HUAWEI

ADN Solution Overview

2022

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1. ADN Exploration and Practices

1.1 Opportunities and Challenges of ICT Network Development

1.1.1 Digital Economy Is the Predominant Trend for the Next Decade

A diverse range of technologies, including 5G, cloud computing, big data, artificial intelligence (AI), Internet of Things (IoT), and blockchain, have seen convergence and innovation in recent years, while governments and enterprises have been accelerating the process of cloud-based, digital, and intelligent transformation. In this context, digital economy is being deeply, rapidly, and widely integrated into all fields and processes of economic and social development. Digital economy is a predominant trend for the next decade.

Various countries have released their vision on digital economy.

By the end of 2021, over 170 countries had released their national strategies for digital development. China has defined intelligent industry transformation as a key development trend for the short and medium terms and in its 2035 vision and formulated clear development goals for manufacturing, energy, agriculture, healthcare, education, government, and other industries. In the 2030 Digital Compass released by the European Union (EU), 75% of enterprises will use cloud computing, big data, and AI services by 2030, and over 90% of small- and medium-sized enterprises (SMEs) will have basic digital technologies. To achieve these goals, the EU will increase investment in energy and the digital infrastructure. In the Vision 2030 report, the National Science Board of the United States also suggested increasing the investment in data, software, computing, and networks over the next 10 years to maintain the country's competitive edge in digital economy.

Converged development across different fields of technology is gaining momentum.

Technologies are progressing at an unprecedented speed. Digital technologies, such as 5G, cloud, and AI, are leapfrogging development beyond established boundaries. Technological innovation is happening not just in one but across various disciplines and technologies (cross-technology collaboration), and not just in vertical industries but across industries (cross-industry convergence), quickly leading us into a digital and intelligent future. By 2030, ubiquitous sensing technologies, wired and wireless 10GE broadband, inclusive AI, and industry-specific applications will be used to deploy digital infrastructure that is more conducive to urban living. Industrial manufacturing will leverage new labor forces, including collaborative robots, autonomous mobile robot (AMR), and digital employees, and the industrial Internet to create a more accurate, cost-effective process from requirements to production and delivery, thereby improving the resilience of the manufacturing industry. Smart finance will combine blockchain, digital watermarking, AI anti-counterfeiting, and privacy-enhancing computing with networks featuring intrinsic security to ensure digital security and trustworthiness.

Various industries are accelerating the use of innovative digital technologies.

Huawei's *Intelligent World 2030* report describes the use of digital technologies in vertical industries from eight dimensions: healthcare, food, housing, transportation, city, enterprise, energy, and trustworthiness.

1. The combination of ICT technologies and human biological data allows health to be calculable, improving the quality of our lives.
2. The scientific decision-making system combining big data, AI, and agronomic knowledge will build a sustainable, inclusive, and green food system.
3. Holographic communication and full-home smart control systems will create a space that "knows exactly what you want", making living space more people-centric.
4. The rapid development of new energy and self-driving technologies opens up a third mobile space outside homes and offices.

5. Digital technologies, such as new urban digital infrastructure, cloud computing, and blockchain, will create more livable cities and improve the efficiency of city governance.
6. New productive forces, such as collaborative robots, AMR, and digital employees, will be deployed in various industries. They will quickly reshape enterprise production and transaction models and improve the resilience of enterprises.
7. The full-link digital energy Internet of "generation-grid-load-storage" will systematically reduce carbon emissions and make green energy more intelligent.
8. Various technologies, such as blockchain, digital watermarking, and privacy enhancing, will lay a solid foundation for the sustainable development of a digital civilization.

1.1.2 Intelligent Industry Transformation Calls for New Network Capabilities and O&M

In the future, communication networks will connect hundreds of billions of things in addition to just tens of billions of people, while networks in various industries will serve the purpose of communication and office work, and play a significant role in production and operations. This requires new capabilities and operations and maintenance (O&M) on carrier networks.

Network performance needs to be improved by 10 to 100 fold.

New service scenarios, such as digital city governance, flexible manufacturing, remote energy control, drone inspection, and self-driving, require 10- to 100 -fold improvement in coverage, user-perceived rate, bearer connection density, user-plane latency, mobility, spectral efficiency, and other performance indicators on communication networks. For example, a smart city requires a connection density of 100,000 to 1 million devices/km^3; drone services require mobility of 500 to 1000 km/hour; self-driving needs an end to end (E2E) latency shorter than 5 ms and submeter-level positioning; the industrial Internet requires an E2E response time of 10 ms and 99.999% reliability.

New network capabilities are urgently needed.

New service scenarios require the following new network capabilities as well as better network performance.

- **The first is differentiated, E2E, and deterministic Service Level Agreement (SLA) assurance,** which can meet the differentiated requirements of various industries, production service scenarios, and users. Networks with this capability can offer various types of services and committed SLAs.
- **The second is converged network sensing and real-time processing,** which enables networks to capture more precise, accurate, and multidimensional data in the physical world and quickly process data. For example, the frame rate of collecting video data to detect industrial anomalies can be increased to 120 frames/s.
- **Last but not least, flexible resource expansion on the entire cloud network** allows efficient usage of network and computing resources in case of dynamic workloads. An example is dynamic linear resource expansion.

Energy saving and emission reduction urgently demand green networks.

It is difficult to constantly improve computing, storage, and network energy efficiency due to the slowdown of Moore's Law and the immaturity of new technologies such as quantum computing. As carbon peak and carbon neutrality gain popularity around the globe, energy saving and emission reduction for base stations and data centers have become the primary social responsibility for carriers. How can we deploy green and low-carbon networks based on innovative basic technologies to increase the network capacity by dozens of times, while keeping the energy consumption unchanged? This will be a daunting challenge for carriers.

Intelligent O&M is required to deliver superior experience.

To provide superior experience for vertical industries, carriers need to comprehensively improve automatic and intelligent O&M from the following aspects:

1. Integrated supply and assurance of cloud-network convergence services;
2. Exclusive networks, slices, or cloud services for all-round security assurance;
3. Real-time, online, one-stop, and on-demand flexible subscription, such as one-point access to the cloud or multiple clouds;
4. Development- and configuration-free integration of heterogeneous systems and devices for minute-level or real-time service provisioning;
5. Customer self-service, visualized service experience, and self-management and assurance.

In summary, the 2030 network will be a cubic broadband and green network that is AI-native, secure, trustworthy, and capable of providing deterministic experience and Harmonized Communication and Sensing (HCS).

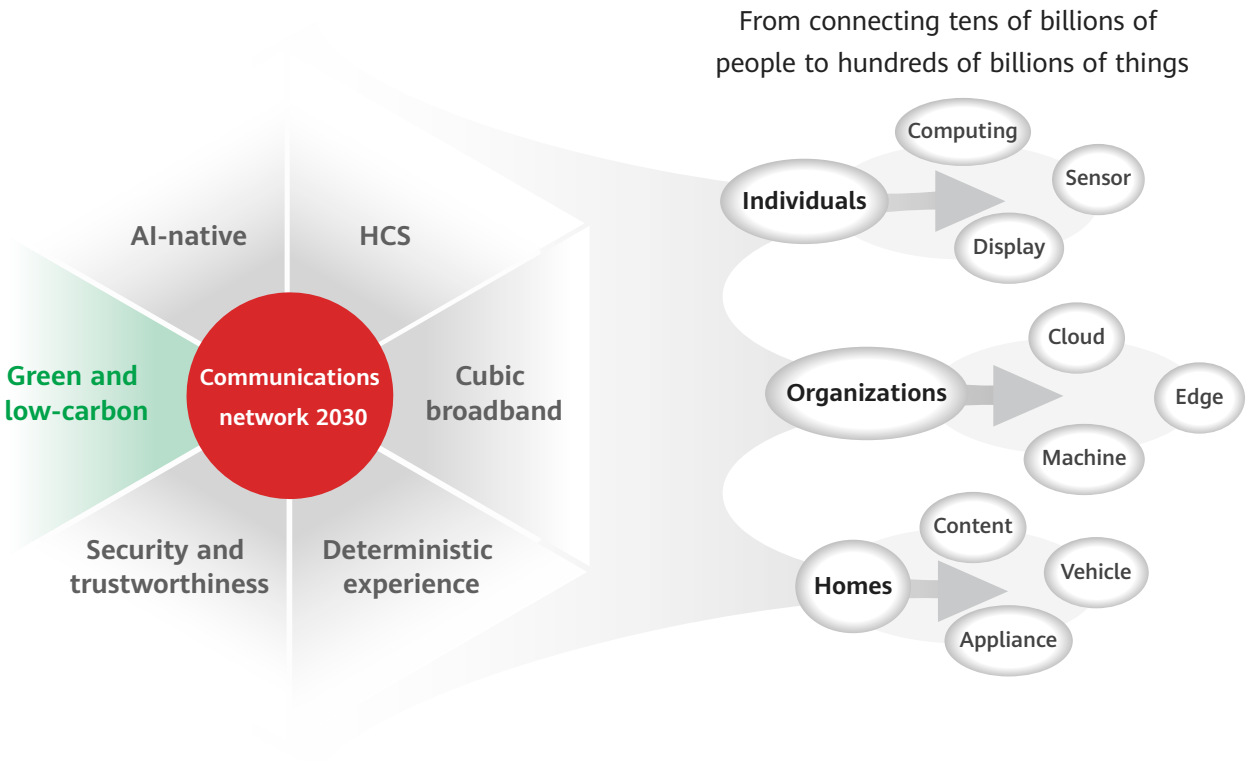


Figure 1-1 Vision on communications networks 2030

1.1.3 Challenges in Intelligent Transformation on Carrier Networks

Carriers have been facing many problems in recent years: increasing network complexity, rapidly increasing operating expense (OPEX), slow service innovation, and lack of monetization capabilities. To explore and implement network automation and intelligent transformation, carriers need to overcome various challenges, including the difficulty in selecting a transformation mode and starting point, lack of unified technical standards, difficulty in network reconstruction or evolution, difficulty in large-scale replication and promotion across the entire network, and many obstacles to operations system transformation.

Difficulty in selecting a transformation mode and starting point

Two modes are available, including the level-based construction mode of single-domain autonomy and cross-domain collaboration, and the linear promotion mode focusing on service scenarios and prioritizing service agility. Two starting points are also available, including operations support system (OSS) reconstruction, and concurrent network upgrade and OSS reconstruction. Therefore, the difficult in selecting a starting point for automation and intelligent transformation is a common challenge for the entire industry.

Lack of unified technical standards

Efforts are yet to be made to formulate unified standards from abstraction to implementation of use cases, in all network and service domains. Technical standards for Autonomous Networks are fragmented and inefficient in terms of collaboration. No unified target architecture is available to standardize the positioning and collaboration of providers, there are no unified definitions of network generations to guide the evolution of carriers, and there is no systematic technical standard to guide providers in the research and development of products and solutions.

Difficulty in network reconstruction and evolution

During network automation and intelligent transformation, carriers prioritize the reconstruction and evolution of traditional network services. However, the reconstruction and evolution are complex, expensive, and difficult. Many network elements (NEs) or devices on the live network have exceeded their service periods, leading to restrictions on scalability, availability, and reliability, and failure in meeting the basic requirements of network transformation. Removing or reconstructing networks is a challenge that must be overcome to implement network transformation.

Difficulty in large-scale replication and promotion across the entire network

During network transformation, most carriers first launch pilot projects for application innovation and business verification to develop success cases. However, these cases are difficult to replicate and promote across the entire network due to different network architectures, technologies, providers, organizations, and O&M processes among operating companies (OpCos).

Many obstacles to operations system transformation

The operations systems in use cannot adapt to automatic and intelligent O&M. Carriers face challenges in transforming the organizational structure, optimizing the process system, changing roles, and improving skills during network transformation.

Many technological breakthroughs, including the following, are required: accurate and real-time awareness in complex scenarios, high-precision maps and real-time simulation based on digital twins, multidimensional AI-based correlation analysis and decision-making.

Accurate and real-time awareness in complex scenarios

To achieve a high autonomous driving network (ADN) level, the status changes of hardware and software and environmental changes must be perceived correctly and reliably. Sensing the data required for implementing ADN in a more accurate, real-time, and precise manner is a major challenge that must be overcome to achieve a high Autonomous Networks level.

High-precision maps and real-time simulation based on digital twins

The risk of network changes increases with network complexity. Take the IP backbone network as an example. An incorrectly sent route can interrupt the network in the entire province, or traffic adjustment in province A may cause egress congestion in province B. Transforming from ticket-driven network services to order-driven network services requires the system to accurately predict the network status after configuration changes. Currently, this task can be completed only by members in an expert team after time-consuming analysis.

Multidimensional AI-based correlation analysis and decision-making

It is a challenge to establish an AI model based on the correlations between user experience, service quality, and network resources and then implement proactive O&M and real-time optimization based on service experience, prepare network resources, and maintain the network in a predictable manner. This is a daunting challenge that must be overcome to achieve a high Autonomous Networks level.

1.2 Autonomous Networks Becomes Industry Consensus and Enters the Planning and Development Phase

Autonomous Networks is a new industry that is highly recognized and continues to witness investment and innovation by industry organizations, standards organizations, carriers, providers, and other industry partners since the concept was proposed in 2019. In just two years, Autonomous Networks has been incubated and entered the planning and development phase. The industry has reached consensus on the vision, target architecture, and level standards of Autonomous Networks. Various organizations collaboratively develop industry standards, and carriers accelerate deployment and practices. Autonomous Networks has entered the planning and development phase.

1.2.1 All Industry Partners Jointly Develop the Vision and Core Concepts of Autonomous Networks

In 2021, nine standards organizations, including TM Forum, CCSA, GSMA, 3GPP, IETF and ETSI, efficiently collaborated through the TM Forum Multiple Standards Developing Organization (M-SDO) platform and leveraged industry standards, white papers, Autonomous Networks summits, and catalysts, and other methods to jointly promote the industry's recognition of the vision, target architecture, and level standards of Autonomous Networks with carriers and providers.

Industry Vision

Autonomous Networks is designed to deliver vertical industries and consumers with Zero-X (zero-wait, zero-touch, and zero-trouble) experience through fully automated network and ICT infrastructure, agile operations, and all-scenario services. Cutting-edge technologies are adopted to "leave complexity to providers and deliver simplicity to customers", and allow carriers to develop Self-X (self-serving, self-fulfilling, and self-assuring) O&M capabilities for automated and intelligent production, operations, and management in their planning, construction, marketing, and O&M departments.

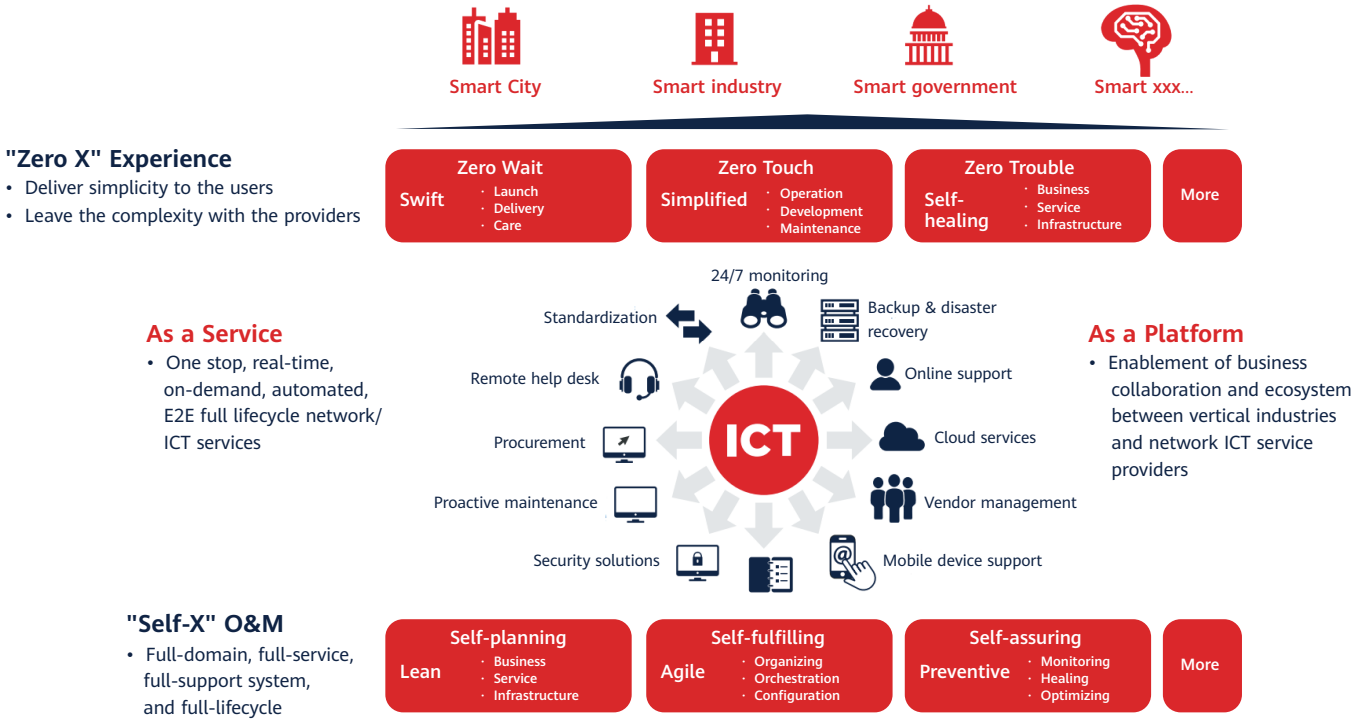


Figure 1-2 Industry vision of Autonomous Networks

Target Architecture

The target architecture of Autonomous Networks is rooted in three layers and four closed-loops. The three layers are business operations, service operations, and resource operations, and the four closed-loops are user, business, service, and resource closed-loops. The three layers are common operation capabilities for all scenarios and services. The four closed-loops enable full-lifecycle interactions between layers. Based on autonomous domains, the business closed-loop, service closed-loop, and resource closed-loop are responsible for the interactions between adjacent layers, while the user closed-loop is responsible for streamlining the business closed-loop, service closed-loop, and resource closed-loop. Interactions between adjacent layers are simplified, driven by services, and implemented based on simplified APIs or intent interfaces, such as business, service, and resource intent interfaces.

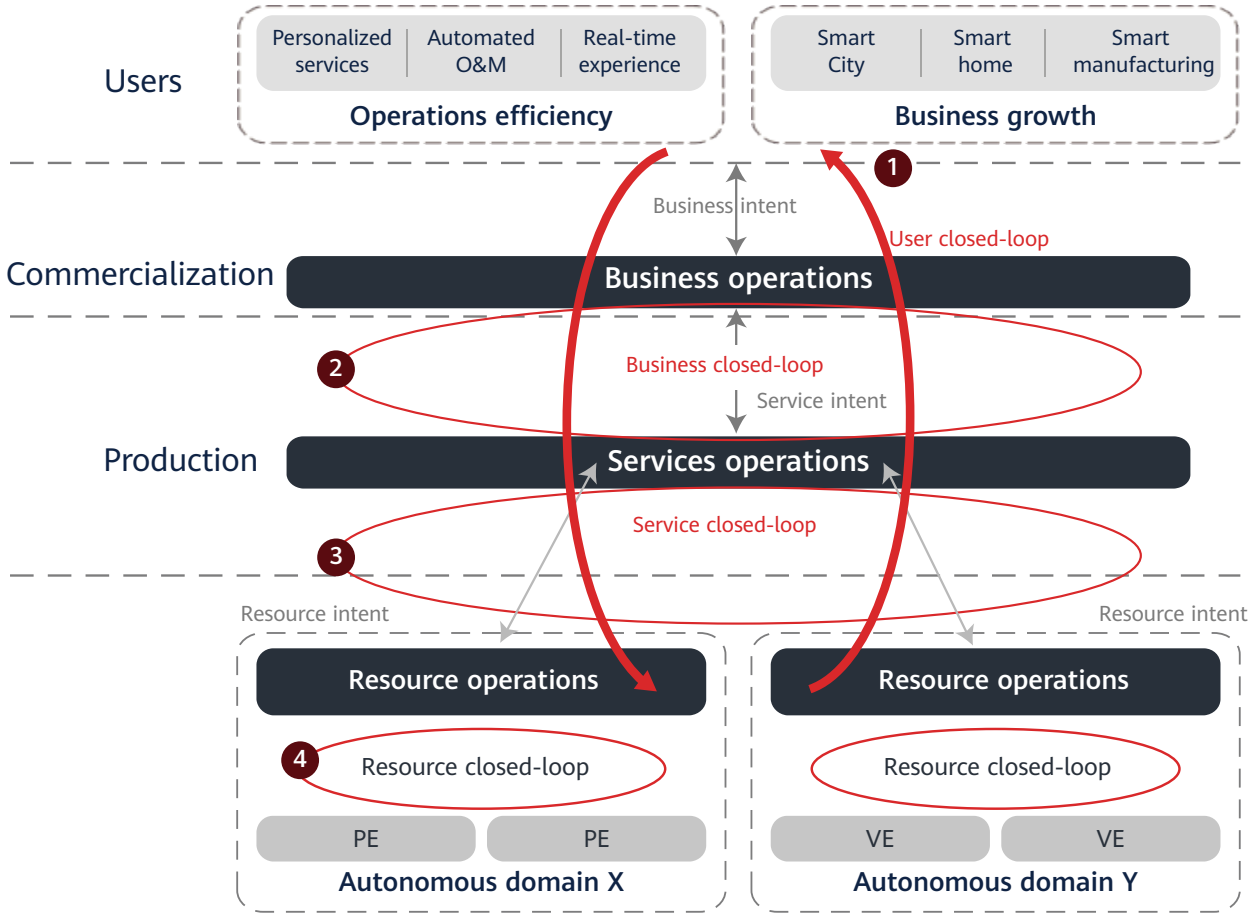


Figure 1-3 Target architecture of Autonomous Networks

Level Standards

Autonomous Networks are classified into six levels (L0 to L5) to measure the level of network automation and service experience. These levels evaluate and measure the benefits and advantages of Autonomous Networks services and facilitate the automation and intelligent transformation of networks and services.

Autonomous Levels	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Networks	L3: Conditional Autonomous Networks	L4: High Autonomous Networks	L5: Full Autonomous Networks
Execution	P	P/S	S	S	S	S
Awareness	P	P/S	P/S	S	S	S
Analysis	P	P	P/S	P/S	S	S
Decision	P	P	P	P/S	S	S
Intent/ Experience	P	P	P	P	P/S	S
Applicability	N/A	Select scenarios				All scenarios
P People（manual） S System（autonomous）						

Table 1-1 Levels of Autonomous Networks

1.2.2 Standards Organizations Collaborate to Develop Universal and Domain-specific Standards for Autonomous Networks

In recent years, standard organizations, including TM Forum, CCSA, 3GPP, and ETSI, have set up ad hoc topics on Autonomous Networks, initiated technical research and standards projects, and collaborated through the AN Coordination Meeting of M-SDO to preliminarily develop universal and domain-specific standards. These standards cover five aspects: requirement cases, reference architecture, level standards, key technologies, and key interfaces, improving Autonomous Networks standards and laying a solid foundation for more efficient industry collaboration and a thriving industry ecosystem. In the next two to three years, the focus of industry standards will be to define key technologies, including level evaluation system standards, intent interface technologies, closed-loop automation technologies, and L4 intent interface standards.

	TM Forum Vision, General Architecture, and Standards	ETSI Transport, Fixed Access, and IP Networks	3GPP SA5 Wireless and Core Networks	CCSA Transport, Access, IP, Wireless, and Core networks
Business Architecture	•IG1218 Autonomous Networks Business Requirements and Framework •IG1218B China Mobile's Practice on Autonomous Networks •IG1218C Autonomous Networks Realization Studies	•F5G-008 use cases	•TR 28.810 Study on Concept, Requirements and Solutions for Levels of Autonomous Network •TS 28.557 Management of Non-Public Networks (NPN) •TS 28.310 Energy efficiency of 5G •TS 28.530 5G; Management and orchestration; Concepts, use cases and requirements	**Intelligent Operations and Management Requirements and Cases of Information Communication Networks** Wireless network O&M, 5G RAN energy saving management, optical network maintenance, and Slicing Packet Network (SPN) maintenance
General Architecture	•IG1230 Autonomous Networks Scenario Realizations •IG1251 Autonomous	•ZSM002 Reference Architecture	•N/A	•Autonomous Networks architecture •Intelligent operations and management architecture for information communication networks - Functional, technical, and data architectures
General Levels	•IG1252 Autonomous Network Levels Evaluation Methodology	•N/A	•N/A	•Technical requirements for intelligent levels and level evaluation for the operations and management of information communication networks (general part)
Domain Architecture	•N/A	•F5G004_ARCHITECTURE •F5G006 End to End Management and Control	•TS 28.533 Management and orchestration; Architecture framework	•Technical requirements for levels (general part) •Technical requirements for level evaluation (general part)
Domain Levels	•N/A	•N/A	•TS 28.100 Levels of autonomous network	•Technical requirements for different levels - Mobile communication network (phase 1), IP network, and service operations systems •Technical requirements for level evaluation - Mobile communication network, IP network, and service operations systems •Level-based research for PTN and SPN networks
Key Technologies	•IG1253 Intent in Autonomous Networks v1.1.0, IG1253A Intent Common Model v1.1.0, and IG1253C Intent Life Cycle Management and Interface v1.1.0	•ZSM005 Means of Automation •ZSM009-1 Zero-touch network and Service Management (ZSM); Closed-Loop Automation •ZSM009-2/ZSM009-3 Zero-touch network and Service Management (ZSM); Closed-Loop Automation •ZSM-011 Intent-driven autonomous networks •ZSM012 Enablers for Artificial Intelligence-based Network and Service Automation •ZSM-014 ZSM security aspects	•TR 28.812 Study on scenarios for Intent driven management services for mobile networks •TS 28.104 Management Data Analytics •TS 28.312 Management and orchestration; Intent driven management services for mobile networks •TS 28.313 Self-Fulfilling Networks (SON) for 5G networks •TS 28.556 Management and orchestration; Network policy management for 5G mobile networks	•Research on the intent translation method and process for Autonomous Networks •Research on general intent management technologies of Autonomous Networks •Core network intent management research report •Technical requirements for wireless intent management services
Interface Standards	•TMF921 Intent Management API Profile		•TS 28 series interface specifications	•Research on interface technologies for intelligent operations and management of information communication networks - optical network and SPN

1.2.3 Leading Carriers Implement Practices to Define Autonomous Networks Strategies and Systematically Develop Autonomous Networks

Global carriers are implementing digital network transformation, and Autonomous Networks has become their first choice. They are exploring and practicing Autonomous Networks based on four elements, including the target architecture, level standards, evaluation system, and operations practices, and developing innovative scenario-based applications, as well as formulating goals for different phases and long-term strategies.

中国移动 China Mobile

At the beginning of 2021, China Mobile announced the goal of achieving L4 by 2025. To achieve this goal, China Mobile proposed a 2-3-4 system architecture for Autonomous Networks (2 goals: customer development and leading quality; 3 closed-loops: single-domain network resource management, cross-domain E2E service management, and customer requirement management; 4 layers: NE, network, service, and business). In 2021, China Mobile preliminarily evaluated the Autonomous Networks level for 31 provincial subsidiaries in China and formulated targeted improvement strategies and plans.

China Telecom considers Autonomous Networks key to their cloudification and digital transformation strategy and has announced the goal of reaching L4 in the short and medium terms. China Telecom has developed innovative applications for various high-value scenarios, such as intelligent 5GC network O&M, intelligent 5G private network, and AI base station energy saving, as well as contributed to TM Forum's popular industry case of customized 5G network and cloud-network convergence. China Telecom Guangdong has evaluated the Autonomous Networks level across all domains and O&M scenarios.

中国电信 CHINA TELECOM

China unicom中国联通

Dedicated to Autonomous Networks practices, China Unicom clarified and practiced the Trinity approach in 2021, and deployed a digital management platform for high-value scenarios, including 5G networks and home broadband, to accelerate the construction and evolution of Autonomous Networks. The Trinity approach allowed China Unicom to inject AI and automation capabilities into the entire lifecycle of network planning, construction, maintenance, optimization, and operations for over 1 million NEs.

Vodafone defined Zero-touch Operation (ZTO) as one of their Tech 2025 strategies and announced the goal of reaching L4 by 2025. They also developed a quantifiable evaluation indicator system to continuously improve Autonomous Networks.

vodafone

orange™

Orange has been exploring new methods and experiments and hopes to use 5G features to deploy Autonomous Networks with E2E automation and make networks more open and flexible through automatic closed-loop, AI, and edge-cloud convergence.

To better implement their Ambition 2025 strategy, MTN announced the goal of achieving L4 by 2025 and planned to develop an Autonomous Networks framework incorporating an Autonomous Networks blueprint, agile development & operations (DevOps) environment, superior performance, and innovative high-value cases. MTN also evaluated the Autonomous Networks level in wireless and IP RAN fault management scenarios and planned to expand the evaluation to more services and scenarios.

MTN

More than 10 other carriers, including NTT, British Telecom, Telecom Italia, and HKT, are deeply involved in TM Forum's Autonomous Networks catalyst project. The project covers vertical industry enablement, AI-enabled 5G intelligent operations, 5G digital mall, intelligent operations of private line services, zero-touch O&M, and other domains.

1.2.4 TM Forum Proposes an Implementation Framework for Carriers to Deploy Autonomous Networks

Deploying Autonomous Networks is a systematic project of iteration and cyclic evolution. Based on the best practices of leading carriers, including China Mobile, China Unicom, Vodafone, and MTN, the TM Forum proposes a collaborative and evolutionary implementation framework for Autonomous Networks regarding top-level design, capability development, evaluation system, and operations system, helping carriers deploy Autonomous Networks.

Top-level design

The strategic goals, target architecture, evolution path, and other key items need to be designed based on network conditions to achieve two goals: improving operational efficiency and increasing service growth.

Capability development

Based on the top-level design, core capabilities need to be developed for key networks and systems to gradually improve the Autonomous Networks level.

Evaluation system

This system measures the impact of improving Autonomous Networks capabilities to achieve business and service operations goals, ensuring that the improvement can help enterprises deliver business value and develop services.

Operations system

To adapt to Autonomous Networks, the network operations system needs to be adjusted or reconstructed from multiple aspects, including enterprise culture (system), organizational structure, work process, and skills.

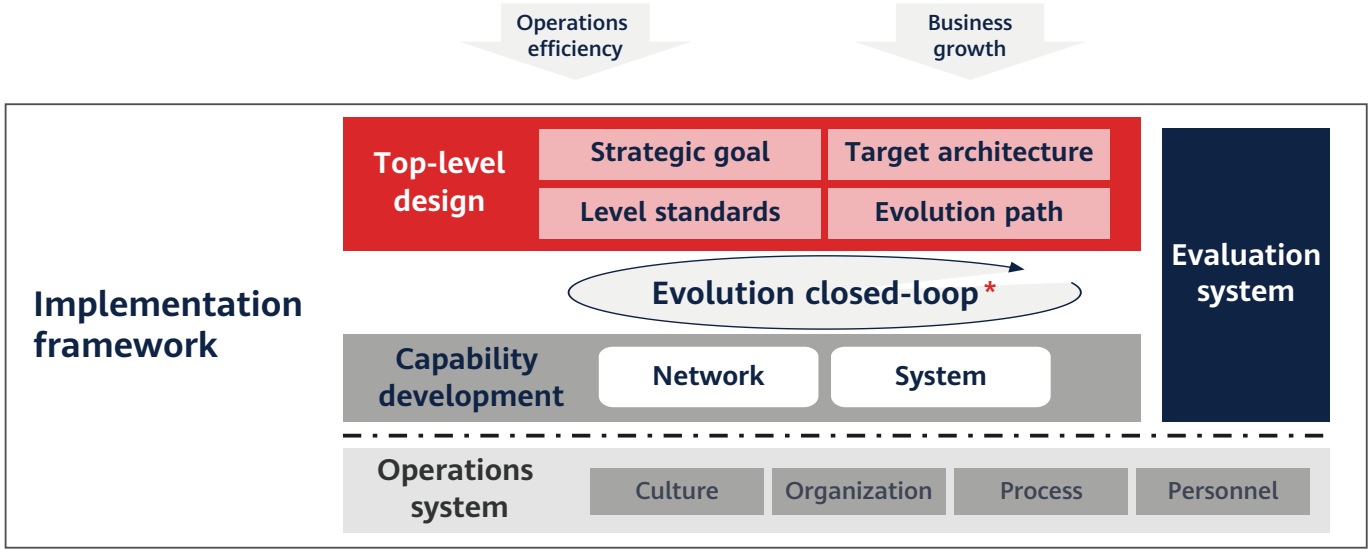


Figure 1-4 Implementation of Autonomous Networks

2. Huawei's ADN Strategy and Architecture

2.1 ADN Strategy

Huawei's vision is to bring digital to every person, home and organization for a fully connected, intelligent world. Building an intelligent world of everything benefits various industries in achieving digital transformation goals. Huawei will continuously innovate cloud services, AI, networks, and low-carbon development to accelerate digital development, industry transformation, and social development.

- **Ubiquitous cloud services**
- **Pervasive AI**
- **Autonomous Networks**
- **Low-carbon development benefiting from digital technologies**

As one of Huawei's four initiatives in continuous digital innovation, ADN is designed to combine connection and intelligence to develop self-organizing, self-healing, self-fulfilling, and autonomous networks. It applies native intelligence, data-based and knowledge-based driving, intent interface interaction, single-domain autonomy, cross-domain collaboration, and other technologies to develop self-serving, self-fulfilling, and self-assuring networks in collaboration with carriers and enterprises, and deliver a superior zero-wait, zero-touch, and zero-trouble experience for consumers and government and enterprise customers.

Huawei's *Intelligent World 2030* report describes a future intelligent world with integrated networks featuring full coverage, pervasive converged services based on cloud-edge-device convergence, and full-scenario intelligence integrated into production and life. Communication networks will become fully autonomous and continue to play a leading role in advancing global development and accelerating the advent of an intelligent world. ADN is the core strategy of Huawei Communications Network 2030.

2.1.1 Huawei Proactively Promotes Industry Development from Four Aspects

As an industry advocate, promoter, and practitioner, Huawei fully leverages its advantages in ICT technologies, customer resources, and industry influence to continuously promote collaborative development of standards, technologies, and businesses, facilitating the achievement of Autonomous Networks. Huawei contributes unique value from the following four aspects:

1. Application innovation: Huawei has put significant effort into innovating applications for key business scenarios (including 5GtoB, enterprise cloudification, cloud-network convergence, smart home, and cross-domain private line) based on the entire network lifecycle from planning to construction, maintenance, optimization, and operations. Huawei accelerates the development of NE intelligence and improves single-domain autonomy. Huawei has carried out research on key technologies, including comprehensive and real-time awareness in complex scenarios, high-precision maps and real-time simulation based on digital twins, multidimensional (user-service-network-NE) AI-based correlation analysis and decision-making. Huawei has developed new capabilities, including 5G real-time energy efficiency, device-level application awareness, IP In-situ Flow Information Telemetry (IFIT), and network path navigation, to provide full-scenario series products and solutions. In addition, Huawei offers simplified application programming interfaces (APIs) and intent-based interfaces to meet O&M requirements, enable agile integration by OSS vendors, and streamline E2E business processes, helping carriers better achieve service goals and create business value. By the end of 2021, Huawei and global carriers had jointly carried out over 200 ADN application innovations, providing high-value use cases and enabling more carriers to deploy ADNs.

2. Live network deployment: Huawei collaborates with leading carriers to refine the unified level-based evaluation system from L0 to L5 in order to overcome common challenges faced during ADN deployment on live networks, including the difficulty in selecting a transformation mode and starting point, significant status differences among OpCos, and obstacles to operations system transformation. Huawei iteratively performs level-based evaluation and weakness identification, system construction and collaborative planning, pilot application and replication to evolve the network, proactively advancing the refinement and standardization of interface specifications in each network domain. Huawei also offers management consulting services for operations system transformation (organization, process, culture, and skill), helping carriers quickly deploy ADNs on live networks. By the end of 2021, Huawei and multiple global carriers had completed level-based evaluation and commercial deployment in over 60 OpCos.

3. Standard formulation: Huawei proactively participates in the formulation of Autonomous Networks standards, leveraging its technical advantages and network O&M experience. Huawei contributes its theoretical research findings, technical achievements, and application innovations to industry standards organizations, and collaborates with leading carriers to carry out level-based evaluation, architecture design, and other practices based on standards guidance. In addition, Huawei shares best practices with the industry to promote the synergy between standards, technologies, and applications, and facilitates the rapid development of Autonomous Networks standards. By the end of 2021, Huawei had contributed to 19 standards documents, covering the Autonomous Networks vision, target architecture, level standards, key technologies, and interface specifications.

4. Industry development: Huawei proactively advances the industry development of Autonomous Networks, and has participated in the entire process, from the proposal of the Autonomous Networks concept by TM Forum to industry planning and development. Huawei proactively strengthens the collaboration of standards organizations (such as TM Forum, CCSA, and 3GPP) to accelerate systematic standards development, as well as promotes the synergy between standards, industries, technologies, and services and builds industry alliances to accelerate the transformation from standards and technology innovations to business solutions. Huawei has built the Intelligent Cloud-Network Integration Lab and other industry collaboration platforms to facilitate effective coordination and parallel evolution of networks and O&M.

2.1.2 Huawei Defines Short-, Medium-, and Long-Term Goals to Orderly Promote Industry Development

Huawei adheres to an innovation mechanism with two driving forces. In the short and medium term, with customers' L3 and L4 requirements as the driving force, Huawei will continue to innovate and develop solutions for L3 and L4. In the medium and long term, with the L5 vision as the driving force, Huawei will enhance technology pre-research and breakthroughs to achieve a leap in technology innovation.

Short- and medium-term goals:

Driven by customers' L3 and L4 requirements, Huawei will plan the evolution path from L2 to L3 or L4 based on the current network and current O&M processes, which are heavily dependent on manual effort. According to the level-based evaluation system that defines five network domains and three service domains, Huawei will identify weaknesses in 37 tasks for process optimization, enhance data awareness on NEs, and deploy digital employees in the network and service layers to implement L3 or L4 scenario applications by domain and layer. Other short- and medium-term goals include:

- **Specify generation standards and help carriers achieve L2 in all service domains.**
- **Develop scenario-specific solutions for L3 based on result key performance indicators (KPIs).**
- **Focus on high-value scenarios and enhance technology breakthroughs to innovate L4 applications.**

Mid- and long-term goals:

Driven by the L5 vision, Huawei will make leap-forward technology innovations. Huawei will carry out machine-oriented research and innovations for 5.5G and 6G networks for 2030. Huawei will carry out research on the multi-agent architecture and autonomy theories in its ADN lab. Taking limited scenarios as a starting point, Huawei will inject intelligence into all aspects, including networking, architecture, forwarding, and signaling, and implement L5 autonomy in specific scenarios. For example, explore the application prospect of big AI models and offer differentiated connection services for various users and sites.

2.2 ADN Business Architecture

According to TM Forum's IG1218 Autonomous Networks Business Requirements and Framework, Huawei believes that to achieve L4 or L5, telecom networks require a clear and widely recognized target architecture to guide production practices across the industry. With this architecture, carriers can systematically evaluate and review their architectures from top to bottom, including OSSs, integrated network management systems (NMSs), vendor element management systems (EMSs) or controllers, and network devices, and then formulate feasible evolution roadmaps that meet their requirements. Based on abundant products and joint innovations with global customers, Huawei proposes an ADN architecture, as shown in Figure 2-1.

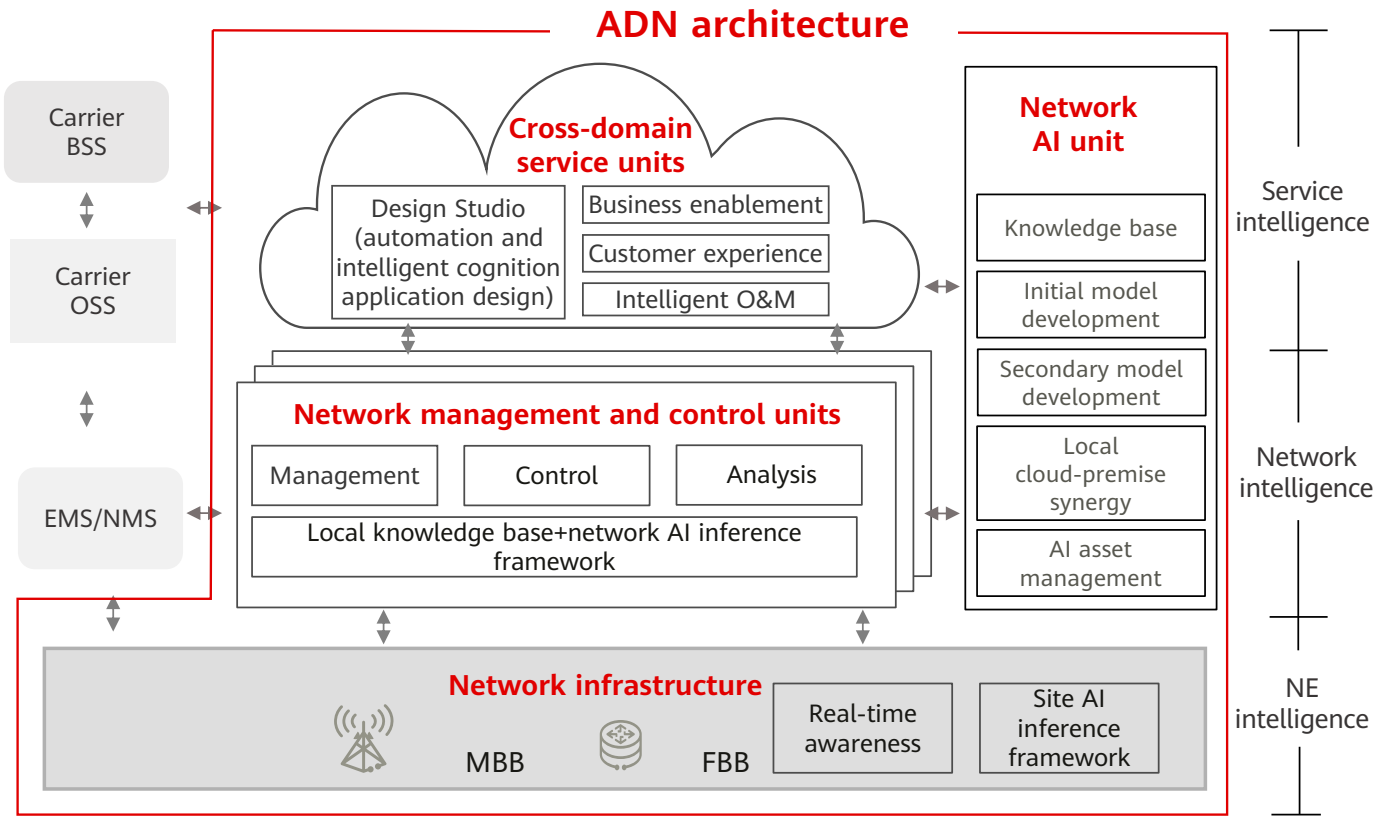


Figure 2-1 ADN business architecture

Network infrastructure

Intelligent network infrastructure is the foundation of ADN. More real-time awareness components and AI inference capabilities need to be introduced to network devices to enhance the digital awareness of resources, services, and environments, while enabling edge intelligence, including analysis, decision-making, and implementation.

Network management and control units

Network management, control, and analysis are integrated to inject knowledge and AI models, automatically translate upper-layer service and application intents into network behavior, implement single-domain, closed-loop autonomy, and ensure a committed SLA for network connections or functions. The network management and control units associate discrete network resources, services, and status data based on digital network modeling to develop a complete intra-domain digital high-

definition (HD) network map and implement integrated network data collection, awareness, decision-making, and control. In addition, new AI models and network O&M knowledge are continuously injected from the network AI unit to enhance and expand the local AI model library and network knowledge base, improving local intelligent awareness and decision-making.

Cross-domain service units

The cross-domain service units provide intelligent business innovation, customer experience improvement, and service and network O&M assurance. The units also offer an application design and development platform and cloud services. The units enable carriers to streamline O&M and business processes, flexibly orchestrate services, and quickly, iteratively develop new service models, O&M processes, service applications, and business products and services based on network characteristics, which is the key to agile services and business. In addition, the units help improve the skills of new-type O&M personnel and business designers.

Network AI unit

As the AI engine of telecom networks, this unit injects intelligence into other units. It is a basic platform for network AI design and development. It continuously performs AI training and extracts knowledge based on various types of uploaded telecom data to generate AI models and knowledge, which can then be injected into network infrastructure, network management and control units, and cross-domain service units to make networks more intelligent. In addition, this unit shares intelligent assets with carriers. It allows carriers to centrally manage, share, and reuse AI models and knowledge developed for network planning, construction, maintenance, and optimization, reducing repetitive development and training. This unit includes basic services and capabilities such as AI model training, data lake, network knowledge base, and AI asset management.

2.3 ADN Architecture Features

Huawei's ADN business architecture is based on TM Forum's industry-recognized Autonomous Networks target architecture featuring single-domain autonomy, cross-domain synergy, and hierarchical closed-loop. The ADN architecture aims at the following four service goals:

- **Self-fulfilling:** The network performs automatic configuration based on user intents.
- **Self-healing:** The network prevents and automatically rectifies faults based on user SLAs, and automatically learns and rectifies unknown faults.
- **Self-optimizing:** The network prevents poor-QoE problems and performs automatic optimization based on users' network quality requirements when poor-QoE problems occur.
- **Autonomous:** The network performs self-learning and self-evolution to fully enable autonomy.

Based on these service goals, Huawei has conducted various theoretical research and practices in recent years. Huawei has carried out research on basic theories, including intelligent control theory, system theory, trustworthy cognition and decision-making, and collective intelligence, and has introduced general technologies into the architecture, including big data, AI, and digital twins.

Through research and practice, Huawei ADN is designed to implement closed-loop control and cognition in autonomous domains based on the system control and cognitive intelligence theories. This will liberate humans from E2E O&M to achieve full autonomous networks.

In the short and medium term, closed-loop control needs to be developed to free humans from the control process and implement network self-configuration, self-healing, and self-optimization. However, humans are still required to accumulate knowledge required during network automation, including rules, policies, and expert experience. The ADN architecture in this phase needs to have the following three features:

1. Intent-driven autonomy and collaboration: The evolution of telecom networks greatly increases network architecture complexity. Networks will be oriented to all scenarios and feature a large scale, heterogeneity, superior network experience, and access in diversified scenarios. To overcome the increasing network architecture complexity, a complex network is divided by a carrier into autonomous domains for management based on different service types, network technologies, deployment locations, maintenance organization relationships, and other aspects. An autonomous domain is a basic unit for closed-loop automation of a specific phase in the operations lifecycle and runs as a system. Driven by intents, an autonomous domain performs intent expression and translation, network awareness analysis, AI-based adaptive decision-making, and intelligent orchestration to achieve closed-loop control within the domain, and perform intent-based collaboration to achieve hierarchical closed-loop and self-evolution across services, autonomous domains, and throughout the entire lifecycle.

2. Real-time awareness based on twin data: A large and complex network requires massive network data to support continuous evaluation of network environments. To obtain clear, complete, and accurate network information, more awareness components need to be deployed to better perceive resources, services, and surrounding environments and provide real-time awareness from multiple dimensions (including service flow, resource, topology status, O&M event, and energy consumption).

3. Trustworthy implementation: Closed-loop control includes various automatic processes, such as automatic network configuration, fault rectification, and quality optimization. To ensure the reliability of these automatic processes, the system applies trustworthy automation knowledge accumulated by humans to perform explainable analysis and decision-making before implementation. This is combined with real-time simulation to enable

In the medium and long term, closed-loop cognition needs to be developed to free humans from the cognition process and implement network self-learning and self-evolution, achieving full network autonomy. The ADN architecture in this phase needs to have the following two features:

1. Intelligent model-driven O&M

In addition to the knowledge accumulated in the short and medium term, intelligent models (such as AI algorithms and knowledge models) can be injected online on demand to speed up evolution. After years of network O&M, carriers and network device providers have accumulated a great number of management rules, troubleshooting methods, and other expert knowledge, which are available in various forms, such as device O&M manuals, network O&M specifications, and other intellectual assets. In automatic closed-loop network O&M, the scattered knowledge that can be understood by humans needs to be injected into computers to form a centralized knowledge base that can be understood and used by computers. The knowledge base is developed based on knowledge graphs that generate fault propagation relationships from expert experience and product knowledge. With AI technologies, computers can quickly make better use of this knowledge to play a key role in automatic network analysis, decision-making, and closed-loop O&M.

2. Knowledge self-evolution

Knowledge models can be automatically trained instead of only being manually injected. For example, new rules can be extracted based on historical data analysis, or knowledge can be updated based on environment changes. Trustworthy intelligent models enable explainable and traceable knowledge evolution processes. In addition, model generalization is the basis of automatic knowledge evolution. Due to different business forms, networking modes, O&M rules, and network data distributions among carrier OpCos, an AI model trained based on the data of a specific OpCo may not apply to other OpCos and fail to generalize and adapt to site conditions. Therefore, efficient model generalization is required.

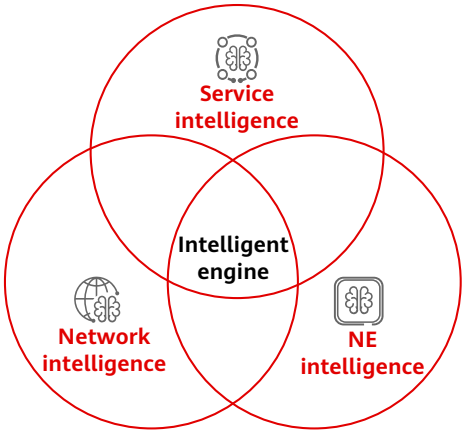
In future-oriented ADN transformation, AI will be ubiquitous in reconstruction and evolution throughout the E2E network lifecycle. To adapt to complex network environments in the future, the AI framework and distributed learning algorithms of the intelligent engine are required to deploy synergistic AI capabilities at the NE, network, and service layers.

NE intelligence: The NE layer enhances NE intelligence in many ways, including the intelligent awareness of dumb pipes and real-time awareness of data on active devices. In this way, it implements comprehensive and real-time awareness in complex scenarios and provides intelligent and digital network infrastructure.

Network intelligence: The network layer implements various innovations, including configuration change simulation and multi-objective collaborative optimization, to enable high-precision network maps and real-time simulation based on digital twins and provide automatic navigation, network optimization, and fault rectification.

Service intelligence: The service layer analyzes user experience and makes decisions based on data to offer digital and intelligent O&M services.

Intelligent engine: As the core enablement center of three-layer intelligence, this engine provides data training, model update, network knowledge management, and other capabilities and continuously injects intelligence into the three layers to make networks more intelligent.



To ensure efficient synergy between the three layers and enable sharing of AI models and knowledge, unified AI specifications (for AI models, knowledge, interference processes, and others) are required. In addition, carrier networks are operated and maintained by OpCos and domains, and their services are prone to changes. This requires that the three-layer AI architecture of carrier networks provide the following unique capabilities:

Generalization and site adaptation of AI models: Due to different business forms, networking modes, O&M rules, and network data distributions among carrier OpCos, an AI model trained based on data of an OpCo may not apply to other OpCos and fail to generalize and adapt to site conditions. This requires that the network AI unit provide good generalization and local re-optimization of AI models.

Continuous evolution of AI models: Changes and upgrades of carrier networks and services may demand updates of AI models and network knowledge. This requires synergy between cloud AI, network AI, and NE AI to support continuous updates of AI models and network knowledge. For example, during AI-based network fault diagnosis, if alarm definitions are significantly different in a new device version or batteries are added, fault propagation relationships may change. As a result, the clustering algorithms and fault propagation rules in AI models may also need to be updated.

2.4 ADN Level Evaluation

As the earliest practitioner of ADN, Huawei has carried out years of hierarchical research on ADN based on the target architecture and theoretical basis proposed by the TM Forum. To further standardize the ADN inter-generation evolution and improve the ADN level in various fields and scenarios, Huawei has performed the following:

(1) Defining Level Standards

Based on the hierarchical concept and framework defined by the TM Forum and the practices of multiple carriers at home and abroad, Huawei has divided the entire lifecycle of "planning-construction-maintenance-optimization-operation" into multiple specific O&M tasks from the dimension of "O&M process - O&M sub-process - O&M task". In this way, a set of O&M tasks is generated, and level standards are defined for each O&M task. Huawei has complied with the following principles when defining O&M tasks layer by layer:

- **Black-box:** Do not describe specific implementation details. Use easy-to-understand and unambiguous names.

- **Closed-loop:** Cover all activities in the O&M process and ensure that the O&M sub-processes can be self-closed.

- **Stability:** Abstract and classify specific O&M activities to ensure the stability of O&M tasks.

- **Moderate granularity:** Do not divide O&M tasks into too small or coarse granularities. If O&M tasks are divided into too small granularities, the universality deteriorates and the evaluation workload increases. If O&M tasks are divided into too coarse granularities, the evaluation result will not be precise enough and the evaluation result objectivity will deteriorate.

O&M Process	O&M Sub-process	O&M Task
Planning	Network planning	Requirement analysis and prediction
		Solution planning
		Solution design
		Simulation and decision-making
Construction	Design and deployment	Integration design and data preparation
		Installation and deployment
		Engineering commissioning and optimization
		Acceptance test and maintenance handover
Maintenance	Monitoring and troubleshooting	Intent translation
		Fault identification
		Risk prediction
		Demarcation and locating
		Solution generation
		Evaluation and decision-making
		Solution implementation
		Service verification
	Routine check	Work solution development
		Work solution execution
		Result analysis
		Closed-loop processing
	Network change	Intent translation
		Change design
Maintenance (Continued)	Network change (Continued)	Evaluation and decision-making
		Change implementation
		Service verification
Optimization	Network optimization	Intent translation
		Performance optimization identification
		Deterioration prediction
		Demarcation and locating
		Solution generation
		Evaluation and decision-making
		Solution implementation
		Effect verification
Operation	Service provisioning	Intent translation
		Resource survey and design
		Solution implementation
		Service verification
	Network complaint	Complaint pre-warning and prediction
		Demarcation and locating
		Complaint handling
Resource data management	Resource data management	Resource data collection
		Resource data association
		Resource data check

Table 2-1 Huawei ADN O&M tasks

After defining all O&M tasks, Huawei has defined level standards for each O&M task from the perspectives of human-machine division of labor and user perception by complying with TM Forum IG1252. The following table uses the monitoring and troubleshooting sub-process an example.

O&M Sub-process	O&M Task	O&M Task Definition	Level Standard
Monitoring and troubleshooting	**Fault identification**	Monitor and analyze network running data and external spatiotemporal data to detect unexpected service interruption or service quality deterioration in a timely manner.	L1: The system collects data (such as alarm serial numbers and KPI data) and O&M personnel manually identify faults based on expert experience. L2: The system automatically identifies faults based on static rules (such as alarm correlation and KPI thresholds) formulated by O&M personnel. Rule customization is not supported. L3: The system automatically identifies faults based on preset models (for example, AI models including knowledge graph and expert experience tree) or autonomous orchestration rules. L4: Same as L3*. L5: The system automatically learns and evolves, and identifies all faults without manual intervention.
	Risk prediction	Monitor and analyze network running data and external spatiotemporal data, predict the development trend of network software and hardware statuses, and detect potential risks that may cause exceptions in advance.	L1: The system collects data and O&M personnel manually check items one by one based on expert experience (such as the checklist) to identify potential risks. L2: The system performs automatic checks based on static rules (such as health check rules and KPI thresholds) formulated by O&M personnel. Then, O&M personnel manually identify potential risks. L3: The system predicts the network status trend and roughly identifies potential risks (for example, a port may have weak optical signals). Then, O&M personnel manually confirm the risks. L4: The system predicts the network status trend and accurately identifies potential risks (for example, there is a 90% probability that a weak optical signal fault will occur on a port within one week). L5: The system automatically learns and evolves, and accurately predicts all potential risks without manual intervention.

Table 2-2 Level standards for fault identification and risk prediction

Fault identification is a perception activity, and risk prediction is an analysis activity. According to the IG1252 hierarchical framework, perception activities are automated in specific scenarios at L3, and analysis activities are automated in specific scenarios at L4.

(2) Specifying Baseline Scenarios

The preceding O&M tasks and level standards are intended for specific service fields and scenarios. Based on rich live network experience, Huawei works with customers to focus on high-frequency and high-value scenarios and consider them as baseline scenarios to improve the ADN capability. The following table uses "wireless network monitoring and troubleshooting" as an example to describe its sub-scenarios. During level evaluation, different sub-scenarios are strictly evaluated according to the level standards, and the corresponding level is provided based on the automation level in different scenarios.

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
5G - base station out-of-service	5G - cell out-of-service	5G - cell performance deterioration	5G - implicit VSWR fault	5G - implicit optical power fault	5G - implicit board temperature fault
Scenario 7	**Scenario 8**	**Scenario 9**	**Scenario 10**	**Scenario 11**	**Scenario 12**
4G - base station out-of-service	4G - cell out-of-service	4G - cell performance deterioration	4G - implicit VSWR fault	4G - implicit optical power fault	4G - implicit board temperature fault

Table 2-3 Sub-scenarios of wireless network monitoring and troubleshooting

(3) Determining Evaluation Methods

After O&M tasks, level standards, and baseline scenarios are specified, a proper level evaluation algorithm is required. Huawei recommends individually evaluating specific sub-scenarios of each self-O&M task, calculating the level score of the O&M task based on the scores of each scenario, and then calculating the score of the O&M sub-process based on the scores of multiple O&M tasks. Assume that an O&M sub-process has O&M tasks and sub-scenarios, which are $[T_1, T_2, ..., T_m]$ and $[S_1, S_2, ..., S_n]$,respectively; and the i th O&M task T_i in the S_j sub-scenario is scored as $L_{i,j}$ according to level standards. The score of the O&M task T_i is $\frac{1}{n} * \sum_{i=1}^{n} {}_{=1} L_{i,j}$. The score of the entire O&M sub-process is the average of the scores of all the O&M tasks.

O&M Sub-process	O&M Task	Level Standard	Sub-scenario				O&M Task Score	O&M Sub-process Score
			S_1	S_2	$\cdots$ S_j $\cdots$	S_n		
Monitoring and troubleshooting	T_1	N/A	$L_{1,1}$	$L_{1,2}$	$\cdots$	$L_{1,n}$	$L_{T_1} = \frac{1}{n} * \sum_{j=1}^{n} L_{1,j}$	$\frac{1}{m} * \sum_{i=1}^{m} L_{T_i}$
	T_2	N/A	$L_{2,1}$	$L_{2,2}$	$\cdots$	$L_{2,n}$	$L_{T_2} = \frac{1}{n} * \sum_{j=1}^{n} L_{2,j}$	
	$\cdots$ T_i	N/A	$L_{i,1}$	$L_{i,2}$	$L_{i,j}$	$L_{i,n}$	$L_{T_i} = \frac{1}{n} * \sum_{j=1}^{n} L_{i,j}$	
	$\cdots$ T_m	N/A	$L_{m,1}$	$L_{m,2}$	$\cdots$	$L_{m,n}$	$L_{T_m} = \frac{1}{n} * \sum_{j=1}^{n} L_{m,j}$	

Table 2-4 Level evaluation methods

(4) Performing Baseline Management

To standardize the level of ADN products and solutions, Huawei follows the preceding methods to evaluate related products and solutions, performs baseline management for evaluation results, and builds the ADN capability improvement sandbox to better guide the capability improvement of Huawei ADN products and solutions.

O&M Scenario		5G Service				Home Broadband		Enterprise Private Line			DC			Enterprise Campus	
		5G RAN	5G Transport	5G Core	...	Fixed Access	...	Optical Private Line	Cloud-Network Private Line	...	DCN	DC Energy	...	Campus Network	...
Planning	Planning and design	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Construction	Deployment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maintenance	Monitoring and troubleshooting	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Service provisioning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Network change	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Optimization	Parameter adjustment for optimization	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Comprehensive domain level		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 2-5 Huawei ADN capability improvement sandbox

3. Huawei ADN Solution

3.1 ADN Solution Features

ADN practices the principle of "Leave the complexity with the ADN, and deliver simplicity to O&M engineers" and the ideas of capability deployment on edges, single-domain autonomy, and open collaboration. Based on the target architecture of Autonomous Networks, ADN builds a three-layer intelligent architecture featuring NE intelligence, network intelligence, and service intelligence, as well as uses knowledge and data to drive continuous innovation of the network architecture, breaking through the limits of manual processing. ADN applies deep learning to help humans understand service intents and objectives, data computing to compensate for human's "lack of consideration", and continuous machine learning to break through the limits of decision-making based on expert experience. The ultimate goal is to achieve self-organizing, self-healing, self-fulfilling, and autonomous networks, providing pervasive intelligent connections and accelerating digital industry transformation.

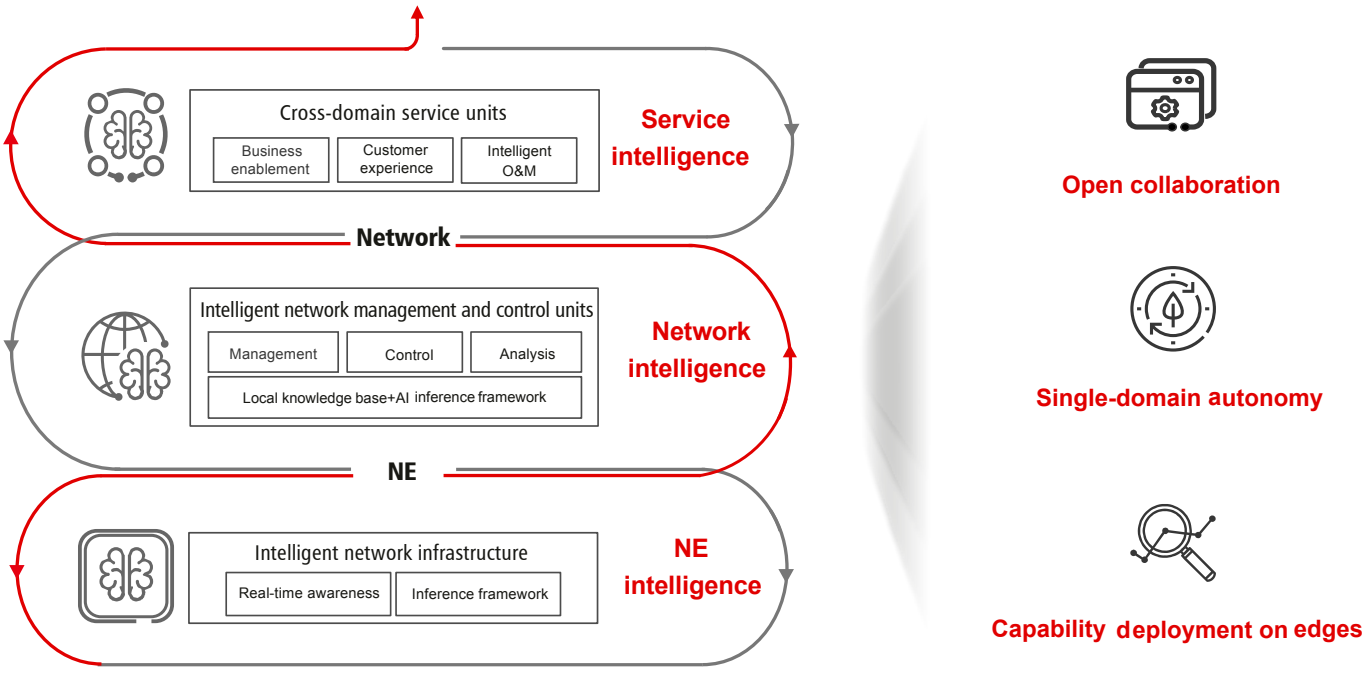


Figure 3-1 ADN solution features

Capability Deployment on Edges

As the foundation of ADN, network infrastructure plays an essential role. The advance of Autonomous Networks towards higher levels requires that network infrastructure provides more powerful capabilities, including more powerful real-time awareness, local inference, and edge computing. As a thriving technology, AI has empowered the infrastructure layer with new capabilities. NE AI uses distributed computing power to implement local inference based on a large number of KPI data generated by NEs. This enables quick risk awareness and analysis, while reducing the amount of data sent to the network layer and pressure on the computing power of the management system. NE AI also implements AI-based edge inference and NE-level quick fault self-healing and decision-making.

For example, Huawei's innovative IP service flow detection protocols (such as IFIT), enable EMSs to quickly and automatically locate faults in complex IP network topologies when service poor-QoE problems or faults occur. IPv6+ greatly simplifies service provisioning processes and improves the automation level of service provisioning. Access edge computing (AEC) boards on access network optical line terminations (OLTs) can analyze application KPIs or key quality indicators (KQIs) to identify poor-QoE users. The optical iris technology of the Digital&Quick optical distribution network (DQ-ODN) can visualize last-mile passive fiber resources. Huawei's optical transmission products can identify co-cable fibers to prevent shared risk link group (SRLG) problems.

Single-Domain Autonomy

The network infrastructure layer and the network management and control layer are coupled with each other. Network domains have different characteristics. Increasingly complex networks and various network infrastructure capabilities make network management and control difficult, especially for cross-layer, multi-domain management. To implement cross-domain management, single-domain autonomy has become the top priority, with cross-domain collaboration performed then. In each network management autonomous domain, standard northbound interfaces (NBIs) are provided for the upper-layer OSS or service orchestration system to invoke and orchestrate capabilities of the domain and offer cross-domain services that require collaboration of multiple domains. In addition, new functions of network devices at the network infrastructure layer are emerging, while the adaption of stan-

dard APIs of new functions is delayed. The coupling between devices at the infrastructure layer and the network management and control systems of device vendors can facilitate single-domain autonomy.

For example, intelligent energy saving for mobile base stations requires dynamic adjustment of many device parameters. Base stations require a network management and control system for precise adjustment of base station device parameters. Huawei's network management and control system can predict cell traffic based on real-time network data and adjust energy saving policies promptly to achieve energy saving while keeping KPIs stable.

Open Collaboration

Most telecom services are dependent on single-domain autonomy and open collaboration. The upper-layer OSS and service layer focus on service policies and innovations, and the lower-layer network management and control layer and infrastructure layer focus on service implementation and technology innovations. Standard intent APIs are developed for the network management and control system in each autonomous domain to implement complete decoupling between the network management and control layer and the service and OSS layer. Services and OSSs can invoke these NBIs to implement cross-domain service management, such as service provisioning and fault correlation analysis.

Take service provisioning as an example. An OSS uses open APIs to deliver service intents, such as source and sink nodes and service SLAs, to the network management and control system in each domain. The network management and control system independently plan and prepare functions and parameters required for provisioning services in the domain and deliver configurations to devices in the domain, as well as device addresses, tunnel addresses, tunnel types, and tunnel parameters. Finally, multiple domains collaborate to quickly configure services.

3.2 Products and Application Scenarios of Huawei's ADN Solution

Huawei's ADN solution has three layers: infrastructure (NE), intelligent management and control, and service operations.

Network devices at the infrastructure layer are managed by the ADN solution and form an integral part of it. Native intelligence, fault detection, perception, and other capabilities of NEs are critical to ADN. ADN's intelligent and powerful digital infrastructure is provided by enhanced NE AI and various advanced features, including the real-time energy efficiency optimization for Huawei mobile products, optical products, IFIT, and intelligent perception of dumb pipes of access products.

The intelligent management and control layer consists of the network management and control units iMaster MBB Automation Engine (MAE) and iMaster Network Cloud Engine (NCE), as well as other products. This layer implements various innovations, including configuration change simulation and multi-objective collaborative optimization, to enable high-precision network maps and real-time simulation based on digital twins, and provides automatic navigation, automatic network optimization, and automatic fault rectification. iMaster NCE is designed for fixed networks. It manages and controls fixed access, IP bearer, optical bearer, data center, and enterprise campus networks, and performs powerful analysis. In the northbound direction, iMaster NCE integrates with the service operations layer to enable secondary programmability for models and processes, flexibly adapting to the O&M processes of different customers. It provides various sub-solutions, including premium broadband, premium private line, 5G X-Haul, intelligent and simplified metropolitan area network (MAN), and intelligent and simplified DCN and campus. iMaster MAE is designed for MBB networks. It manages and controls radio access networks and cloud core networks, as well as coordinates with the service operations layer to implement 5G E2E intelligent O&M, convergent telecom cloud, and other sub-solutions.

The service operations layer focuses on customers' core service processes. This layer consists of AUTIN for intelligent O&M, SmartCare for improving customer experience, Agile Digital Operations (ADO) for business enablement, and other products. In the southbound direction, this layer coordinates with iMaster NCE and iMaster MAE (the intelligent management and control layer) through data and interface collaboration to support network self-configuration, self-healing, and self-optimization. In the

northbound direction, this layer coordinates with digital products in Business Support Systems (BSSs) to provide open APIs for networks and services, enable service agility, and deliver zero-touch, zero-wait, zero-trouble experience to end users. Product solutions at the service operations layer adopt an architecture that decouples the design from runtime. The design time provides zero-code and low-code development systems for multiple scenarios, including O&M applications, fault trees, automatic policies, and data orchestration. The runtime architecture decouples platform capabilities from applications. Technical capabilities, including digital twins, super automation, O&M knowledge center, and intent engine, are continuously developed at the platform layer. In addition, this architecture provides agile and intelligent scenario-specific applications based on business enablement, customer experience, and O&M processes, aggregates data and capabilities, and reshapes and optimizes operation processes to offer agile services, improve service quality, and efficiency.

In addition to the native intelligence of NEs, products at the intelligent management and control layer, including iMaster MAE and iMaster NCE, and products at the service operations layer, including automation and intelligence (AUTIN), SmartCare, and ADO, also integrate AI capabilities. The Network AI Engine (NAIE) can be deployed at both the intelligent management and control layer and the service operations layer. Each product transmits data to the NAIE, which retrains, updates, and iterates AI models, and sends the models back to the products. This 3-layer open AI architecture provides network intelligence and an O&M platform, accelerating carriers' digital and intelligent transformation.

iMaster NCE: This is an intelligent network management and control system for FBB networks. It can manage fixed access, IP bearer, optical bearer, microwave bearer, data center, and enterprise campus networks. iMaster NCE is designed to deploy digital twins for FBB networks and implement autonomous closed-loop within a domain, heralding an era of automatic and intelligent networks that prioritize user experience. Based on a centralized cloud-based architecture, iMaster NCE integrates management, control, and analysis systems and introduces big data and AI technologies to centrally manage, control, and analyze intra-domain networks. It meets the requirements for full-lifecycle automation and intelligent transformation for services and users on FBB networks, from planning, construction, and maintenance to optimization. It also provides on-demand deployment and flexible expansion capabilities based on different network technology domains and service domains. iMaster NCE provides open and programmable northbound interfaces, API orchestration, and southbound integration to orc-

hestrate, quickly adapt to, and iteratively develop services based on application scenarios and service characteristics.

iMaster MAE: This is a network management and control unit for MBB networks. In the southbound direction, it manages radio access networks and cloud core networks. It provides the following core functions:

(1) Control core of mobile networks and a network engine that integrates management, control, and analysis. MAE provides new network capabilities, including scenario awareness and identification, network prediction, and self-learning.

(2) Full-scenario solution based on customer workflows and the entire network lifecycle, including planning, deployment, maintenance, optimization, and service provisioning.

(3) Hierarchical closed-loop autonomy, which shields the complexity of mobile networks; scenario-specific service APIs, which efficiently collaborate with customer workflows, simplify service workflows, and help carriers evolve toward network autonomy.

Huawei leverages these products to provide the ADN solution for wireless, cloud core, transport, and datacom domains, and a cross-domain intelligent data O&M solution.

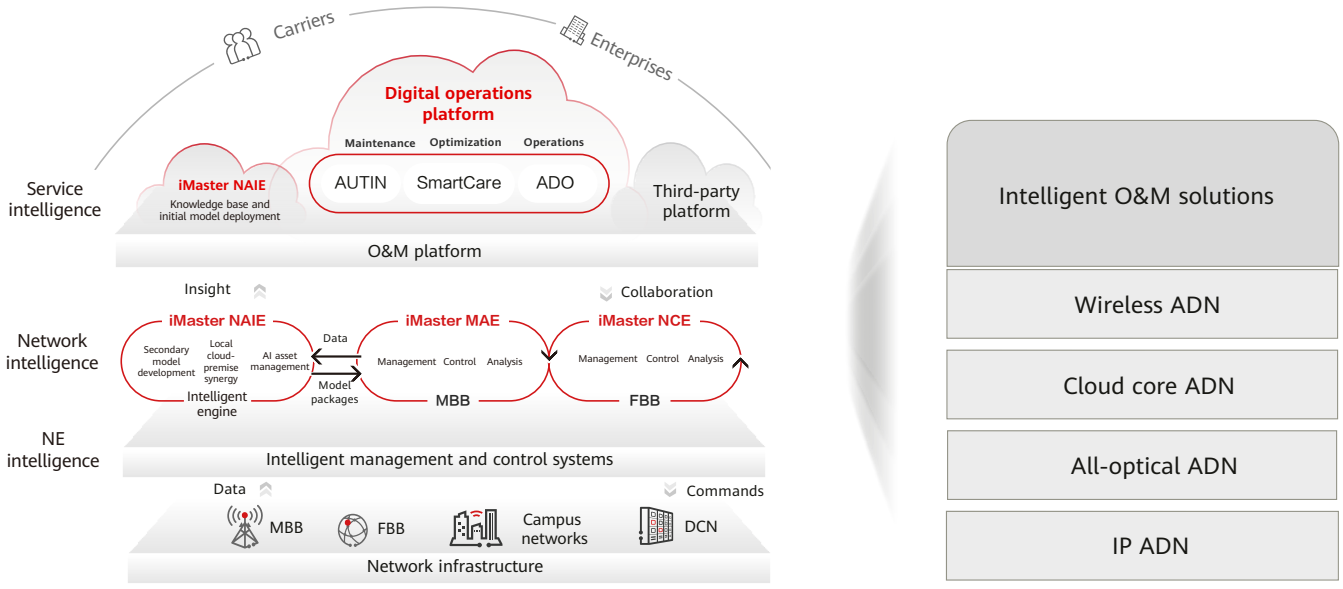


Figure 3-2 ADN product and solution overview

3.2.1 Wireless ADN

5G network deployment is in full swing around the world. New site types are emerging, multi- radio access technology (RAT) networks coexist, and 5GtoB services are diversified. As networks become increasingly complex, automation has become a necessity for 5G networks. Since Huawei released ADN in 2018, iMaster MAE, as the mobile network automation engine in the ADN strategy, has been commercially used on multiple networks around the globe. Its industry-leading large-scale network management capability and effective application of AI in wireless networks help customers achieve efficient and high-quality site construction, intelligent collaborative network O&M, and agile and precise service provisioning. iMaster MAE also helps customers build 5G network automation capabilities and facilitates the rapid development of 5G.

iMaster MAE-M (MBB Automation Engine-Mobile) is a mobile network automation engine (referred to as MAE). It provides automatic network O&M capabilities to facilitate network automation. The customer-oriented production process of MAE provides scenario-based apps based on the life cycle of network deployment, maintenance and optimization, and service provisioning. This greatly reduces the OPEX, optimizes service experience and operation efficiency, accelerates the all-scenario automation of carriers' workflow, and helps carriers implement network automation. It integrates traditional network management systems, introduces cloudification and AI capabilities, providing breakthroughs in architecture and use cases, and has the following features:

Intelligence: Full-stack AI collaboration (site intelligence, network intelligence, and cloud intelligence) provides powerful data processing and analysis capabilities based on the unified data base PAIR. As the intelligence engine of mobile networks, MAE implements network intelligence by means of upper-layer and lower-layer collaboration.

Scenario-based: MAE provides scenario-based app solutions, including Site Express, Radio Express, Alarm Turbo, Capacity Turbo, Power Turbo, WTTx Suite, and 5GtoB Suite for carriers' O&M scenarios, including construction, maintenance, optimization, and operation, to achieve closed-loop automation of network O&M by integrating expert experience.

Openness: Scenario-based APIs and programmable environments are provided, allowing customers to customize automation apps and build a new O&M ecosystem.

High-Value Use Cases of Wireless ADN

Efficient Site Deployment

In the network construction phase, there are a large number of wireless sites, and data configuration and site acceptance are complex. Traditional site design relies heavily on the experience of experts. Manual site design is complex, and many parameters need to be negotiated in the deployment phase. Therefore, data configuration and site acceptance need to be simplified during 5G base station construction to reduce costs and improve efficiency.

Site Express is an automatic integrated deployment solution for wireless base stations. It minimizes manual intervention, lowers skill requirements for operators, and improves delivery quality.

- **Agile design:** Site Express simplifies the site design process and supports automatic optimal allocation of service resources. After the site design is complete, Site Express can automatically convert and export configuration data for use in the subsequent site deployment.

- **Simplified deployment:** Site Express uses a simplified customer-oriented model to further simplify user-plane input parameters. In addition, hardware self-check and self-configuration eliminate the need for configuring hardware-related parameters. In this way, the number of user-plane parameters is reduced from over 3000 to less than 90.

- **Intelligent commissioning:** Site Express provides automatic detection and acceptance of base station status, thus improving base station commissioning efficiency. AI is introduced to quickly identify problems such as disconnected waterproof connectors by taking photos and uploading the photos, further reducing second site visits.

- **Automated process:** Site Express provides open APIs to help customers streamline the workflow of each phase during site deployment and achieve E2E automation of the entire process.

High-Quality Commissioning

After a single 5G site is deployed, cluster coverage and user throughput in the engineering optimization phase are two key factors that affect fast service rollout and brand influence. Planning and adjustment of parameters such as neighbor relationships, optimization of thousands of massive MIMO beams, and optimization of handover and scheduling parameters are involved. These capabilities are beyond expert experience.

Radio Express is an engineering optimization solution for wireless networks. It uses automation and AI algorithms to efficiently complete engineering optimization at the initial stage of network construction. It offers the following capabilities:

- **Reducing load and improving efficiency:** Initial parameters can be optimized in one-click mode. Radio Express automatically calibrates engineering parameters, checks parameters, and generates and issues neighbor relationship configurations online in one-click mode. The accuracy is 100%, and the handover success rate increases by 10%.

- **Reducing site visits:** Radio Express implements intelligent collaborative optimization of SSB and CSI beams. It provides accurate beam grid model profiles for air interfaces to match road scenarios and user characteristics, and quickly locates the optimal pattern combination for massive MIMO using high-dimensional optimization algorithms.

- **Reducing drive tests (DTs):** Radio Express implements personalized optimization of experience parameters. It generates optimal parameter sets for different cells to achieve cell-level optimization. In addition, it supports automatic optimization and analysis based on measurement reports (MRs) reported by UEs, reducing the number of DTs and DT costs.

Network Optimization

As more and more 5G networks are deployed around the globe, routine network optimization becomes an important part of carriers' OPEX. Traditional routine network optimization relies on experts, who need to perform a large amount of repetitive work, such as DTs, data collection, data analysis, and policy verification. The optimization efficiency is low. In addition, due to limited expert resources, carriers can select only top *N* cells for optimization and adjust network parameter configurations in a small range, which cannot maximize network potential.

Capacity Turbo is a routine optimization solution for wireless networks. It automatically collects traffic statistics, call history records (CHRs), and configuration data, analyzes root causes of problems, and orchestrates different optimization methods, including radio frequency (RF) optimization, neighboring cell optimization, and radio resource management (RRM) algorithm parameter optimization. It issues optimization commands online based on the optimization objectives defined by users, and automatically evaluates optimization results. This improves routine optimization efficiency, improves user experience, and maximizes network performance. It offers the following capabilities:

- **RF parameter optimization:** Capacity Turbo automatically identifies weak coverage cells to be optimized on networks based on network coverage and user experience visibility. This function integrates global network optimization experience and constructs a six-layer fault tree for multi-frequency and multi-RAT networks. The fault tree contains tens of thousands of root causes, covering 90% of the optimal top N root causes. The fault tree is iteratively updated. For coverage, interference, and CQI problems with clear root causes, Capacity Turbo uses AI-based model construction and training to simulate and predict optimization results, scores parameter combinations to automatically generate the most appropriate power, and optimizes the tilt to resolve RF-related problems.

- **Iterative optimization of radio parameters:** Due to network adjustment such as site deployment, iterative optimization of radio parameters is still required to ensure optimal network performance. Capacity Turbo builds multi-frequency virtual grid models using radio feature data, such as reference signal received quality (RSRQ), reference signal received power (RSRP), and load. It predicts user equipment (UE) rate changes through cell reselection and load balancing. It uses advanced optimization algorithms to continuously optimize multi-frequency parameters iteratively. It continuously monitors KPIs and UE counters, and generates the optimal combination of radio parameters for each to-be-optimized cell to achieve the optimal optimization effect.

Coordinated Energy Saving

The energy consumption of mobile networks accounts for more than 20% of the network OPEX (including equipment, air conditioners, and power distribution). The large-scale construction of 5G networks further increases the energy consumption. Network energy consumption has become a concern for carriers, and energy saving and emission reduction have become a trend. Traditional network energy saving requires manual intervention and conservative energy saving policies, and cannot be adapted to services.

Power Turbo is a multi-band and multi-RAT intelligent coordinated energy saving solution for wireless networks. It automatically collects network performance traffic statistics and configuration information, analyzes big data to establish a traffic model, and uses AI algorithms to help achieve optimal network-level energy efficiency. It offers the following capabilities:

- **Intelligent analysis and coordinated energy saving:** Power Turbo automatically identifies co-coverage cells (that is, inter-frequency co-coverage relationships between capacity cells and basic cells) based on network engineering parameters and inter-frequency MRs reported by UEs. When the load is light, the traffic of the capacity cell is migrated to the co-coverage basic cells that can handle the additional load, and the capacity cell is shut down to reduce the base station power consumption.

- **One policy for one site and precise energy saving:** Power Turbo creates a traffic model based on big data analysis, identifies typical energy saving scenarios, and predicts the traffic trend using the traffic model. In addition to traditional energy saving at night, MAE accurately identifies multiple energy saving periods in a day and provides scenario-based energy saving solutions to implement refined energy saving policies using one policy per site.

- **Online optimization and continuous potential exploration:** By using online machine learning algorithms, Power Turbo continuously performs iterative optimization and dynamically adjusts energy saving parameters. It optimizes the optimal PRB shutdown threshold and UE number threshold while ensuring KPI stability to maximize the energy saving potential.

Intelligent O&M

Many software and hardware alarms are generated on wireless networks every day. According to current statistics, millions of network alarms are generated in one month at 800 sites. Among these alarms, there are many redundant and repeated alarms that need to be handled, resulting in high network O&M costs. After services are running, larger-scale and more complex 5G networks need to adopt a new mode for fault identification, analysis, prevention, and handling. In this way, 5G networks can implement self-detection, self-analysis, and self-processing of faults, achieving higher reliability.

Alarm Turbo is an intelligent fault management solution for wireless networks. By using AI algorithms, it builds a wireless network fault tree layer by layer and provides E2E solutions including alarm noise reduction, aggregation, root cause analysis, and remote self-healing & isolation, facilitating efficient troubleshooting. It offers the following capabilities:

- **Alarm noise reduction:** The FP-Growth AI algorithm is used to mine frequent patterns, find related alarms within the specified time window, and remove redundant alarms. (Currently, the identification rate of redundant alarms by Alarm Turbo is around 99%.)

- **Intelligent association:** Using the random forest algorithm for learning and training, Alarm Turbo discovers the internal association between different components, objects, and counters, and builds a fault handling tree for alarms to quickly identify the root alarm.

- **Precise locating:** Alarm Turbo finds the fault cause list using the fault knowledge graph of NEs and provides the analysis conclusion, greatly shortening the fault locating and handling time.

- **Prediction and prevention:** Based on the NE site running information, hardware dotting information, and wireless network performance information, Alarm Turbo proactively identifies common problems on the wireless network, such as abnormal power modules on RRUs and abnormal transmit power. It then reminds customers to check and replace corresponding hardware devices as soon as possible so that hardware faults can be rectified in advance. This transforms passive response to proactive network evaluation and ensures secure and stable running of wireless networks.

Agile Home Broadband

Because of the pandemic, the demands on fixed wireless access (FWA) services have increased exponentially. Carriers need to quickly develop FWA services. Traditional FWA service application requires users to submit applications in the business hall. Carriers need to assign dedicated engineers to measure signals onsite to determine whether services can be provisioned. The labor cost is high. In addition, carrier networks change dynamically, involving scenarios such as site densification and service provisioning to new users. Dynamic network load changes affect user experience of FWA services.

WTTx Suite is a one-stop solution of MAE for wireless home broadband service provisioning and O&M assurance. It uses AI algorithms to construct a spectral efficiency feature library based on historical CHR and MR data and quickly provides broadband package suggestions through simulation, facilitating sustainable and rapid development of FWA services. WTTx Suite provides reliable customer-premi-

ses equipment (CPE) allocation check, user experience evaluation, network-level monitoring, and capacity expansion guidance. WTTx Suite provides the following improvements to cater to 5G FWA services:

- **Pre-sales:** WTTx Suite implements zero-touch precise service provisioning. Users can apply for FWA services online. WTTx Suite integrates the upper-layer IT system of carriers through APIs. It also supports 3D service provisioning map and beam-level resource evaluation. It visualizes the RSRP of the grid where services are to be provisioned, throughput capability, and serving cell load. It provides CPE allocation suggestions, including the package size and CPE type, based on carriers' package configurations and simulation capabilities. Tests on multiple carrier networks show that the CPE allocation efficiency is improved from days to minutes and the CPE allocation precision is higher than 90%.

- **Post-sales:** WTTx Suite proactively manages user experience. The built-in LTM of WTTx Suite effectively manages CPEs. The LTM analyzes the status information reported by UEs and KPIs on the wireless network side to identify poor CPE user experience in advance. It quickly locates network and CPE problems in the event of mobile CPE monitoring, performance monitoring for specified user groups, and CPE user complaints, and monitors and identifies network-level coverage and capacity problems. On the live network of Smart in Cambodia, the proportion of CPEs with poor user experience decreased by 10%.

5GtoB Industry Private Network

5G empowers a wide range of businesses and sectors. In the ToB field, differentiated SLAs for various businesses have different network requirements. To adapt to ToB industry applications, the network O&M approach must be changed. Carriers must shift from the traditional "Best Effort" pattern to an SLA-centric experience assurance pattern.

5GtoB Suite is an O&M solution for carriers' industry networks. It comprehensively analyzes massive data, such as service traffic models, network scenarios, and industry terminal types, and uses AI deep

learning algorithms to implement link-level performance simulation. This facilitates intelligent and accurate planning of private networks. MAE-based visualized O&M capabilities help achieve efficient O&M in industry networks. 5GtoB Suite helps industries build highly reliable 5GtoB networks. It offers the following capabilities:

- **Intelligent and precise planning:** Resource planning is centered on service SLA requirements. 5GtoB Suite comprehensively analyzes industry traffic distribution, network scenarios, and industry terminal types, performs rate and coverage simulation, and predicts and allocates network resources (such as sites and spectrums) based on service SLA requirements.

- **Proactive terminal and network O&M:** For 5GtoB services, visualized display of network performance and service status is critical to ensuring a highly reliable SLA. After services are provisioned, 5GtoB Suite monitors networks, terminals, and service performance in a visualized manner and quickly demarcates faults. The fault locating duration is reduced from hours to minutes. AI technologies, such as time sequence prediction technologies of Temporal Convolutional Network (TCN) and Relevance Vector Machine (RVM), can also be used to predict the changes in service and network performance by using historical data. In this way, network risks can be identified in advance to ensure high reliability of 5GtoB networks.

3.2.2 Core Network ADN

The core network is the brain of a communications network and is responsible for scheduling and managing global network resources. After the network function virtualization (NFV), slicing, mobile edge computing (MEC), and microservice technologies were introduced, the core network cloud architecture became more complex and the number of managed objects increased. Cross-layer and cross-DC network visualization and obtaining real-time NE status have always been recognized as technical difficulties in the industry. Traditional manual operations cannot meet O&M requirements in the new era, and carriers are facing huge OPEX pressure. In addition, as vertical industry apps gain momentum, carriers are more concerned about how to monetize differentiated network services and quickly roll out new service apps.

To address the OPEX pressure and monetization challenges, core network O&M must undergo architectural innovations. To help carriers overcome the preceding challenges, Huawei launches the core network ADN solution. By building a diamond model, reporting key counters, and obtaining key data such as transmission, infrastructure layer, and NE data in real time, a digital twin network is formed to implement real-time network visualization. The automatic orchestration engine and intelligence engine are introduced to realize intelligent service management and control. The entire process of planning, construction, maintenance, optimization, and operation is automated, enabling an automatic, self-healing, and self-optimization core network.

Real-time data visualization

The system uniformly obtains perception data, and aggregates and associates network status, service processes, and user behavior on the entire network. It then forms shared and unified network data assets to support intelligent model training and closed-loop policy triggering. It also provides horizontal (cross-service) and vertical (cross-layer) topology display of network-wide data assets, helping carriers intuitively observe and monitor the service running status on the entire network.

Automatic orchestration engine

The engine flexibly and efficiently orchestrates atomic capabilities to implement full-process automation in scenarios such as upgrade and capacity expansion of core network NEs and telecom cloud. This reduces risks caused by manual operations, lowers skill requirements for operation personnel, and improves upgrade and change efficiency.

Intelligent O&M engine

Intelligence technologies centered on machine learning are introduced to control network behavior based on models and policies. The result data of network behavior is collected again for local model retraining, model optimization, policy update, and local reasoning, implementing network-level closed-loop control.

iMaster MAE-CN provides the native data, orchestration workflow engine, and AI engine capabilities. With the hierarchical closed-loop autonomy system of the 5G core network, iMaster MAE-CN introduces automation and intelligence capabilities at different network layers to implement E2E autonomy of the 5G core network. iMaster MAE-CN enhances intelligence and automation capabilities. It enables networks to be dynamically and flexibly adjusted based on carriers' business intents or injection policies, detects network challenges in real time, and implements policy-driven closed-loop control to achieve network autonomy.

High-Value Use Cases of 5G Core Network ADN

- **Network Change Scenario — Efficient Network Change Solution**

When 5G services are developing, networks change more frequently to meet the agile rollout requirements of many industries. Traditional network changes (such as upgrade and capacity expansion) are mostly performed manually. Many steps are involved, the process is long, and a large amount of work requires manual intervention. Numerous manual operations lead to low efficiency and increase upgrade risks. The efficient network change solution uses the advanced DevOps concept in the industry and introduces the automatic orchestration engine and automatic test system to implement efficient and secure change operations.

Full-process automation: Through flexible scheduling of the workflow orchestration engine, manual breakpoints are removed, and the entire core network change process is automated. On the unified operation interface, the core network software package can be downloaded in one-click mode, risks can be automatically checked, and the upgrade can be automatically performed. This greatly reduces risks caused by manual misoperations.

Multi-channel concurrent upgrade: The concurrent NE upgrade capability is introduced. In traditional mode, one person can upgrade one NE in one operation time window. In concurrent mode, one person can upgrade multiple NEs concurrently in one operation time window, doubling the upgrade efficiency and ensuring the agile rollout of 5G apps.

Machine attendance for network changes: During network changes, intelligent machine attendance is used to automatically monitor and compare various counters and exception alarms, identify exceptions in advance, and take measures to prevent network faults from escalating. In addition, the rollback function supports manual intervention when an exception occurs, implementing one-click suspension and ensuring reliable upgrade results.

Hitless upgrade: During an upgrade, services will not be affected, peripheral interfaces will not change, peripheral devices will be unaware of the upgrade, old services will not be interrupted, and new services can be accessed within seconds.

Automatic test and acceptance: Automatic acceptance of 5GC, IMS, and MEC changes is supported.
Onsite environment parameters can be configured at a time.
The system automatically collects test information, analyzes test results, and outputs test reports in one-click mode.

- **Fault Scenario — High-Stability Network Solution**

The core network is located in a high position, bears a large number of users, and is affected by faults. Therefore, high stability is always the top priority. The high-stability network solution features intelligent methods for exception prediction and prevention, quick fault detection, precise fault demarcation, hitless fault recovery, and disaster recovery (DR) process visualization, ensuring high stability and reliability of the core network.

Exception prediction and prevention: In routine monitoring scenarios, continuous machine learning is performed on historical KPI data to set and maintain a wide range of dynamic KPI thresholds. In this way, exceptions can be identified first to implement proactive prevention. In network change scenarios, three lines of prevention are built: before, during, and after an event. Online health check is performed before a change. Change preparations and operations are automatically performed in compliance with specifications. Machine-assisted change and exception detection helps prevent problems caused by changes.

Quick fault detection: Key counters are introduced to the network to automatically reduce noise, associate and aggregate information such as KPIs, alarms, logs, and MML commands, and report an incident. Fault information is quickly and accurately reported, and preliminary fault diagnosis is quickly completed based on the fault diagnosis result.

Precise fault demarcation: Both horizontal and vertical fault scenarios are covered. Based on the symptoms, online expert experience, and knowledge graph, the diagnosis rules and processes of relevant fault modes are inferred by analyzing the time and topology space. When a network fault matches a preset typical fault pattern, the system automatically analyzes and demarcates the fault following the inferred diagnosis rules and process.

Hitless fault recovery: When a major fault occurs on the network and a DR switchover is required, MAE simulates a traffic surge on each 5GC node by using the multi-dimensional intelligent evaluation capabilities of the NE information model, flow control model, terminal behavior model, networking model, and fault recovery model to identify the surge traffic volume and overload risks of the switchover path. MAE draws the flow control data curve, surge traffic curve, and fallback user curve, and outputs multi-dimensional simulation evaluation results, to guide flow control parameter design and predict the service recovery period.

Visualized DR process: The observer view displays key counters such as the number of users and number of sessions in seconds and displays DR risks in real time. The operator view provides full-process capabilities such as event identification, DR evaluation, DR execution, and DR attendance, and provides preset switchover scripts, one-click switchover, and flexible counter configuration to implement E2E visualization of the entire DR process.

3.2.3 IP ADN

With more 5GtoB services alongside rapid enterprise digitalization and intelligentization, IP wide area networks (WANs), data center networks, and campus networks are facing increasingly diversified and complex service requirements. Integrating network management, control, and analysis functions, IP ADN enables network automation, intelligence, and NaaS. It not only helps carriers migrate networks to the cloud and digitalize operations, but also helps enterprises speed up digital innovation. Global carrier networks and various industries — such as finance, government, and transportation — have deployed iMaster NCE on a large scale. Serving as the intelligent network management and control system for IP ADN, iMaster NCE possesses the following key capabilities:

Agile go-to-market: Online invocation of network capabilities enables agile rollout of user production services through digital and intelligent networks.

- **Service programmability:** Supports network programmability, ensuring fast service rollout.
- **Cloud architecture:** Auto-scaling meets elastic network requirements.
- **On-demand access:** Various access modes are available, allowing data to be flexibly scheduled between users and computing power or between computing power.

Superior experience: Offers a deterministic experience for congestion-free, low-latency, zero-packet-loss networks.

- **Low latency:** Intelligent optimization lowers Wi-Fi latency (42% lower NOF+ latency) and routes traffic through the optimal path.
- **Deterministic:** Centralized path scheduling along with precise and visualized network latency enable deterministic latency and bandwidth for sliced networks.
- **Reliability:** Includes architecture/node/link protection, fault recovery within 50 ms, and zero packet loss during Wi-Fi roaming.

Openness and compatibility: A rich set of ecosystem interconnections facilitate multi-vendor management and control.

- **Compatible with multi-vendor devices:** Heterogeneous management for multi-vendor devices maximizes customer benefits.
- **Compatible with IoT ecosystems:** Digital services are enabled through comprehensive terminal management functions, open APIs, and various ecosystems.between users and computing power or between computing power.

Efficient O&M: Intelligent maintenance automates the full lifecycle, making network planning, construction, maintenance, and optimization autonomous.

- **Intelligent planning:** Pre-event AI simulation prevents human errors. Wi-Fi 3D planning minimizes interference.
- **Automatic configuration:** Plug-and-play (PnP) ensures instant availability of services upon provisioning between branch networks or clouds.
- **Self-service troubleshooting:** With visualized service SLAs, tenants can perform flow diagnosis themselves. Campus user faults are entirely visualized.

High-Value Use Cases of IP ADN

WAN

Path Computation NEs Are SRv6-ready and Build a Real-Time Digital Map

Focused on SR/SRv6 protocol control, path computation NEs use the standard BGP protocol to replace conventional command lines/NETCONF, making network integration 50% less complex. The NEs construct a dynamic digital map from the global perspective of the network. They support millions of tunnels, fault convergence in subseconds, and multi-factor path computation (for example, based on cost, bandwidth, and SLAs). Resources on single-vendor or multi-vendor networks can be globally and optimally scheduled.

AOC Enables Network Capability Openness and Improves Network Integration Efficiency

AOC enables fast southbound/northbound integration with open programmability. By pre-installing the drivers of mainstream vendors, AOC can complete product prototypes within 1 week. Lego-style programming makes development easier and streamlines verification, achieving PoC in 1 month. Since service packages are loaded online, NCE does not need to be upgraded and therefore can be delivered in a single quarter.

Intelligent Analysis Assures Congestion-Free Networks

Covering all three phases of network development, iMaster NCE offers a Congestion-Free solution for carriers. For network analysis, the solution provides basic performance analysis, such as querying resource loads and traffic rates. In terms of service analysis, IFIT is used to detect service congestion. Finally, for data-driven O&M requirements, the incident function combines big data with algorithms to identify the root causes and potential risks of congestion. Compatible with both legacy and new devices, the solution can accurately identify root causes in 80% of cases and give suggestions for the remaining 20%.

Data Center Network

Digital transformation in industries leads to many new services and service changes, increasing the need for fast service rollout. For example, a bank that sees over 2000 service changes in a year, set a rule to address tickets received before 15:00 on the same day, and those received after 15:00 to be dealt with the next day. Our SDN solution, which is widely commercialized, achieves the automatic deployment of logical networks. However, there are still many manual operations, such as linking application rollout, network provisioning, and network change processes. When done manually, frequent changes face many mistakes — statistics show that nearly 40% of data center network faults are caused by human errors.

Intent-driven planning and deployment: iMaster Network Cloud Engine (NCE) can understand and translate customer services and network intents, and then automatically select the optimal network deployment solution, enable E2E automatic service provisioning, and implement full-lifecycle, automatic closure of intents.

Zero-error change through intelligent verification: iMaster NCE also provides intelligent simulation. It evaluates change risks, preventing any human errors in areas like design logic and configurations. First, iMaster NCE models the network and performs formal verification. Then, it uses inputs such as device configurations, topologies, and resource information on the live network to decide if there are sufficient remaining resources. It also displays detailed connectivity relationships, and analyzes and evaluates the impact of changes on existing services.

Troubleshooting 1-3-5: During O&M, many applications, such as mobile payment and flash sales, require response in seconds. Often, upper-layer applications are faster than networks in detecting faults and making complaints, putting networks under significant pressure. In addition, network faults are passively detected and fault diagnosis still depends on specialist experience. Segment-by-segment demarcation, flow-by-flow analysis, and packet capture make the entire process inefficient — data shows that the mean time to repair (MTTR) on data center networks is over 70 minutes.

To address these challenges, iMaster NCE uses Telemetry to collect all-scenario data on the management, forwarding, and data planes and then comprehensively evaluates network health based on ser-

vice experience. It proactively identifies more than 60 key risks before they develop into faults. If faults do occur, it can identify more than 90 common faults within 1 minute. Then, the knowledge graph works with a unique AI algorithm to aggregate faults and trace their sources. It takes just 3 minutes to automatically locate root causes. With the help of an intelligent decision-making subsystem that analyzes fault impact and recommends the optimal troubleshooting method, typical faults can be recovered within 5 minutes.

Industry ecosystem enablement: Huawei ADN can be seamlessly integrated into the O&M systems of enterprise customers as a key step in their O&M processes. It helps automate the entire management process of data center networks in the most efficient way. The solution automates various capabilities, such as undifferentiated management and control, flexible orchestration and collaboration, and simulation on multi-cloud/multi-vendor networks. For this, iMaster NCE is upgraded and interconnected with customers' IT management systems, forming an automated process:

- Device driver packages are made and loaded in an open programmable framework to efficiently manage multi-vendor southbound devices.
- The service designer opens more than 100 atomic capabilities and flexibly orchestrates network-wide service flows.
- Network-wide simulation ensures precise undifferentiated deployment of various networks.

iMaster NCE opens full data services, supports one-click publishing of scenario-specific APIs, and quickly integrates service performance monitoring systems to integrate the O&M of services and networks. Through cooperation with service performance analysis systems, such as Netis BPC for fault reporting, iMaster NCE analyzes all service and network traffic to quickly demarcate and locate faults.

Campus Network

Enterprises are quickly going digital, so campus networks are becoming wireless, cloudified, and intelligent. New services are constantly emerging, increasing the network scale exponentially. At the same time, the frequent rollout, adjustment, and experience assurance of digital services create a lot of challenges for campus network management and O&M. iMaster NCE integrates the management, control, analysis, and AI functions of campus networks to automatically and intelligently manage the entirety of network O&M.

Intent-driven planning and deployment: In the network planning and deployment phase, iMaster NCE supports one-stop network planning and deployment as well as automatic policy delivery based on service intents, accelerating service rollout.

- **Scenario-specific automatic deployment:** When planning and deploying their campus networks, SMEs like stores and hotels only need to select their industry scenarios and service requirements. Then, iMaster NCE automatically generates a network topology, brings devices online, and provisions services. Deployment takes only half a day, instead of three.

- **Zero-error change through intelligent verification:** iMaster NCE's formal network change verification method is a lot faster than conventional options. Normally, a change takes just 10 minutes but verification lasts for 4 hours, and there could be many complaints if verification is not sufficient. With iMaster NCE, verification takes just minutes and assures changes with no errors.

- **Secure access in seconds with intelligent identification:** IoT terminals require secure access, so iMaster NCE supports intelligent terminal management. It features a conventional terminal fingerprint library and innovative application AI clustering and identification capabilities. As such, iMaster NCE can accurately identify networked terminals — 98% of known types and 95% of unknown types, allocate them with correct networks, and prevent access by counterfeit terminals. This assures secure access in seconds.

Intelligent preventive maintenance: In the O&M phase, iMaster NCE proactively identifies, analyzes, and predicts 85% of network faults by using big data analysis and multiple AI algorithms.

- **Precise and fast O&M:** Telemetry collects network data in real time, visualizing the experience of each user and application and reducing user complaints by 90%. In addition, the AI engine continuously performs online training. Huawei has over 30 years of experience in O&M, enriching the fault knowledge base. Network faults that would have taken 4 hours, now only take minutes to fix.

Automatic and intelligent optimization with superior experience: In routine network optimization, iMaster NCE implements automatic and intelligent network optimization. It also differentiates roaming guidance for terminals based on historical data and AI algorithms such as reinforcement learning. This improves overall network performance by 58% and the roaming success rate exceeds 90%.

3.2.4 All-Optical ADN

The all-optical network uses optical fibers as the transmission media and includes one network and two services. "One network" is the all-optical infrastructure network, which is the fundamental bearer network of the telecom network. "Two services" are premium broadband and private line services. All-optical ADN is a scenario-based solution that implements Huawei's autonomous driving strategy in all-optical networks. It uses the iMaster NCE intelligent management and control system as the key elements and introduces AI at the NE, network, and service layers to make passive fiber resources visible and implement efficient O&M of all-optical networks. In addition, Huawei provides home and industry customers with zero-touch, zero-wait, and zero-trouble experience of premium home broadband and private line services, facilitating the high-quality development of enterprise and home broadband services. iMaster NCE-FAN (for all-optical access domain) and iMaster NCE-T (for all-optical transport domain) are two products of the iMaster NCE intelligent management and control system.

High-Value Use Cases of All-Optical ADN

All-Optical Infrastructure Network

As the fundamental bearer network, the all-optical infrastructure network must be secure, reliable, and efficient in O&M. The all-optical ADN solution resolves key issues in resource management, planning, maintenance, and optimization. It introduces big data and AI technologies at the NE and network layers to digitize optical networks, enhance O&M efficiency throughout the process, and ensure all-optical network reliability.

Make passive resources visible: Optical networks consist of passive components (passive resources), which are difficult to accurately manage. The all-optical ADN solution makes passive resources visible from two aspects. The first aspect is digitalized ODN — The ODN pre-connection solution or optical iris technology is introduced on the NE side, and on the network side, iMaster NCE-FAN performs AI image recognition, automatic analysis, and ODN topology restoration to accurately record ODN resources. The second aspect is to automatically detect cable-sharing risks of fibers on a WDM

network. Optical NE probes are used to analyze various fiber data changes, such as Rayleigh scattering effect, Brillouin scattering effect, and Raman scattering effect, to effectively identify co-cable risks of working and protection routes. In this way, service rectification can be performed in advance to eliminate potential risks.

Online planning of WDM services: In traditional WDM service planning, planning personnel usually check resources segment by segment, check idle routes, and plan and design services offline based on inventory data and manually maintained planning tables. The planning efficiency is low and the time to market (TTM) takes weeks. In addition, the planning data, project deployment data, and live network data are stored separately and cannot be synchronized timely, causing many planning errors and much reworking. The online planning solution of iMaster NCE-T uses the same data source for planning, deployment, and live network data, performs automatic E2E optical network resource check, and ensures zero resource conflict and zero rework in terms of planning, greatly shortening the TTM.

Optical network health assurance: In the maintenance phase, fiber deterioration faults account for more than 30% of fiber faults and are all handled passively. iMaster NCE-T provides the optical network health assurance solution. Based on the device-side optical network probes, seconds-level collection, and edge inference capabilities, the Huawei-developed subhealth prediction algorithm performs big data intelligent analysis to predict deterioration faults of fibers and Ochs hourly, daily, weekly, or monthly, changing O&M from passive to proactive, preventing risks, and reducing service interruption.

Availability assurance: Availability is the service indicator that carriers are most concerned about. However, currently no effective methods are available to ensure service availability. The availability is not monitored, and risk identification and optimization suggestions are not provided. The iMaster NCE-T availability assurance

solution evaluates and analyzes the availability, monitors the availability in real time, and automatically generates warnings if the availability exceeds the threshold. In addition, the availability optimization function automatically provides suggestions for detected availability risks and estimates the availability after optimization to prevent breach of contract.

Premium Broadband

The COVID-19 pandemic has extended workplaces to homes. Services such as online office, online education, online entertainment, and virtual reality (VR) video are growing rapidly. Users have higher requirements on home broadband. These requirements herald the era of refined experience operations for home broadband services and bring the following challenges to carriers:

More than 50% of home broadband faults occur on home networks. Traditional NMSs can manage only the network segment to optical network terminals (ONTs). Home networks are an "O&M black box" and carriers lack effective O&M methods.

There is a lack of effective home broadband troubleshooting methods. 90% of reported experience issues are driven by complaints. Troubleshooting relies heavily on home visits for segment-by-segment check. Field engineers spend 90% of their work time on onsite fault locating and analysis, resulting in low efficiency.

Conventionally, outgoing calls, door-to-door visits, brochures, and sales during installation and maintenance are main methods for home broadband marketing and user acquisition. However, these methods are inefficient and impact user experience due to the lack of effective methods to identify potential users.

The all-optical ADN solution uses iMaster NCE-FAN as the core to incorporate intelligence into access networks. Based on its big data collection and intelligent analysis capability, iMaster NCE-FAN identifies and locates home broadband issues, and builds a digital operations base featuring accurate awareness, fault diagnosis, and closed-loop, helping carriers improve the quality of home broadband services and increase revenue.

Accurate awareness: To provide insights into the "O&M black box" of home networks, iMaster NCE-FAN provides intelligent terminal identification capabilities that automatically identify the types and bearing capabilities of terminals (including third-party devices) connected to ONTs and automatically restore the home network topology to identify comprehensive information of home networks. The collection frequency and scope of network KPI data are greatly improved. Through seconds-level data collection and minutes-level intelligent analysis, iMaster NCE-FAN automatically identifies the bandwidth capability, Wi-Fi coverage/roaming capability, service bearing capability, and network bottlenecks of home networks.

Accurate fault diagnosis: iMaster NCE-FAN collects and aggregates KPI data of the home network, passive optical network (PON), and OLT in a unified manner, and performs correlation analysis on application KPIs and network KPI data in seconds from the time and space aspects. It then automatically demarcates faults on the home network, PON, OLT, or upstream segment of the OLT, and locates the root causes of more than 30 types of home broadband issues, such as network congestion and 100BASE-T network cable.

Accurate closed-loop: iMaster NCE-FAN automatically detects, analyzes, and optimizes non-hardware issues, without the need for home visits. It also sends the analysis conclusion and improvement suggestions to the field service app to help field engineers proactively rectify, track, and close home broadband issues. It provides in-depth insight and analysis of home broadband terminals, networking, experience, and bottlenecks to help carriers identify potential business opportunities such as home networking and gigabit users, improving the marketing success rate.

Premium Private Lines

For carriers, private lines are high-value services and an important source of revenue. With features such as high security and reliability, low latency, and hard pipe isolation, optical private lines have become the first choice of leading enterprises among finance, media, and industry VIP customers. In addition, the rapid development of cloudification, go-online, and intelligence brings new requirements and opportunities to optical private lines. First, customers have differentiated requirements on the SLA (bandwidth, latency, and availability) of optical private line services. Carriers intend to provide E2E assurance methods for private line SLAs to achieve differentiated business monetization of SLAs. Second, fast provisioning, bandwidth on demand (BoD), and self-service capabilities of private line services have become common requirements of customers, driving carriers to further improve the automation level of private line services. Third, video-based, high-bandwidth, and strong-interaction services are emerging, which gradually extends premium optical private line services from leading enterprises to small- and medium-sized enterprises. Some carriers have piloted the OTN point-to-multipoint (P2MP) optical private line solution that reuses PON fibers at the access end, resulting in O&M requirements of E2E OTN+PON service provisioning and management.

Based on automatic awareness and intelligent analysis of optical networks, iMaster NCE-T performs digital measurement on SLA indicators of optical private line services, such as latency, availability, and bandwidth. The intelligent route calculation capability is upgraded to implement multi-factor collaborative route calculation based on customer intents, instead of experience-based rules, and intelligent route recommendation with multi-policy solutions is provided to replace single-route result. In addition, iMaster NCE-T provides various capabilities, such as the latency map, all-scenario E2E service provisioning, BoD, private line SLA analysis, and ACTN standard APIs, are quickly integrated into carriers' private line service operation process, helping carriers provide differentiated high-quality services throughout the pre-sales, in-sales, and post-sales processes, and enabling agile monetization of premium optical private line services.

Pre-sales phase

Based on tests on boards of NEs, iMaster NCE-T provides a microsecond-level, real-time, and dynamic network-level latency map, which makes the private line latency that could not be accurately measured, to be perceivable and accurately measurable. Similar to Google Maps, the latency map allows sales personnel to evaluate whether the latency and bandwidth between sites meet tenants' requirements. In this way, network resources can be quickly matched and private line services with differentiated SLAs can be flexibly marketed.

In-sales phase

iMaster NCE-T supports all-scenario E2E service provisioning (including E2E OTN, Legacy+OTN, MSTP+OTN, and P2MP OTN+PON), CPE PnP, and open network service capabilities through ACTN standard APIs, simplifying integration with the OSSs/BSSs. iMaster NCE-T quickly integrates with carriers' private line service production processes to implement automatic provisioning of private line services and improve the self-service capability.

Post-sales phase

iMaster NCE-T monitors the SLA of private line services in real time and automatically generates warnings when the indicators exceed thresholds, enabling carriers to eliminate potential default risks in advance. In addition, the optical network health assurance solution proactively analyzes the health status of each fiber and OCh, predicts fault risks, and proactively generates warnings. This helps in identifying potential network risks and service interruptions in advance, changes the O&M from passive to proactive, and ensures high quality of optical private line services.

3.2.5 Digital and Intelligent O&M Solutions

Practice is what underpins digital and intelligent transformation. On the one hand, Huawei has implemented digital and intelligent transformation practices through several platforms, including the digital sales platform iSales, the Three Cloud digital marketing platform, and the digital delivery platform ISDP, making overall operations more intelligent and efficient. On the other hand, Huawei has helped more than 100 carriers worldwide implement digital and intelligent transformation and provides professional services covering planning, construction, O&M, optimization, and marketing.

Huawei Global Service helps carriers with systematic and scenario-based digital and intelligent transformation: Predictable intelligent O&M, data-driven optimal experience, as well as convergence and intelligence enable business agility and continuously unleash the value of digital assets.

Intelligent O&M: AUTIN implements automatic and intelligent fault prediction, automatic demarcation, automatic diagnosis, and knowledge recycling, improving O&M efficiency and quality.

Optimal experience: SmartCare improves scenario-based experience based on the industry-leading OSS+BSS data convergence engine.

Business agility: ADO, Huawei's agile digital operations solution for fixed network services, improves the quality and business of premium home broadband services.

AUTIN: Intelligent O&M

Network O&M is facing unprecedented pressure and challenges due to the commercial 5G networks rolled out by carriers, requirement of fast response to new services, multi-RAT network environments, new virtualization and cloudification technologies, and explosive number of connections. Carriers have accelerated intelligent O&M transformation amid the pandemic and most of them have made remarkable achievements despite adopting different paths and solutions.

To improve quality, enhance efficiency, and accelerate talent transformation in carriers' O&M scenarios, AUTIN uses the automated, digital, and intelligent engine that features continuous iteration and the new generation orchestratable digital and intelligent platform based on data and knowledge assets and injects intelligence into each phase of O&M. In addition, Huawei continuously opens platforms and capabilities to improve O&M quality and efficiency, helping carriers accelerate transformation that features zero service impact, zero-touch NOC, and zero-code development, and improve processes, platforms, organizations, and talent.

Quality Improvement

In the 5GC scenario, a major fault affects hundreds of thousands of users, and fault demarcation and locating normally takes several hours. AUTIN adopts the event management mode of TM Forum to cope with service impact, changing network fault-oriented O&M to service impact-oriented intelligent event management. Backed by 150+ domain-specific intelligent models and 300+ knowledge graphs, O&M personnel can implement intelligent risk prediction and automatic diagnosis within minutes, compared with the traditional manual handling and hour-level manual fault diagnosis. Fault rectification is so fast that there is no impact on user experience. In the projects of China Mobile Zhejiang and Jiangsu, Huawei shortened the MTTR of critical faults by 85% and helped China Mobile Zhejiang rank the first in Autonomous Networks groupwide. With the wide application and self-evolution of digital and intelligent technologies, Huawei is ensuring zero perception of service interruptions on the end user interface.

Higher Efficiency

More than 90% of traditional NOC O&M operations such as front office (FO) monitoring and analysis, back office (BO) diagnosis, and remote repair are performed manually and 70% are routine operations, leading to low efficiency and high dependency on expert experience for verification. With automation rules that feature continuous iteration in 1000+ domains, AUTIN enables automated and integrated FO monitoring and maintenance, intelligent assistance for BO diagnosis, and self-service loop closure of FME operations through mobile phone digitalization. In this way, the automatic fault diagnosis rate is greatly improved, some deterministic faults are automatically rectified, and the overall O&M automation level is improved from L1 to L3. AUTIN greatly enhances the efficiency of O&M personnel, accelerating the evolution to zero-touch NOC.

O&M Talent Transformation

Because O&M operations are being gradually automated and diversified services are being developed in an agile manner, it is imperative to transform traditional O&M talent into artificial intelligence for IT operations (AIOps) digital talent. With the exposure of 200+ atomic capabilities and 1000+ scenario-based APIs, AUTIN provides an orchestratable low-code O&M application development platform to lower the technical and programming thresholds for O&M talent transformation and provides accompanied flight and certification services for systematic talent transformation. In this way, AUTIN implements agile development of O&M applications, shortening the development period from months to weeks and enabling fast O&M personal upskilling within one week. It accelerates O&M talent transformation and ushers in a new era of zero-code O&M application development.

Digital O&M transformation cannot be achieved overnight. Based on the cooperation of industry organizations, carriers, and partners, and Huawei's practices in more than 170 O&M digital and intelligent transformation projects worldwide, Huawei has summarized six key capabilities of the next-generation digital and intelligent O&M platform.

Deterministic Network Assurance (DNA)

- ToB determinative network - connection-level SLA
- 5G service indicator system
- Reliability model of complex system

Hyper-Automation (HA)

- RPA/RBA
- iBPMS
- Causal inference

Ecosystem Enabler (EE)

- Developer ecosystem: platform and enablement system
- Asset capability exposure in the telecom domain
- Integrated assets: east-west/north-south

One Trustworthy DevOps (OTD)

- Low threshold (no/low code)
- Trusted and reliable
- One-stop shop

Model & Algorithm of Telecom (MAT)

- All-domain data model (full network domain and full lifecycle (providing, construction, maintenance, optimization, and operation)
- Algorithms and models in the telecom domain (prediction, prevention, and root cause)

Telecom Knowledge Platform (TKP)

- Native telecom knowledge graph (KG-Native)
- Knowledge recovery

Figure 3-3 Six key capabilities of the next-generation digital and intelligent O&M platform

SmartCare: Optimal Experience

Evolving digital services have brought about differentiated requirements on service experience, ranging from high bandwidth, low latency, to wide connectivity. Service experience management cannot be guaranteed by monitoring simple and fixed service and network KPIs. Rather, service modeling based on different service scenarios and specific services is required in order to monitor service quality and ensure optimal experience.

SmartCare experience management aims to provide optimal user experience and drives network management, which is the key to implementing ADN. According to the target architecture defined by the TM Forum, SmartCare experience management is the link between business automation and network automation. SmartCare enables carriers to monitor E2E service quality across network domains. By virtue of real-time analysis and smart insight functions, carriers can determine the domains that need to be optimized and know where to prioritize resources when service quality deteriorates. Customer experience management (CEM) provides root cause analysis of high granularity, troubleshooting data, as well as in-depth analysis at the network or user level. Experience management drives network resource optimization and fault prediction and rectification, achieving network automation. SmartCare also helps carriers make better market decisions based on business data with its real-time insights and analysis of user service experience, implementing business automation. From network and business aspects, SmartCare helps carriers further improve the ADN level.

SmartCare DataCube provides powerful data integration, governance, and analysis capabilities. DataCube supports single-domain and cross-domain data analysis. It not only integrates abundant probe service data, wireless coverage data (MR/CHR), and network management data (FM/PM), but also quickly integrates market data (CRM and billing) and third-party social data, such as crowdtesting data. The platform provides E2E efficient data modeling and low-code data orchestration tools to support data exploration and analysis and implements quality and efficient data openness through APIs and other methods. In this way, the platform meets the requirements for data analysis and precise decision-making in multiple scenarios and supports agile development and quick rollout of scenario-based applications.

Intelligent prediction model

The powerful data analysis and processing capability is closely related to the support of the intelligent analysis model. The SmartCare platform is equipped with more than 100 general intelligent algorithms and operators and more than 30 scenario-specific intelligent models, including traffic prediction, intelligent service experience analysis, and service identification.

Expert knowledge model

SmartCare has more than 200 expert knowledge models in 13 categories related to service experience management and optimization. With these expert knowledge bases, the system quickly demarcates and locates faults through data analysis and provides maintenance, optimization, and capacity expansion suggestions, implementing E2E experience management.

Various scenario-based applications

Through API capability development, SmartCare flexibly supports carrier operations on the digital and intelligent network and implement agile development and quick rollout of scenario-based applications. These applications include Smart Experience that provides optimal experience management and assurance for multiple services (such as VoLTE, OTT, video, and cloud VR), Smart Planning and Smart Optimization for network automation, and Smart Decision for business automation.

SmartCare helps carriers shift from manual to automated analysis and decision making, which is the key for carriers to evolve from L3 (conditional autonomous) to L4 (high autonomous).

In addition, SmartCare has more than 10 years of experience in serving 180+ global carriers' networks and various services such as enablement, accompanied flight, and consulting, which help carriers implement digital and intelligent transformation in network O&M and improve the ADN level.

ADO: Business Enablement

ADO is a solution for fixed network services. It supports carriers' E2E home broadband services, from planning, development, marketing, to quality improvement.

The home broadband service is highly localized. The stiff market competition has gradually evolved into a battle for acquiring users. Grid-based and refined operations are key to winning the "squad leaders' fight". Based on the planning, development, marketing, O&M, and optimization processes of customers' fixed network services, ADO provides small, medium, and large screens for carriers' grid operations and production processes. In business scenarios such as service planning, grid operations and management, and quality improvement, ADO uses intelligent digital methods to enable customers' home broadband service digital operations, collaborative management, and intelligent decision-making. In this way, ADO builds digital capabilities that support efficient operations, refined management, and scientific decision-making in each business unit, helping carriers achieve precise investment, higher efficiency, and revenue increase.

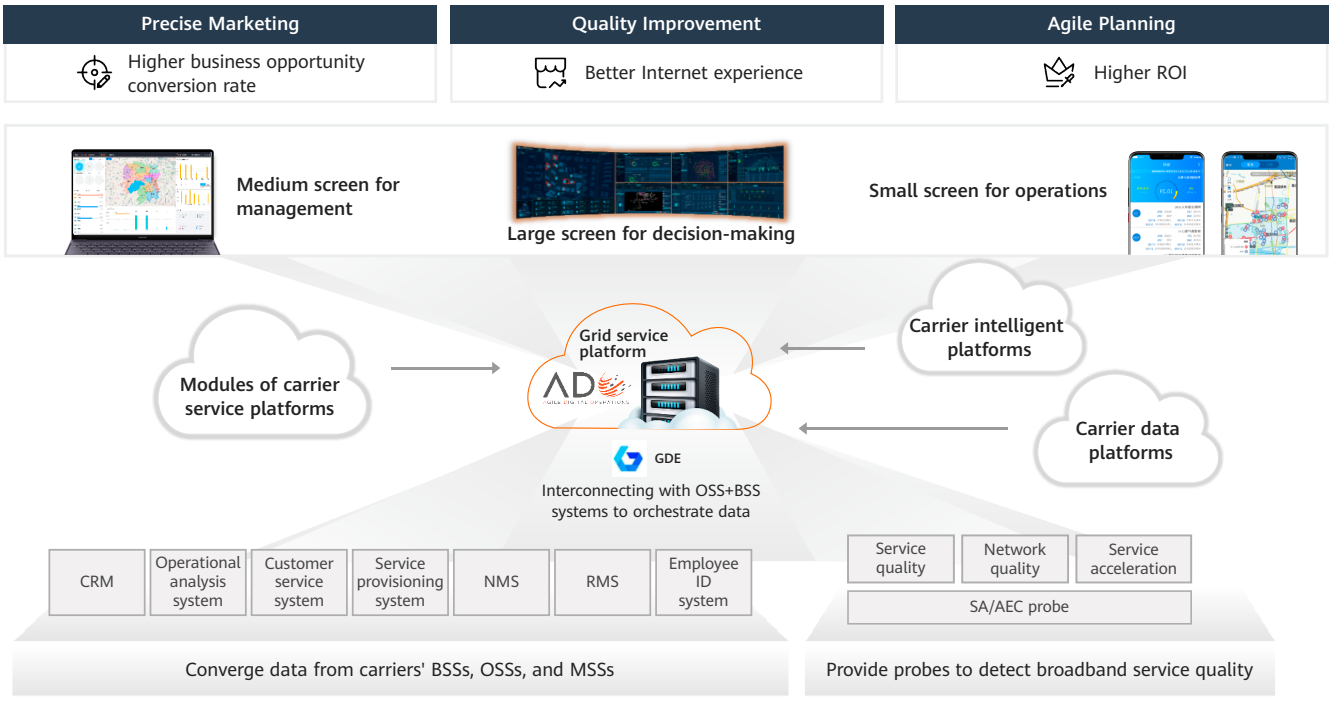


Figure 3-4 ADO solution architecture

In the future, ADO will continue to create value in terms of efficiency improvement, quality improvement, and transformation, achieve L3, and finally achieve L5.

Higher efficiency - operations support

Provide a digital and mobile app for frontline marketing teams to help them quickly deliver marketing strategies/tasks, query customer information at any time, record business opportunities/requirements, and share effects/suggestions, thereby improving operations efficiency.

Higher quality - management support

Provide multi-dimensional profiles, policy models, process-based management and control, and resource scheduling capabilities so that the market development management team can build an integrated market operations system that supports insight, policy, execution, and review, enabling carriers to improve quality.

Transformation - decision-making support

Implement visualized decision-making and differentiated management based on the inverted pyramid data support, online management assessment, and indicator optimization capabilities.

ADN shows the direction for digital operations and is developing rapidly. ADO enables accurate data-driven operations, accelerates industry digital transformation, and creates value through data monetization. ADO puts customer needs first and helps customers achieve business success. Huawei will continue to adjust and improve our ADO's capabilities and service quality, and play an indispensable role in carriers' digital transformation and value-oriented operations.

3.2.6 iMaster NAIE

ADN provides autonomous domain AI capabilities. iMaster NAIE (NAIE for short) is a key ADN component deployed on carrier networks that continuously injects strong AI competitiveness into ADN. It belongs to carriers and is deployed together with the management and control units in an autonomous domain to provide onsite training and inference capabilities. The NAIE collaborates with the management and control units in the autonomous domain. The NAIE provides various functions, such as lightweight secondary development, retraining, AI asset management, and network knowledge base, and collaborates with the AI inference and knowledge base functions integrated in single-domain management and control units (MAE and NCE). The NAIE has powerful computing and abundant feature samples. With a global view, the NAIE serves not only as an agile tool for the management and control units to continuously perform AI training and development, but also a knowledge center and library of the network. The NAIE can also release and share models to reduce repetitive development, facilitating AI ecosystem construction and model replication. The built-in AI of the management and control units and NEs focus on real-time collection and filtering of network data, and implement real-time inference and closed-loop management of AI capabilities locally.

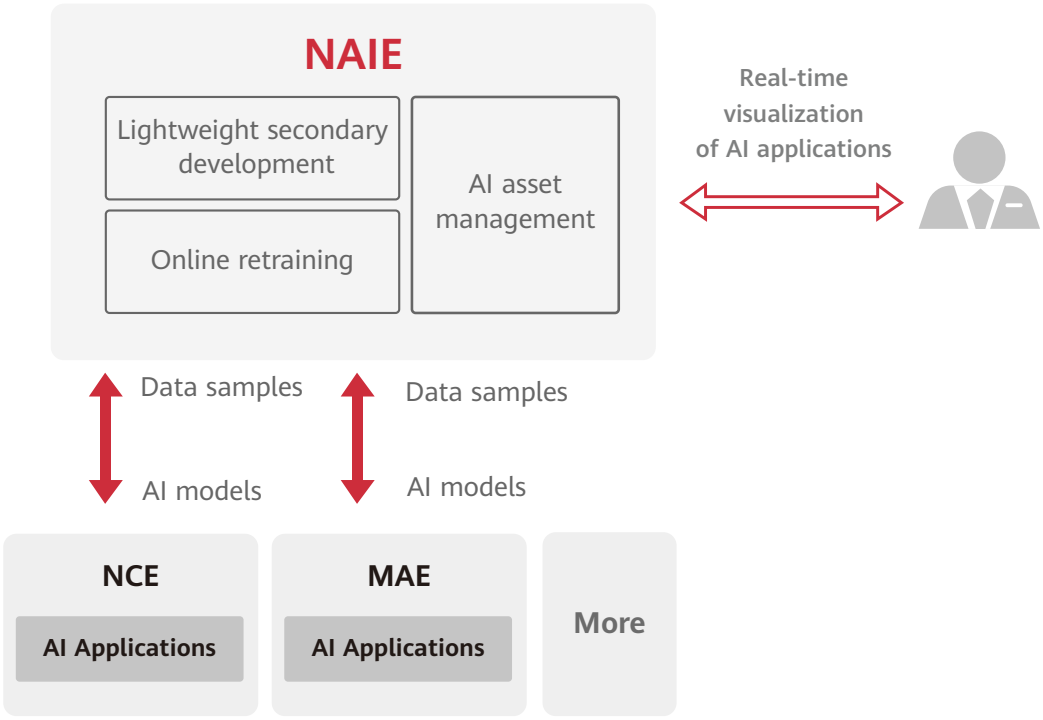


Figure 3-5 NAIE injecting AI capabilities into autonomous domains

With AI Technologies, ADN Uses AI to Solve Problems Related to Awareness, Prediction, Root Cause Analysis, and Optimization, Improving Carriers' O&M Efficiency

AI is a key technology for improving telecom network automation and intelligence. The NAIE uses AI technologies to solve preceding problems. The NAIE starts with use cases that significantly improve carriers' O&M efficiency, continuously expands the use case scope, and gradually applies AI to the carrier network through data collection, algorithm improvement, knowledge accumulation, and deployment mode exploration. Currently, typical applications of the NAIE to carrier networks can be summarized as three multiplications on O&M efficiency, energy efficiency, and resource efficiency improvement.

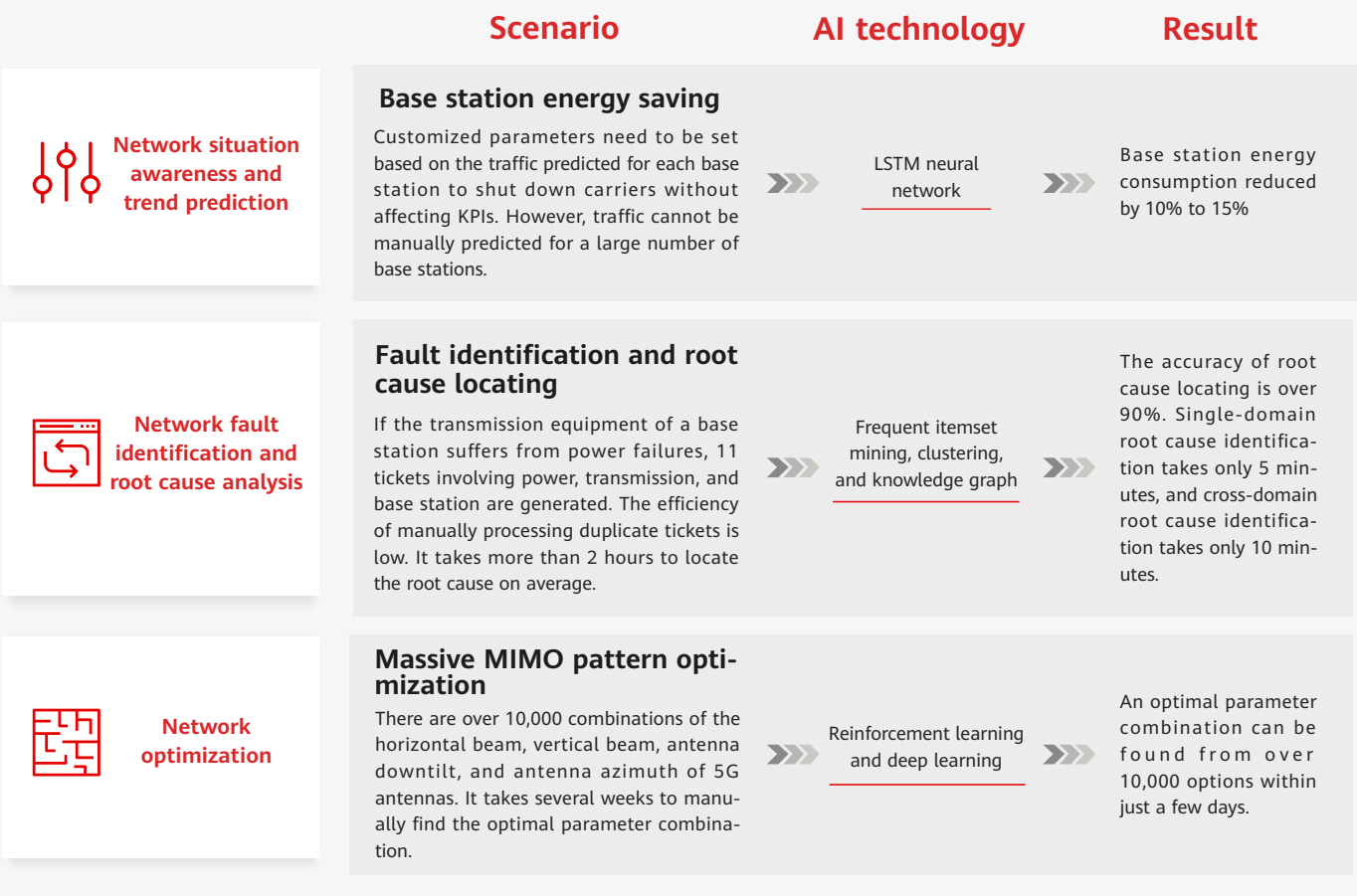


Figure 3-6 Typical application scenarios of network AI

Collaborative Management and Control Units Enabling Fast and Large-Scale AI Deployment on Telecom Networks

The NAIE is applied through the entire network lifecycle. As an AI engine of ADN, the NAIE not only considers issues from the perspective of AI technologies, but also solves the problem of applying AI to telecom networks. It transforms AI capabilities from labs to live networks, supports flexible deployment, and ensures high quality and trustworthiness, providing reliable AI capabilities for carriers to integrate to their production processes. In the telecom field, the NAIE has three unique benefits:

Benefit 1 Local Lightweight Secondary Development

In the telecom field, AI often encounters a series of problems, such as difficult model generalization, no outgoing data transfer, time-consuming model development, and difficult scenario expansion. Therefore, secondary development is required if a basic AI model needs to be deployed at a site for commercial use. Basic model development requires the knowledge of both services and AI algorithms, while secondary development requires the knowledge of only local services. To obtain a local personalized model package, personnel need to enter local service information, adjust model parameters, and train the model based on local data. In this way, AI models can be efficiently generalized in the telecom field. Take data center power usage effectiveness (DC PUE) optimization as an example. Secondary development reduces the local adaptation of AI models from four weeks to two days.

Benefit 2 Local Cloud-Premise Synergy

There is another obvious problem in AI application in the telecom field: concept drift, that is, the AI model precision deteriorates with time. For example, in the digital energy and wireless fields, due to limited resources and samples of AI inference modules built into the management and control units, models cannot be effectively retrained. The NAIE, being a key component that injects intelligence into the management and control units, efficiently collaborates with the management and control units. This synergy is called local cloud-premise synergy. It ensures that models are updated and prevents deterioration of model precision. The synergy process is as follows: The NAIE collects data samples in a domain and processes them through the data service to generate valid labeled samples. The AI inference module built into the management and control units monitors and evaluates models. If the model precision deteriorates, the AI inference module sends a retraining request to the NAIE. The NAIE receives the retraining request. In the retraining process, parameters are adjusted based on the service or network changes, and the retrained model is delivered to the management and control units. After receiving the new model package, the AI inference module built into the management and control units performs optimal evaluation and upgrade to improve model precision. Take base station energy saving as an example. Without updates, the AI model precision decreases by 10% within two months. This deterioration can be effectively prevented by model retraining.

Benefit 3 AI Asset Management and Explainability

The value of AI is hard to demonstrate due to a lack of GUI for AI asset management in the telecom industry. In addition, AI lacks explainability during running. For example, cause analysis of inference failures and quantification of data feature contributions during training are major obstacles that must be overcome by network maintenance personnel and AI developers to better understand telecom AI.

The NAIE supports AI asset management. AI assets include models, datasets, software development kits (SDKs), knowledge bases, robotic process automation (RPA) robots, AIOps, applications, and Notebooks. Reuse of AI assets can greatly improve the local AI application efficiency. AI asset management also supports visualization of AI assets and displays the invoking, result, and status of assets. In this way, AI assets can be managed systematically and the application benefit of AI assets can be measured.

The NAIE enables AI explainability. Quantifying the contribution of data features makes AI models explainable and enhances service personnel's awareness of the AI application process.

4. ADN Industry Development Suggestions

The large-scale application of ADN requires device vendors to provide intelligent network products and solutions, and OSS vendors and integrators to provide intelligent operations platform. More importantly, to deliver business value to carriers, it requires actual deployment and extensive collaboration with industry-university-research institutes on AI and computing technologies. To this end, Huawei advocates industry partners to strengthen collaboration and accelerate transformation in the following aspects:

1

Through top-level design and coordinated management, strengthen the collaboration between standards in different domains, establish a mechanism for standards co-development and recognition, coordinate domain self-management and industry supervision, and accelerate the transformation of industry standards into business and technical implementation solutions.

Based on business values and service requirements, strengthen cross-layer collaboration (between the NE layer, network management, control, and analysis unit layer, and integrated OSS layer), build standard large-granularity intent interfaces, and accelerate the transformation from capability improvement to O&M efficiency and business value improvement.

2

3

Innovate application scenarios and business models to strengthen collaboration between carriers and vendors and among vendors, build a sustainable industry ecosystem, and accelerate the transformation of key services and networks to L4 by 2025.

Huawei will continue to work with industry partners, increase investment in basic theory and technology research, and leverage its technical advantages in the ICT field to contribute to standards, technology, and business innovation. In addition, Huawei will promote high-quality network development with industry partners, and build quality, intelligent, sustainable, and innovative information communication services.