TMF White Paper v4.0 "Autonomous Networks: Empowering Digital Transformation – from strategy to implementation" with modification and additional contributions.
2.0.0	05-Dec-2022	Alan Pope	Final edits prior to publication

7.1.2. Release History

Release Status	Date Modified	Modified by:	Description of changes
Pre-production	26-Nov-2021	Alan Pope	Initial Release
Production	21-Jan-2022	Adrienne Walcott	Updated to reflect TM Forum Approved Status
Pre-production	05-Dec-2022	Alan Pope	Updated to version 2.0.0
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