HUAWEI

Striding Towards
the Intelligent World
White Paper 2023

# ADN

## Intelligence + Connectivity for High Autonomous Networks

Building a Fully Connected, Intelligent World

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# 01

# Overview of the AN Industry

Countries around the world are committed to promoting the digital economy and facilitating ICT innovations using AI. In the context of digital transformation, the industry is now placing a greater emphasis on creating value and fostering collaboration across industry and value chains, rather than solely aiming for efficiency improvements within a single enterprise. 5G networks have been deployed on a large scale, and cutting-edge technologies such as generative AI are being widely used, accelerating the digital transformation of operators and enterprises and promoting network evolution toward automation and intelligence. As such, enterprises and operators are more capable of driving service innovation and improving operations. Operators anticipate that platform- and service-oriented products and capabilities, such as Network as a Service (NaaS), will invigorate the development of the digital economy, thereby unlocking the network potential and expanding their markets.

Autonomous Networks (AN), a concept jointly proposed by TM Forum and industry partners in 2019, aims to transform network infrastructure and operations systems toward automation and intelligence. Over the past four years, systematic AN concepts, standards, implementation methodology, and deployment cases have been defined, resulting in a resounding consensus on AN across the industry and significant achievements in AN practices and deployment.

1. Industry consensus: Many concepts, such as the Zero-X/Self-X vision, level standards (L0 to L5), 3-layer and 4-closed-loop architecture, single-domain autonomy and cross-domain collaboration, and intent-driven full-stack AI, are widely recognized in the industry.

2. Standards development: Nine standards organizations, including TM Forum, 3GPP, CCSA, and ETSI, have initiated and released more than 80 standards/research topics in five areas. M-SDO has helped standards maintain a unified architecture.

3. Deployment: 14 leading operators, including China Mobile, China Telecom, China Unicom, Deutsche Telekom, and Vodafone, have incorporated AN into their group strategies. They are developing autonomous capabilities and have conducted level evaluation, aiming to achieve L4 during the period from 2025 to 2027

to create more business value and gain greater operational benefits.

By the end of September 2023, 66 industry partners have contributed to the fifth edition of the *Autonomous Networks Whitepaper*. Four years ago, AN was but a vision. Now, a thriving AN ecosystem and a comprehensive standards system are developing, with more operators planning and deploying AN using a wide range of innovative technologies and applications. These advancements are empowering the evolution toward an automated, intelligent, converged, and green ICT infrastructure, comprehensively improving platform- and service-oriented network capabilities, and laying a solid foundation for the rapid development of the global digital economy.


14 leading operators have incorporated AN into their group strategies.


By the end of September 2023, 66 industry partners have contributed to the fifth edition of the *Autonomous Networks Whitepaper*.

# 02

# Trends and Suggestions

## 2.1 Trend 1: Livestreaming Is Evolving Toward Outdoor and Multi-spot Scenarios and Creating New User Behaviors and Network Requirements

5G networks have been deployed on a large scale, significantly boosting the livestreaming experience. As a result, the livestreaming industry is developing quickly. There were 751 million livestreaming users in China by the end of 2022, accounting for 70.3% of the country's Internet users. The number of live streamer accounts has exceeded 150 million. Globally, there are more than 1.5 billion users active on TikTok. Apart from the user scale, there is also increased diversity in the livestreaming content and scenarios. Livestreaming is no longer limited to live commerce and live gaming in indoor scenarios; users can now livestream a variety of outdoor scenarios, such as charity events in rural areas, sharing tourist attractions, street arts, and large-scale trending events. This trend is characterized by highly dynamic user behaviors and user aggregation.

Highly dynamic user behaviors: Since there are more types of livestreaming scenarios, it is difficult to predict when and where large-scale and large-capacity requirements will occur. As such, network assurance is difficult, requiring more intelligent adaptability.

User aggregation: Distributed users may flock to one place due to a breaking event, requiring ultra-high bandwidth not just for a few users, but for a multitude of users on a single node.

## Challenges and Opportunities

**It is increasingly difficult to ensure a good network experience for livestreaming users with highly dynamic behavior.** Zibo is a small city located in Shandong Province, China. In the spring of 2023, Zibo barbecue went viral on Chinese social media, attracting many tourists. This led to a surge of network traffic in Zibo. Operator data shows that the average daily traffic of 92 large-scale barbecue locations in Zibo reached 43 TB in April, with a daily traffic increase of up to 40%. The total traffic increased by 41.8% compared with early February. Live streamers flocked to Badaju (a local market in Zibo) and other barbecue locations in Zibo after Zibo barbecue went viral on Douyin (Chinese version TikTok). Short videos and livestreaming generated the most network traffic. So, operators had to adjust their assurance plans to ensure a reliable uplink network and smooth livestreaming for mobile users. Also, the 30,000-square-meter Haiyue Longgong market was open to the public from April 27 to May 3 during the barbecue festival in Zibo. As such, the network needed to support phone calls, Internet access, and livestreaming for tens of thousands of concurrent users.

**Extensive user aggregation requires better network resource preparation and dynamic scheduling.**

Livestreaming is sensitive to uplink bandwidth. For smooth livestreaming in 720p on a mobile phone, the uplink bandwidth must be 10 Mbit/s or higher. In addition, the end-to-end network latency must be within 100 ms to livestream e-commerce, education, and online performances, supporting real-time interactions among streamers and a high-quality user experience.

Most daily network traffic is used for common online user behaviors, such as watching videos, browsing web pages, and downloading files (eMBB and FTTH). These applications mainly occupy the downlink bandwidth. So, operators tend to allocate more resources to the downlink during network planning and design. As a result, the peak rate and capacity of the downlink tends to be far greater than the uplink. For example, the typical time slot ratio (downlink:uplink) of 4G and 5G networks is 8:2 or 7:3.

In this case, when a lot of livestreaming traffic suddenly gathers in a few hotspots, the uplink network will experience extreme pressure. The traffic is usually unpredictable and can reach a peak very quickly or see a tidal effect. This requires better network planning, design, and dynamic optimization scheduling. Currently, operators primarily adopt the following methods to expand the uplink bandwidth: 1. Adjusting the network plan, deploying new base stations, or deploying temporary base stations. 2. Deploying digital indoor distributed systems to supplement indoor coverage. 3. Diverting the uplink traffic through fixed network Wi-Fi coverage.

**Operators should seize new business opportunities by differentiating services for livestreaming users.** Using the 5G QoS mechanism, a provincial branch of an operator launched a dedicated package for 5G livestreaming. The package provides a traffic quota that is 50% higher than other packages, four times higher uplink rate, and three times better VIP services. Subscribers can enjoy a higher network priority when using livestreaming services on major Chinese livestreaming platforms such as Douyin, Kwai, and Bilibili. Since launching in 2022, over 190,000 subscribers have chosen this package. 70% of the subscribers upgraded from other packages, increasing their spend by more than 50%. Due to the commercial success of this package, the operator has decided to launch it across China. In addition, to meet the user requirements in different livestreaming scenarios, the operator plans to develop new services such as 5G livestreaming accelerator and low-latency packages dedicated for live gaming competitions, allowing more people to enjoy uninterrupted livestreaming.

## Suggestions

**1. Provide differentiated products and e-commerce-based self-service** to ensure a "Zero X" user experience (zero-wait, zero-touch, and zero-trouble) in different scenarios.

**2. Improve the flexibility and timeliness of network resource deployment and scheduling**, and predict network resource utilization more accurately, ensuring a good experience even during dynamic changes and user aggregation.

## 2.2 Trend 2: New 3D Devices Are Enabling New Applications and Require Higher Network Assurance

The mobile communications industry has been continuously evolving and developing over the past decade, largely due to the increased popularity of smartphones. However, a recent report reveals that global smartphone shipments have declined by 11.3% year-on-year in 2022 and by 14% year-on-year in the first quarter of 2023, indicating a significant shrinkage in the smartphone market. As a result, there is a pressing need for new smart devices to offer consumers a fresh experience, generate more value, and drive industry growth.

2023 witnesses a surge in the end-to-end maturity of naked-eye 3D devices and content, with a significant reduction in the cost of 3D devices. This will pave the way for the launch of new commercial devices such as naked-eye 3D mobile phones, tablets, monitors, and laptops. At the annual I/O conference in May 2023, Google presented Starline, a light field display device. This technology uses 3D telepresence to enable virtual face-to-face conversations on TV-sized devices. It creates a sense of reality that makes people feel as though they are chatting with someone in a coffee shop or office, rather than communicating online from a distance. Alongside technical breakthroughs and experience improvement, the advent of AI has brought about a remarkable 100-fold reduction in the cost of converting 2D content to 3D content. As a result, content is no longer a bottleneck, and users can effortlessly switch between 2D and 3D viewing modes in real time, catering to their individual preferences.

At the same time, Apple launched Apple Vision Pro, a mixed reality (MR) head-mounted device. It is set to hit the market in early 2024. This cutting-edge device combines virtual reality (VR) and augmented reality (AR), allowing users to fully immerse themselves in a high-definition virtual world and experience a wide range of applications, including videos and games, in an entirely new and innovative manner.

### Challenges and Opportunities

The emergence of new 3D devices and applications offers a completely new user interaction experience and boosts enterprise productivity. However, it also imposes more demanding standards for network connection quality. A 10 Gbit/s access rate, low latency, and high uplink traffic become essential prerequisites for differentiated networks. Furthermore, ensuring a novel service experience and delivering differentiated services are crucial for network evolution.

**The increasing demand for 8K video and extended reality (XR) video conferencing may lead to bursts in network capacity and uplink traffic.** Apple Vision Pro is a good example of this when watching videos. Network

traffic will be 250 times higher when streaming five 8K/500 Mbit/s video streams compared to one 4K/10 Mbit/s video stream. To ensure a seamless service experience, a bandwidth of 5–10 Gbit/s will be required soon.

**Ensuring a smooth experience for services like XR relies heavily on networks that are both low-latency and high-reliability.** To achieve large-scale real-time rendering and 3D reconstruction for XR, ultra-broadband, low-latency, and high-reliability networks are necessary for transmitting data to the cloud for processing. This shift in direction will drive the transformation of computing and network architectures. The trend towards ultra-broadband, low-latency, and reliable networks is becoming increasingly important, as achieving an optimal XR experience requires ubiquitous gigabit bandwidth and millisecond-level latency.

**New business opportunities in network services will arise from SLA assurance and differentiated services for high-value customers.** Soft power, such as the self-serving XR private line, SLA commitment and assurance, and predictive quality assurance services, will play a crucial role in driving these opportunities.

## Suggestions

**1. Construct a deterministic target network that incorporates perceptible experience,** enhance the network's awareness capabilities, improve service identification and experience awareness at the NE layer, offer experience analysis and prediction at the network layer, and upgrade from guaranteed bandwidth to guaranteed experience.

**2. Provide differentiated network services that guarantee an exceptional user experience,** and enhance NaaS capabilities by flexibly customizing products and services per customer requirements, including uplink, downlink, delay, jitter, and SLA assurance.

## 2.3 Trend 3: There Is a Pressing Global Need for Automation and Intelligence. AN Is Stepping into the Implementation Phase

The aftermath of the COVID-19 pandemic has witnessed a sweeping wave of automation across the globe, profoundly reshaping the growth and development trajectory of organizations. Enterprises are increasingly leveraging various aspects of automation — like intelligent automation, super automation, and chatbots — to process vast amounts of data, automate service operations, and enhance speed and efficiency. Evolving customer needs have prompted enterprises to intensify their investment in delivery, prioritizing operational efficiency, productivity, and resilience.

A Deloitte report reveals that more than half of all organizations (53%) have already begun implementing robotic process automation (RPA). Meanwhile, Gartner predicts that by 2024, super automation will lead to a 30% reduction in operating costs for organizations. By 2025, the market size of super automation software is expected to reach almost US$860 billion. In today's fast-paced business environment, enterprises need to be agile and innovative. Automation can help them achieve this by repurposing existing infrastructure to meet changing customer demands and fostering customer loyalty in a cost-effective manner.

AN was first proposed in 2019. The concept and vision have since received active interest and investment from industry organizations, standards organizations, operators, vendors, and analyst firms. Within four years, AN has progressed from a concept to industry incubation and from a vision to practical implementation. According to a third-party report, 91% of surveyed operators have already started implementing AN and plan to expand their investment. Ten or more top global operators have set the goal of achieving L4 by 2025–2027. With the addition of 66 companies, the latest TM Forum's AN white paper (5.0) continues to gain momentum. The AN industry has entered a critical period of substantial implementation and rapid development.

### Challenges and Opportunities

Over the years, there have been numerous attempts to upgrade and reconstruct networks through automation and intelligence. AN has now entered the practical implementation phase and have achieved remarkable results. However, implementing AN is a systematic project that cannot be completed overnight. The road to a High Autonomous Networks still presents many challenges.

**The development of a unified standardized industry level and effectiveness system is of the utmost importance to unite the industry and facilitate collaborative evolution.** Operators are currently working on defining classification and measurement criteria for effectiveness. However, the absence of industry standards impedes joint industry innovation, unified intergenerational progress, and benchmarking advancements.

**We need to effectively explore and categorize market demands to guide the innovation and development of autonomous applications.** How can we improve our understanding and classify the needs of industry customers and consumers in terms of communication network performance, service quality, and user experience? Answering this question will help us direct the innovation of autonomous applications for all industry partners and facilitate the autonomous upgrade of operator networks. It is crucial for all industry partners to collaborate and conduct joint exploration and research in this area.

**Achieving the full potential of AN requires a comprehensive approach that includes end-to-end value streamlining, cross-layer interoperability, and cross-domain collaboration.** This will enable the conversion of autonomous capabilities into tangible benefits for operators, customers, and industries. Autonomous capabilities are constantly evolving towards L5, empowering operators to succeed and quickly improving network quality, increasing service revenue, reducing costs, and enhancing efficiency. We must facilitate the digital transformation of industries, offering convenient and on-demand access to cloud and network services. We must also ensure SLA assurance and offer autonomous visualized management and control. These actions will enable consumers to fully embrace a digital lifestyle, gain access to a variety of digital services, enjoy high-quality networks, and experience the convenience of smart home services, ultimately providing them with an unparalleled user experience.

**Suggestions**

**1. Accelerate the definition of industry intergeneration.** Align the goals for advanced AN, specify intergenerational characteristics and effectiveness indicators, and guide industry development.

**2. Speed up the development of industry standards.** Collaborate to create hierarchical standards for AN in various scenarios and at all levels, establish high-level capability interfaces, and encourage effective industry collaboration.

**3. Accelerate breakthroughs in core technologies.** Work together to promote advancements in AN technologies, including converged perception, digital twin, AI large models, and intelligent decision-making, to drive the industry's technological leap.

**4. Drive business innovation and practice.** Jointly explore various business use cases, focus on value creation, actively implement end-to-end process innovation, and expedite the creation of business value.

## 2.4 Trend 4: AI Commercialization Is Going Beyond Point Solutions, Evolving Toward Application and System Solutions

During the Second Industrial Revolution, a traditional steam-powered factory went through a transition toward electrification. The transition first occurred on a single machine (point solution), then on specific machines or production lines (application solution), and finally on all machines, all production lines, and the entire factory (system solution). In Power and Prediction: The Disruptive Economics of Artificial Intelligence, Ajay Agrawal points out that the rise of AI will undergo a similar process, from point solution innovation to application solution innovation and finally to system solution transformation.

- **Point solution innovation:** AI is used to address very concrete problems by improving an existing procedure. It can be independently adopted without changing the existing system.
- **Application solution innovation:** AI is used to cope with a series of problems and enables a new procedure that can be independently adopted without changing the existing system.
- **System solution transformation:** AI can improve existing procedures or enable new procedures by changing dependent procedures.

In the past few years, AN exploration by global operators has primarily focused on innovative use cases for the network O&M process. These are point solutions where hundreds of identified capabilities for dozens of O&M tasks can be iteratively improved through AI replacement and reconstruction.

With in-depth practices in AN, leading operators began to introduce mechanisms for effectiveness where business scenarios and values drive innovation. Innovative application and system solutions will gradually remove constraints from existing business procedures, which will be reconstructed top-down through collaboration among operators' network, customer, and marketing departments.

## Challenges and Opportunities

To introduce innovations in AN application solutions and system solutions, operators need to thoroughly review the drawbacks of inventory network automation and intelligence from multiple perspectives (including organization design, procedure walk-through, effectiveness indicators, and target architecture) and reconstruct their systems to meet specific objectives. Such innovation is far more difficult than point solutions.

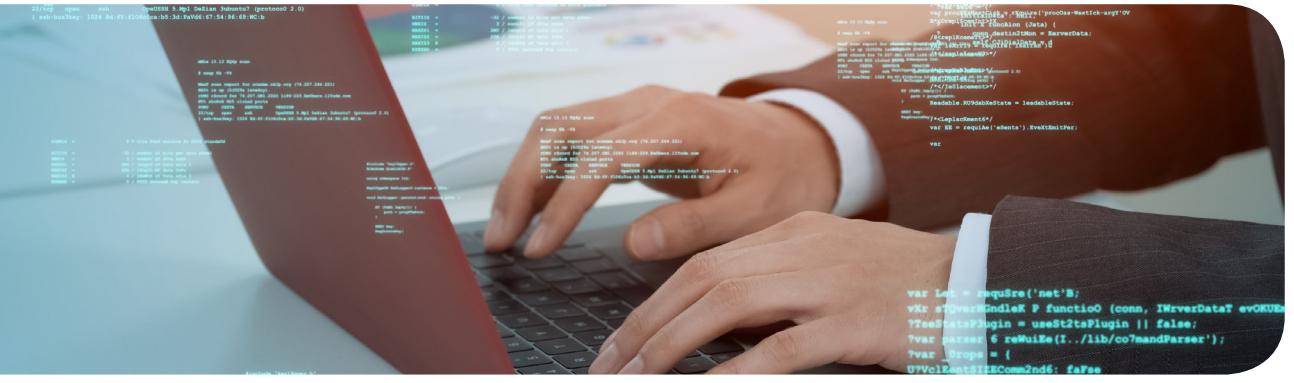
**There is no scientific effectiveness indicator system to guide AN innovation.** Currently, different operator departments and domains set KPIs and KQIs to improve the network O&M efficiency. There is no effectiveness indicator system that targets better user experience or higher business value and reflects the comprehensive impact of network operations.

**Due to increasingly complex network services and technologies, operators are typically large organizations with segregated responsibilities, hindering collaboration among departments and technical domains.** For instance, the customer and marketing departments focus on satisfying customer requirements, responding to complaints, business monetization, and market growth. In contrast, each network department is responsible for the domain-specific network operation quality and service SLA commitments within their purview.

**It is challenging to design and reconstruct existing procedures top-down and achieve procedure walk-through.** Changes should not affect the network experience and service SLA of existing customers. Migrating and upgrading procedures and data before and after reconstruction should be smooth. In addition, network technologies are evolving rapidly. The existing procedures need to be compatible with existing devices and services, resulting in complicated procedure branches.

## Suggestions

- **Build an integrated scientific effectiveness indicator system:** Share best practices in setting effectiveness indicators through industry cooperation. Jointly define a common network effectiveness indicator system and share definition methods with the help of standards organizations.
- **Enable cross-department innovation:** Focus on improving customer experience and creating business value. Innovate to generate a positive business cycle. Business enablement, procedure walk-through, and the evaluation of technical architecture should be simultaneous; organizational design and optimization are also crucial for making innovation.



## 2.5 Trend 5: Innovative Scenarios of Network AI Extend from AI-Assisted Network Awareness and Analysis to AI-Enabled Network Decision-making. Technical Breakthroughs Need to Be Made in AI System Trustworthiness and Correctness of Decisions

According to a case analysis report for the medical care industry released by Gartner in April 2022, when AI models lack explainability, we may try to accumulate different types of cases by phase to help improve the credibility of AI systems from the perspective of business value. In the field of autonomous vehicles, the most important standard ISO 21448 Road vehicles — Safety of the intended functionality was officially released in June 2022. The above standard is concerned with addressing unintended behavior caused by insufficient design or functional restrictions, guiding intelligent vehicles to fulfill the trustworthiness objectives of correct design and safe behavior.

Likewise, as AI applications in communications networks continue to grow, from AI-assisted applications with low criticality (such as network fault detection and root cause analysis, network traffic prediction, and network status awareness) towards decision-making and configuration instruction delivery applications, AN is facing a trustworthiness challenge. Let's take data center networks as an example. With the rapid development of Internet and public cloud services, the total number of switches in a region has significantly increased from several thousand in 2018 to tens of thousands in 2023. It is estimated to reach hundreds of thousands in 2028. To prevent severe network interruption incidents caused by incorrect network configuration changes or inappropriate maintenance and capacity expansion, operators have adopted trustworthiness technologies on data center networks to check network planning, verify configurations, and identify potential risks in network design. This helps cope with complex services in network changes as well as capacity expansion and can guarantee correct configurations.

As steady progress has been made in AI commercialization, AI has become crucial for the development of various industries. AI technologies are applied to the telecom field to cover the understanding of known information (such as an intelligent application for deterministic network parameters) and understanding of basic network knowledge (such as an intelligent application for networking). They will also be utilized for intelligent decision-making in open and complex key scenarios. This is a long-term systematic project centered on making fair and secure decisions under any circumstances.

Telecom networks are large-scale, complex, dynamic, and uncertain, making it difficult to evaluate the reliability of AI systems. AI predicts network trends based on limited conditions. A key issue for O&M personnel is to properly understand and rely on the AI result, and make

decisions based on the understanding of probability, especially in the case that the AI result contradicts with their judgment. The above matter is concerned with AI system trustworthiness.

AI system trustworthiness is related to explainability and accumulation of credits, and can be expressed as follows:

**AI System Trustworthiness**

$$Trustworthiness_{system} = Explainability_{system} + \lim_{n \to \infty} \left( \sum_{i=1}^{n} (Credit_i(\mathrm{AI})) \right)$$

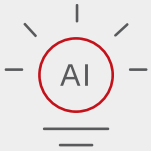
## Challenges and Opportunities

As AI technologies rapidly develop, larger and more complex AI models are used, making explainability of the models more challenging. It is exceedingly difficult to make theoretical or technical breakthroughs in the short term. AI systems are faced with the following challenges:

**There is lack of methods and tools for network system architecture design for applications with high criticality to help explain and verify AI systems.** Instead of relying on explainability of AI models, AI is constrained into a carefully designed architecture with digital system objectives, behavior, and dynamic environment modeling.

**There is lack of criticality evaluation and dynamic measurement methods for network applications.** Various system design methods need to be used for network applications of different criticality levels. The criticality levels vary with scenarios and environment status, and in turn dynamically change the system objectives and behavior.

**Suggestions**




- **Explore core trustworthiness technologies for network AI systems to guarantee decision-making and configuration correctness in key scenarios such as network changes and capacity expansion.** Academia, industries, and standards organizations need to jointly explore systematic design methods, processes, and tools, and develop standards to lead the industry development.
- **Accumulate network AI use cases and improve credibility of network AI systems by innovative practices.** Industries should share innovative methods and practices and work together to enhance network AI confidence.

## 2.6 Trend 6: Foundation Models Are Constructed by Layer, and Those Integrated with Telecom Knowledge Will Drive the Productivity Transformation of the Telecom Industry

ChatGPT has set off a new wave of AI development around the world. Major tech companies are constructing basic foundation models using their own computing power and algorithm capabilities. Meanwhile, various industries are building industrial foundation models by incorporating service data into these basic foundation models. These emerging models are triggering a productivity transformation across various industries.

Foundation models are being explored and developed quickly. Once ready, they are not just used as chat bots but are gradually integrated into various industry activities, boosting service production. Here are some examples.

- **Meteorology:** Meteorological models can provide a global weather forecast at a second-level resolution. The forecast results are accurate, including potential, humidity, wind speed, temperature, and sea level pressure; they are significant for disaster prevention and mitigation, as well as the assurance of people's lives and property safety.

• **Drug R&D:** AI foundation models can predict the absorption, distribution, metabolism, excretion, and toxicity (ADMET) attributes of compounds, generate compounds with high binding energy, and even predict the interaction between targets and potential drugs. On average, a foundation model can shorten the drug R&D period by 70%, significantly reducing costs and improving the success possibility ten-fold.

• **Telecom:** Foundation models are built using vast amounts of telecom knowledge. They have good generalization capabilities and can shield site differences to quickly deploy AI applications. Additionally, these foundation models are good at understanding intent, so they can control, use, configure, and manage network devices through northbound interfaces, accelerating the deployment of AN. Currently, the telecom industry is actively using foundation models.

**Communications vendors are releasing various application solutions based on foundation models.** For example, Cisco released the NetworkGPT plug-in to analyze logs and identify potential risks and faults. Juniper launched the ChatGPT-powered Marvis VNA assistant for Q&A, root cause analysis of cross-domain faults, troubleshooting priority recommendation, and analysis of Zoom conference performance. AsiaInfo developed intelligent network O&M applications using open-source or business models to support network O&M and production through AIGC Q&A.

**At the same time, operators are also starting to build and release their own foundation models.** For instance, China Mobile released the Jiutian industrial foundation model, which mainly uses the customer service model to redefine customer service and improve its efficiency. China Telecom published the TeleChat foundation model, which is used for the intelligent data middle-end, intelligent customer service, and smart government service. China Unicom developed the Honghu foundation model, which is positioned as a value-added service foundation model and offers services like text-to-image generation, video clipping, and image-to-image generation.

In July 2023, Huawei officially released the Huawei Cloud Pangu Models 3.0 and proposed a development architecture consisting of three layers: L0 (functioning as the basic foundation model), L1 (serving as the industrial foundation model), and L2 (acting as the scenario-specific model). For the telecom industry, Huawei constructed a telecom industry model based on L0 by incorporating billions of corpuses and thousands of instances of expertise. In addition, Huawei provided many model applications, such as intent-driven dialog-based O&M and expert experience-based network self-optimization.

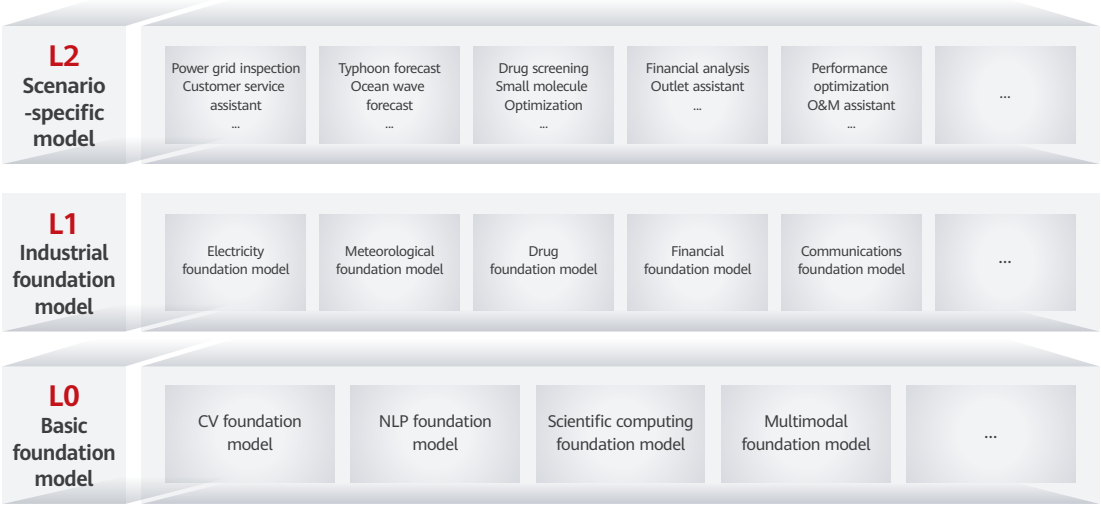



Figure 2-1 Layered architecture of foundation models

## Challenges and Opportunities

Current research and existing practices demonstrate that compared with traditional AI models, foundation models have obvious advantages in intent understanding, judgment, and decision-making. Telecom networks have significant requirements and must be reliable. So, foundation models should first be applied in low-risk human-machine interaction scenarios, for example, O&M, network design, customer service, and marketing.

**Fault O&M:** Dialog-based O&M uses foundation models. Specifically, O&M is converted into dialog interaction between O&M personnel and machines. Problems can be identified and diagnosed through intent understanding, guiding O&M personnel to quickly rectify faults. Dialog-based O&M improves O&M efficiency and reduces errors that could be caused by manual operations.

**Network analysis and warnings:** User feedback and system logs are collected for comprehensive analysis. Once an exception is detected, a warning message is sent to the service personnel, who can focus on device performance problems or faults and handle them quickly. This makes the telecom network more secure and stable.

**Network solution design:** Chat-as-solution-design is implemented through intelligent assistance and human-machine collaboration and interaction. Solution input is automatically archived and recorded in real time, making the input information

traceable. In addition, tasks can be broken down, automatically dispatched, and tracked, and reminders are proactively sent to achieve end-to-end quality management of design solutions.

**Customer service:** The customer service scenario relies on massive amounts of business knowledge and service experience. The AIGC foundation model demonstrates amazing semantic awareness and intelligence generation capabilities. It can parse users' questions expressed in natural language and quickly provide answers, significantly reducing the response time.

**Self-marketing and promotion:** Currently, the AIGC foundation model has powerful capabilities in long-text processing, scenario and intent understanding, and continuous contextual dialogue. It customizes marketing content using generative AI and constructs marketing scenarios through various touch points, such as customer service based on users' preferences, behavior, and network experience feedback. This enables more personalized and experiential marketing and promotion activities.

Despite these achievements, foundation models face a series of challenges in the telecom industry.

- Foundation models will play an increasingly important role in telecom networks in the future and have outstanding performance in intent understanding. However, foundation models still underperform in case of the complex cognitive problems such as thinking, recommendation, decision-making, and association.
- To maximize the value of foundation models in the telecom industry, we need to consider how to implement effective business management, encourage stakeholders to identify a wider range of value scenarios, and develop more innovative foundation model applications through full cooperation among vendors and operators.

**Suggestions**

· **Foundation models can be combined with cognitive intelligence** to implement knowledge conflation, representation, reasoning, and decision-making. In addition, cognitive intelligence can be efficiently invoked by foundation models and serve as an efficient assistant to help foundation models provide more reliable conclusions.

· **Innovation is possible in business patterns.** Model as a Service (MaaS) may become an important business pattern in the future. Most enterprises lack the capacity to build foundation models but they have rich data. Large-scale pre-training combined with fine-tuning based on foundation models can support applications in various AI-derivative industries. These enterprises can use MaaS to quickly build their own industry- or scenario-specific models based on the basic foundation models provided by high-tech companies.

## 2.7 Trend 7: Operators Are Actively Building a New Ecosystem for Network Capability Openness, Promoting Standardization and Commercialization of Network APIs, and Increasing Business Revenue by Leveraging NaaS

Industries are rapidly undergoing digital transformation, extending from IT support systems to core areas such as production and decision-making systems. As a result, various network capabilities and value-added services are emerging. These include enterprise branch interconnection, multi-cloud connection, security protection, hard isolation, and SLA assurance. To support these changes, the communications industry is actively seeking new business paradigms. By exploring and opening their network capabilities and collaborating with enterprises, the communications industry is facilitating digitization and innovation while boosting business revenues.

Since the beginning of 2023, network as a service (NaaS) has once again become a trending topic in the industry. Standards organizations,

open-source communities, operators, and vendors have initiated new research on NaaS technology and business opportunities, hoping to uncover new ways to monetize networks and enable novel service capabilities.

At MWC 2023, the GSMA and 21 mobile operators unveiled the Open Gateway Initiative. The main goal of this initiative is to actively explore new growth opportunities by embracing network capability openness and looking for ways to deploy digital service roaming through API roaming similar to the way voice roaming was implemented 36 years ago. Top European operators, such as Telefonica, Deutsche Telekom, Orange, and Vodafone, have actively embraced the initiative. In collaboration with device vendors and cloud service providers, they have released API innovation cases and the first batch of eight common network APIs, such as Quality on Demand (QoD) and Number Verification. Moving forward, they will focus on 5G technology and invoking more advanced network capabilities, such as network slicing, 5G new calling, and private line/network.

Additionally, GSMA cooperated with the Linux Foundation to launch the CAMARA open-source project. The project introduced standardized service APIs for developers and end consumers. Their focus is on defining interfaces and open source codes. They also partnered with industry organizations, such as the TM Forum, to streamline API layer definitions and develop the NaaS implementation architecture. The project aims to simplify technical implementation and open network capabilities over developer-friendly APIs. Additionally, the project invites cooperation from industry partners, such as cloud service providers, OTT providers, app service providers, and enterprise customers, to explore new business scenarios and capitalize on emerging market opportunities by leveraging network capabilities.

## Challenges and Opportunities

One of the aims of AN is to offer network users innovative and high-quality digital communications services that are characterized by "zero-wait," "zero-touch," and "zero-trouble" user experience. AN enables operators to become NaaS and integrated digital service providers. However, completely overturning network usage and O&M is not a simple task. NaaS may be ideal for employees working at home or small enterprise branches. However, migrating a large enterprise campus or data center network to NaaS is challenging.

**NaaS requires further standardization:** Southbound network APIs and eastbound and westbound roaming APIs of the NaaS platform have not been standardized. This leads to low efficiency in multi-party collaboration across operators and technical domains. To achieve convergence from thousands of atomic APIs to hundreds of network APIs, it is necessary to classify, define, and converge APIs by scenario. Additionally, we need to further standardize network API protocols that vary among different vendors.

**Comprehensive invocation and monetization capabilities are lacking in complex service scenarios.** Currently, NaaS monetization opportunities are limited, and there is a need to enhance comprehensive multi-capability invocation in complex service scenarios.

## Suggestions

· **Standardize NaaS APIs:** Speed up the definition and standardization of service APIs, network APIs, and roaming APIs for different service scenarios. This will help eliminate discrepancies among device vendors, operators, and regions while reducing the complexity of network API orchestration and invocation.

· **Explore new service scenarios for capability openness:** 5G and 5.5G represent new communications networks with significant business potential. Operators, OTT providers, and device vendors should collaborate to improve comprehensive invoking capabilities in complex scenarios, such as E2E network slice, 5G new calling, cloud-network private line BoD, OTN low-latency private line, cloud + network convergent services, and edge capabilities. This collaboration will open NaaS monetization opportunities.

# 03

# Autonomous Networks Framework (ANF)

The digital transformation of operator networks requires an efficient systematic framework to guide the entire process of automated and intelligent transformation, from strategy to implementation. This framework should consistently provide value through self-iteration and continuous evolution. In pursuit of this objective, the TM Forum collects AN expertise and experiences from major operators. It is optimizing the existing four-elements methodology to evaluate AN, and is upgrading it to a more systematic and comprehensive Autonomous Networks Framework (ANF). With this framework, the TM Forum expects to develop a new set of out of the box (OOTB) implementation guides and toolkits that operators can use for network automation and intelligent transformation, helping operators plan and implement AN more efficiently and systematically.

The ANF includes four key elements, operations practices, and industry assessment and certification. The four key elements are key effectiveness indicators (KEIs), level standards, target architecture, and AN map; these have been widely recognized around the world. Operation practices will help operators in formulating AN strategies and continuously improving AN capabilities. Industry assessment and certification can be performed to evaluate the service level of operators and vendors' solution capabilities.

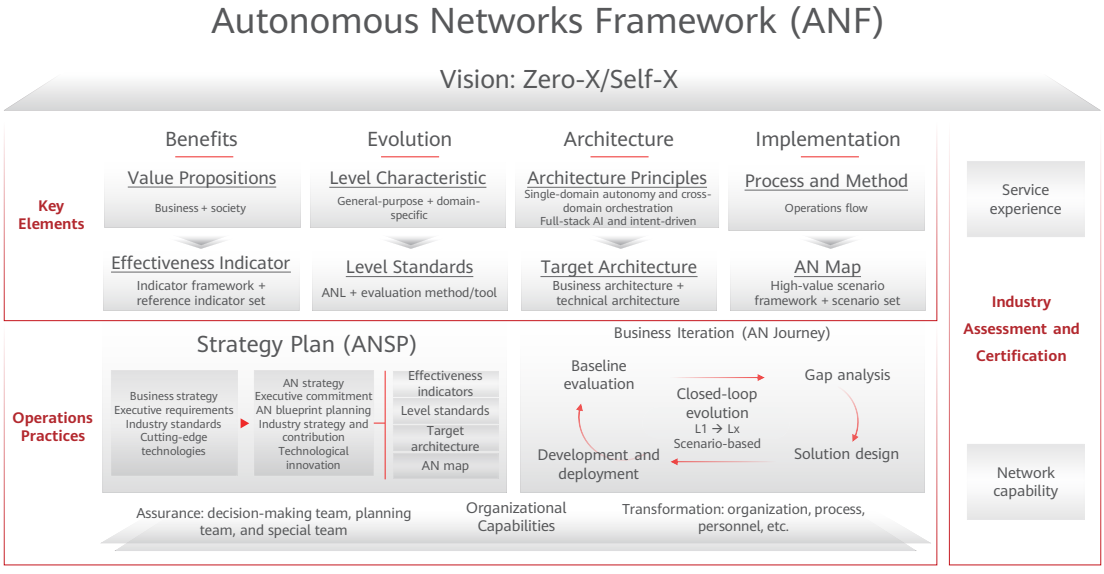



Figure 3-1 ANF

The ANF mainly includes **four key elements, operation practices, and industry assessment and certification.**

**Four key elements** define the AN KEIs, level standards, target architecture, and autonomous map based on the AN's benefits, evolution pace, division of labor, and implementation scope.

**Operations practices** are systematically implemented based on the four key elements, including AN strategic planning (ANSP), AN iterative implementation (AN Journey), and organizational capabilities.

**Industry assessment and certification** include the assessment of service experience and network capabilities. Service experience is assessed from the perspective of industry customers by conducting black-box tests and certifying the levels of operators' networks and services. This supports their development and improves the services that target industry customers. Network capabilities are evaluated based on the level of solutions by multiple vendors, scenarios, and domains, looking to support autonomous operations, facilitate the evolution of autonomous capabilities, promote cross-vendor and cross-domain collaboration, and streamline E2E business processes. Industry assessment and certification can enhance AN benchmarking, improve the credibility of AN, accelerate the fulfillment of a win-win business outcome, and promote prosperity in the AN industry.

# 04

# Huawei ADN Solution

The vision and mission of Huawei is to bring digital to every person, home, and organization, and build a fully connected, intelligent world. Building a fully connected, intelligent world is a process of helping various industries to implement digital transformation. Huawei is committed to continuous innovation in cloud services, AI, networks, and low-carbon development to accelerate digital development, spark a new revolution for human civilization, and stimulate industry innovation, industry upgrade, and social development. The focus of Huawei's unceasing innovations is directed at the autonomous driving network (ADN), ubiquitous cloud services, pervasive AI, and low-carbon development benefiting from digital technologies.

Ubiquitous cloud services


Pervasive AI

ADN

Low-carbon development benefiting from digital technologies

ADN is Huawei's autonomous networks solution and a core strategy of Huawei Communications Network 2030. ADN aims to leverage connectivity and intelligence to deploy a self-configuring, self-healing, and self-optimizing autonomous networks. ADN implements single-domain autonomy and cross-domain collaboration, providing operator and enterprise networks with self-configuration, self-healing, and self-optimizing network capabilities and delivering a zero-wait, zero-touch, and zero-trouble experience to consumers, public sectors, and enterprises. In line with TM Forum's ANF,

Huawei has significantly advanced key technologies, including converged sensing, digital twin, intelligent decision-making, and human-machine symbiosis, building a High Autonomous Networks foundation and speeding up the evolution toward High Autonomous Networks.

**Converged sensing:** High-precision, real-time network data provides a robust foundation for upper-layer automation. For instance, the optical power sensing duration can be shortened from 15 minutes to a few milliseconds.

**Digital twin:** Based on a large amount of converged sensing data, high-precision digital twins are generated to implement real-time network simulation. This facilitates network planning, construction, maintenance, optimization, and operations. For instance, online simulation can prevent and eliminate network faults caused by manual configuration errors.

**Intelligent decision-making:** Based on high-precision digital twins, intelligent algorithms are used to make decisions for the entire network. For example, single-objective optimization has evolved towards multi-objective collaborative optimization, which can achieve an optimal balance between multiple objectives, including network energy efficiency, rates, and coverage.

**Human-machine symbiosis:** Huawei's language foundation model Pangu and a professional knowledge base, including telecom corpus, standards and documents, and case summaries, are used to develop a telecom foundation model that significantly improves human-machine interaction. The model enables the O&M assistant tool to offer interactive assistance equivalent to that provided by senior experts. Previously, this tool could only provide assistance equivalent to that provided by the average engineer.

## 4.1 Network Architecture and Value Proposition

The telecom industry needs a clear service architecture as a reference and consensus to carry out production practices to achieve the goal of reaching high ANLs. Based on this service architecture,

operators can systematically evaluate and analyze the architecture of current OSSs, integrated NMSs, vendor NMSs/controllers, and network devices using a top-to-bottom approach, and formulate a feasible evolution roadmap that meets their own requirements. Huawei proposes the following ADN service architecture based on the recommendations for the service architecture provided by TM Forum in IG1218 and various innovative practices developed in collaboration with global operators.

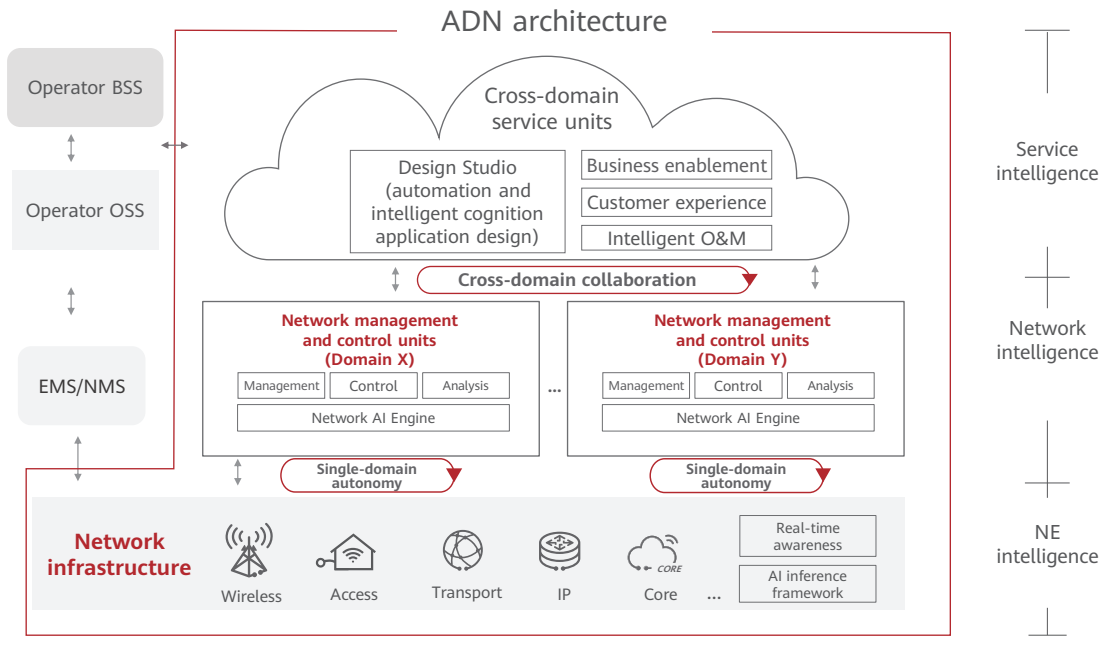



Figure 4-1 ADN service architecture

**Intelligent network infrastructure** is fundamental to High Autonomous Networks. Network devices need to possess more real-time sensing components and AI inference capabilities to detect the changes in resources, services, and surrounding environments, and they also need to possess intelligent analysis, decision-making, and execution capabilities.

**Network management and control units** need to perform network digital modeling to associate discrete network resources, services, and status data, generate a comprehensive domain-specific HD network map, integrate data collection, awareness, simulation, decision-making, and control, and implement single-domain autonomy, guaranteeing network connection quality and timeliness.

**Cross-domain service units** provide three capabilities (intelligence business innovation, customer experience improvement, and service and network O&M assurance), an application design and development platform, and cloud services. This platform enables operators to streamline O&M and business processes, and facilitates flexible service orchestration based on

network characteristics. Operators can use it to quickly and iteratively develop new business models, O&M processes, service applications, and business products and services. This enables operators to achieve business agility and improve the skills of new O&M personnel and business design personnel.

**The network AI unit,** a basic platform for network AI design and development, performs continuous AI training and knowledge extraction for various types of telecom network data to generate AI models and network knowledge. The AI models and network knowledge can be incorporated into the preceding three units to make networks more intelligent. The network AI unit is also an asset center for operators' AI assets. It manages AI models and network knowledge developed and trained by operators during planning, construction, maintenance, and optimization. The AI models and knowledge can be fully shared and reused to reduce repetitive development and training.

Business value is the key driving force for AN deployment and promotion. Huawei strives to provide the following four key business values to differentiate its products and solutions from competitors and help the industry advance toward High Autonomous Networks.

**Service agility+:** Network monetization capabilities will be developed to help customers increase their revenue, build a solid NaaS foundation, achieve zero-wait service provisioning, and shorten the product TTM.

**Customer experience+:** Key indicators such as the service quality fulfillment rate and complaint handling timeliness rate will be achieved to proactively optimize QoE and deliver an ultimate, full-lifecycle experience.

**Resource efficiency+:** Network device energy consumption will be reduced through approaches such as multi-dimensional collaboration. In addition, dumb resources will be visualized using digital methods to improve the accuracy of dumb resource data, guaranteeing precise scheduling of network resources. Furthermore, network paths will be optimized to prevent network congestion and improve network resource utilization.

**O&M efficiency+:** In-depth AI applications, such as predictive maintenance and dialogue-based O&M will be utilized to significantly reduce manual workload, lower the operation time per unit, and enhance the efficiency of O&M personnel.

Focusing on these four values, Huawei's ADN solution is gradually advancing towards L4 AN, transforming the scenario from machines assisting humans to humans assisting machines. In L2 and L3, humans perform O&M by operating machines through CLIs and GUIs and interact with other people in natural languages. In L4, machines take on major O&M responsibilities. Machines rely on generative foundation models to understand human intents, provide suggestions for next-step network planning and optimization, and rely on decision-making foundation models for intelligent decision-making. This achieves machine-centric AN.

| Perspective | Dimension | Level Characteristic | |
|---|---|---|---|
| | | L3/Machines assisting humans | L4/Humans assisting machines |
| Customer | Zero-wait | Automated service provisioning | Automated service delivery |
| | Zero-trouble | Experience awareness and visualization | Experience evaluation and assurance |
| | Zero-touch | Visualization | Interaction |
| Network | Self-configuration | Automated configuration delivery | Pre-event simulation<br>Post-event verification |
| | Self-healing | Precise fault diagnosis | Potential risk prediction and prevention |
| | Self-optimizing | Single-objective exclusive optimization | Multi-objective collaborative optimization |

Table 4-1 ANL characteristics

Huawei's ADN solution continues to evolve based on the "Zero-X and Self-X" vision and ANL characteristics clarified in Table 4-1, aiming to achieve High Autonomous Networks. Take zero-wait provisioning of private line services as an example. In L3, private line services are provisioned by one-click E2E network configuration delivery over APIs after personnel understand customer intents, conduct resource survey, and participate in cross-department collaboration. In L4, private line services are automatically delivered throughout the process. Machines understand customer intents, digital surveys are carried out, and cross-domain collaboration is intelligently and automatically implemented.

## 4.2 Panorama

Since Huawei first proposed the concept of ADN at UBBF 2018, it has developed a series of innovative ADN strategies for various domains, including wireless, core, access, transport, IP networks, data centers, and enterprise campuses. Adhering to the concept of Intelligence for ICT, Huawei is committed to systematically applying AI technologies to ICT infrastructure to overcome key challenges and fulfill the vision of building an intelligent world.

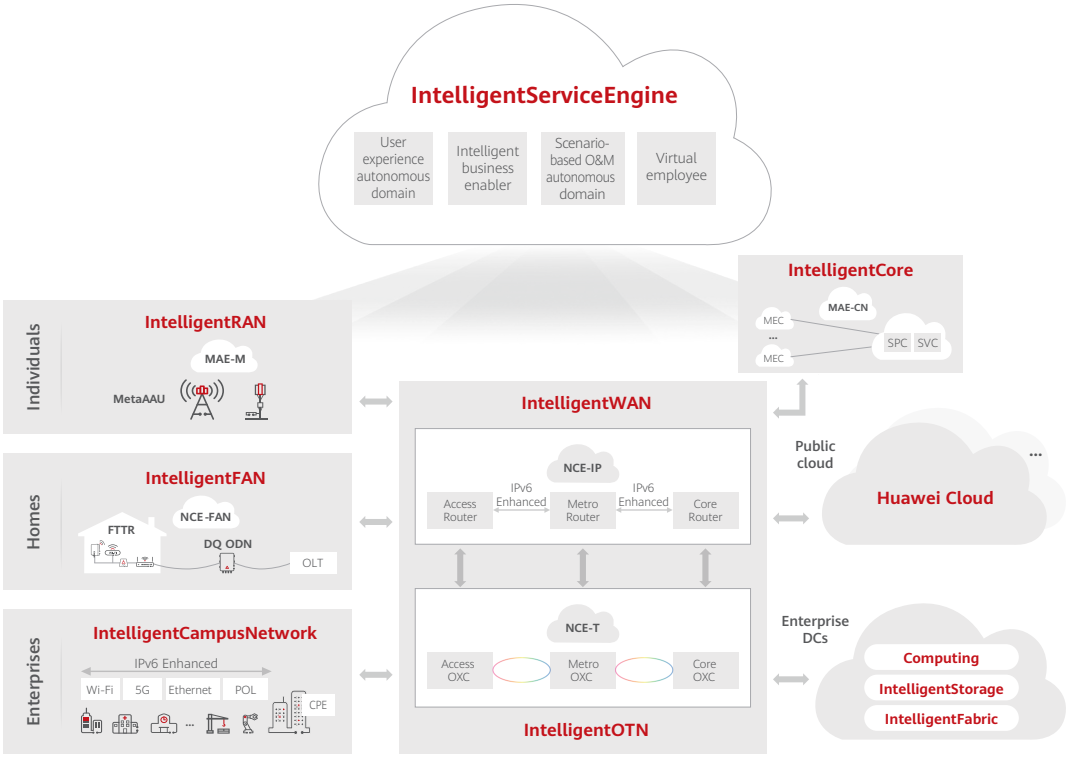



Figure 4-2 ADN product and solution overview

### 4.2.1 IntelligentRAN — Wireless ADN Solution

As the industry progresses towards L4 AN and develops L4-related specifications in 3GPP Release 18, the concept of network intelligence is evolving. It is no longer limited to intelligent network elements (NEs) but is expanding to cover the entire network. IntelligentRAN,

Huawei's ADN solution for wireless networks, is constantly evolving by leveraging L4 value scenarios. It utilizes iMaster Mobile Broadband Automation Engine (MAE) to enable single-domain single-vendor basic O&M in the wireless network domain. Furthermore, it incorporates the Mobile Intelligent Engine (MIE) to deliver intelligent UCs through collaboration with intelligent gNodeBs. In this solution, MAE and gNodeB collaborate on data and policies. They share capability intents with cross-domain platforms, such as the operations support system (OSS) and SMO, to achieve intelligence and seamlessly integrate with operators' production services.

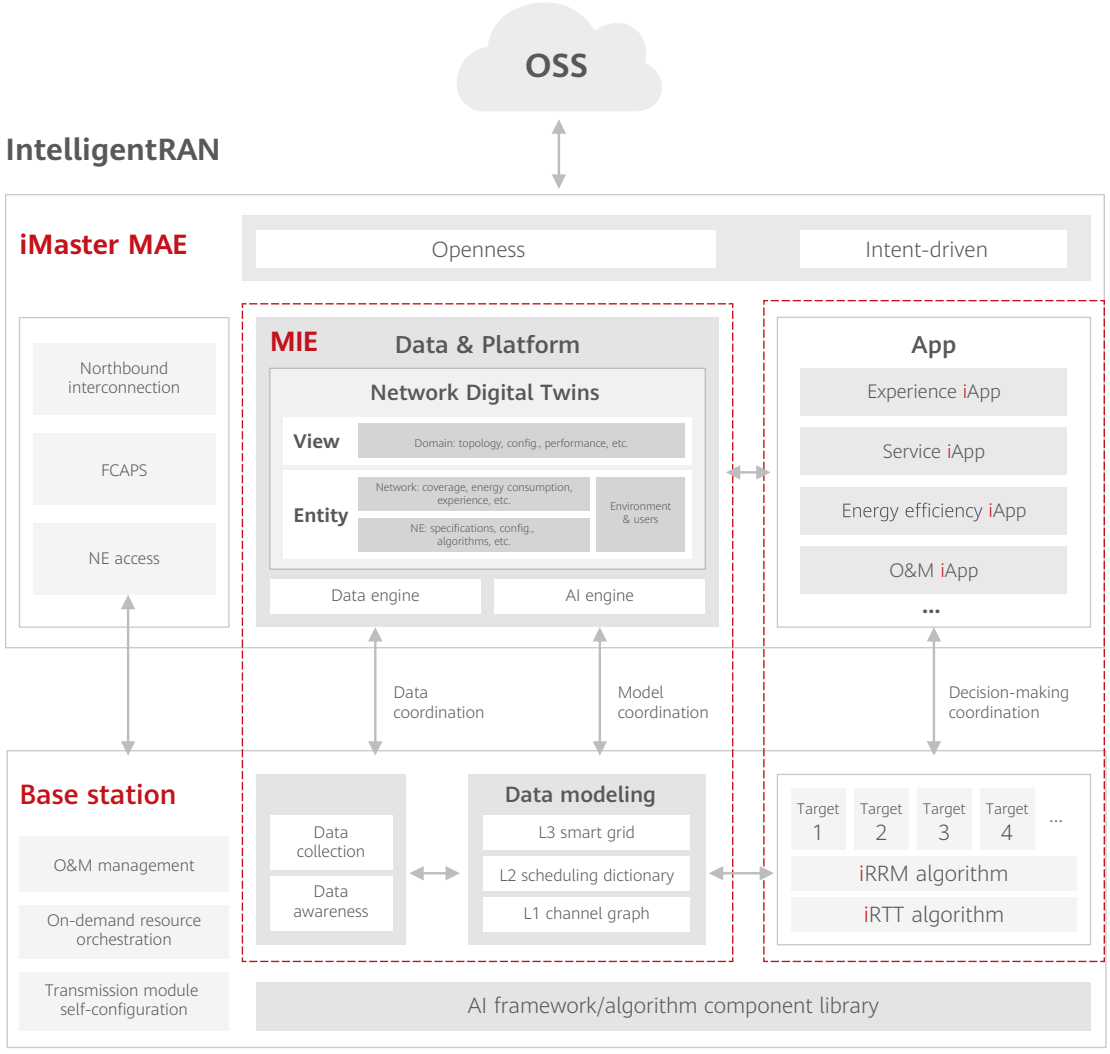



Figure 4-3 IntelligentRAN

## Solution Benefits

With the rapid development and diversification of new mobile network applications, operators face increasing demands for high-quality service assurance. This includes the introduction of naked-eye 3D video, which requires stringent bandwidth and latency requirements, and the need for large uplink bandwidth and precise positioning in industry applications. In addition, the introduction of new sites, frequencies, and technologies to wireless networks brings about structural challenges. The inclusion of more spectrums (sub-6 GHz, C-band, mmWave, and U6 GHz) and site types (macro, pole, and micro sites) further complicates O&M tasks. To achieve the "zero fault" vision, operators must implement intelligent fault prevention and prediction to address these challenges.

In response to these challenges, IntelligentRAN integrates intelligence into wireless network services, experience, O&M, and energy saving to build an L4 wireless AN that features **intelligent and simplified O&M, intelligent network optimization, and intelligent service operations**.

**Intelligent and simplified O&M:** IntelligentRAN evolves from self-diagnosing faults to predicting and preventing them. It intelligently predicts a range of faults, such as high-temperature outages, optical fiber fronthaul faults, and backup power system faults. In the case of cell outages, it leverages intelligent coverage compensation solutions to quickly compensate for coverage holes and minimize traffic loss in cells.

This solution helps operators transition from a responsive O&M mode to a predictive and preventive O&M mode, achieving the "zero" network faults vision.

**Intelligent network optimization:** IntelligentRAN evolves from only optimizing network performance to optimizing both network performance and energy saving. It enables adaptive optimization solutions for various scenarios, such as macro-micro environments, fluctuating traffic patterns, and multi-band networks, ultimately enhancing user experience. It utilizes a network-level intelligent engine to facilitate intelligent collaboration based on multiple intents and objectives. This helps operators transition from ensuring only optimal performance to ensuring both optimal performance and energy saving.

**Intelligent service operations:** IntelligentRAN evolves from user-centered service scheduling to application-centered experience deterministic assurance. It implements precise network planning considering various objectives such as coverage, rate, and latency through user-level dynamic simulation, thus meeting the differentiated service SLA requirements and facilitating service deployment and provisioning. In addition, it leverages prediction capabilities to dynamically allocate resources based on service demands, ensuring a deterministic service experience.

## Key UCs

**Intelligent and Simplified O&M**

- **Predictive and preventive fault management is implemented to transform O&M from a responsive approach to a proactive one.** In the 5G era, services must be always online, rendering the traditional post-event ticket dispatching approach far insufficient for meeting O&M requirements. To achieve the "zero fault" vision, it is necessary to shift the O&M approach from being responsive to becoming predictive and preventive. By leveraging the collaboration between the RAN EMS and NEs, IntelligentRAN utilizes long- and

short-term perception data to predict and identify over 80% of software and hardware faults and performance deterioration issues. These include board high temperature, optical module faults, and backup power duration faults. This significantly reduces the risk of faults. For example, service outages related to backup power account for 15% to 30% of all work orders. Predicting the duration of backup power can significantly decrease the number of work orders caused by this issue.

**Intelligent Network Optimization**

- **Intelligent selection of multi-band carriers based on smart coverage grids to achieve optimal network performance:** In multi-band networking scenarios (such as FDD+TDD, TDD+FDD and FDD+FDD), IntelligentRAN constructs coverage grid models to replace inter-frequency measurement results with prediction results. This allows UEs to access cells that offer optimal coverage, improving user experience. If inter-frequency coverage does not exist, this approach increases throughput by approximately 10% compared to conventional methods. If inter-frequency coverage exists, this approach reduces handover delay by approximately 300 ms compared to conventional methods.

- **Multi-intent-based multi-dimensional collaborative energy saving, achieving both optimal performance and energy savings:** Operators are placing a growing emphasis on green energy saving in response to the significant challenges posed by the ever-growing scale and complexity of networks. These challenges primarily involve network energy consumption and operational expenses (OPEX). IntelligentRAN leverages network features, including base station load, user distribution, coverage, interference, and energy consumption, to train and model its algorithms. By accurately predicting changes in energy consumption and rates under various energy-saving and performance policies, it enables the optimization of multiple objectives through collaboration. This approach can increase the network-level energy savings by 5% to 10% on the live network without affecting user experience.

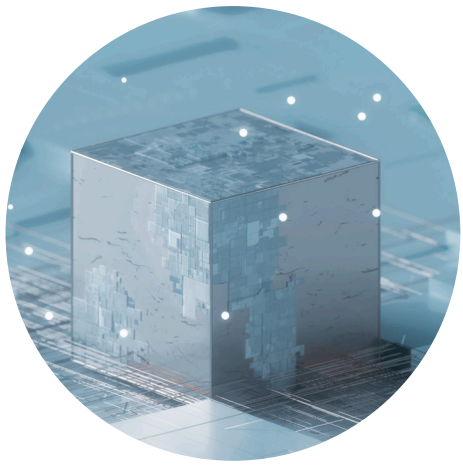
**Intelligent Service Operations**

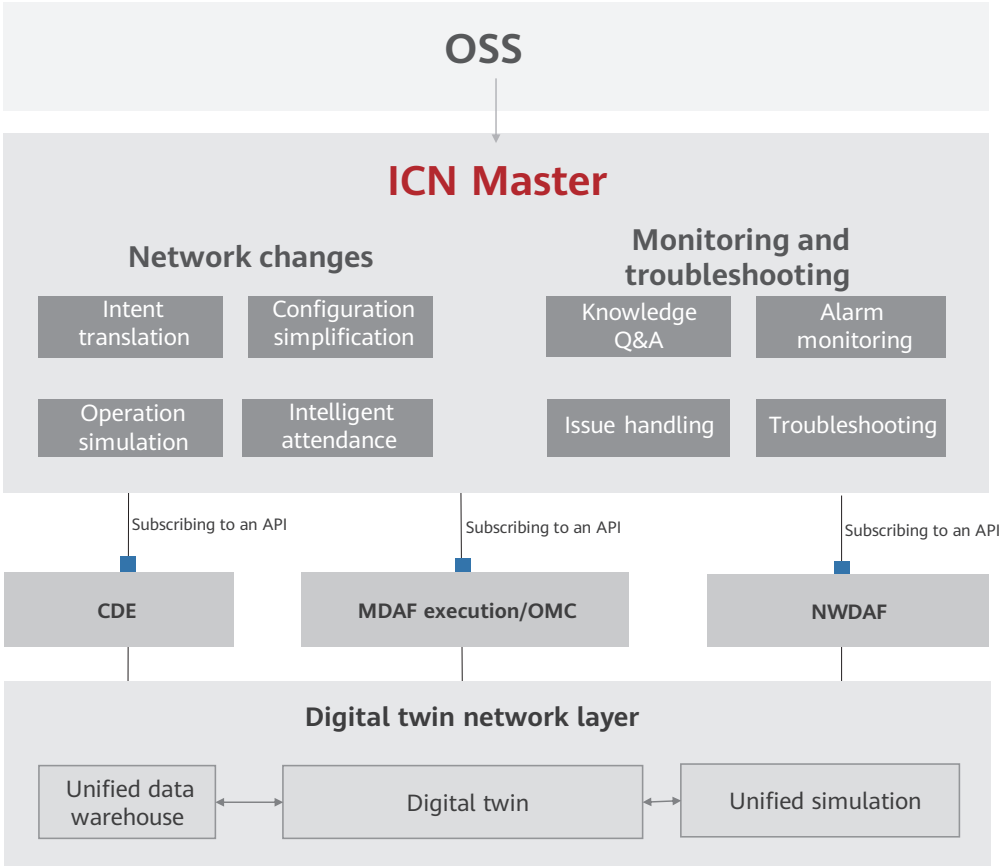
- **SLA-oriented precise network evaluation and planning, facilitating precise and fast service provisioning:** There are a variety of 5GtoB services. The services have high SLA requirements and the application environments are complex. The traditional mode of manual network planning based on expert experience cannot meet the deterministic network planning requirements of thousands of industries. In a scenario involving public networks for dedicated use, the network coverage and data rate of given areas are accurately evaluated, greatly reducing the cost of onsite measurement and evaluation. In industry-specific network scenarios, industry profiles, environment modeling, user-level simulation evaluation, and SLA-based precise planning are used to meet SLA requirements of various services on the live network, improving network planning efficiency.

- **Prediction-based slice SLA assurance, enabling deterministic service experience:** There are diverse service requirements in network slicing scenarios, including live streaming services. These service requirements contribute to the growth in network traffic. However, live streaming services pose high requirements for the data rate, resolution, and latency of wireless networks. Traditional SLA assurance approaches typically rely on reserving resources that are several times greater than the actual requirements. IntelligentRAN, on the other hand, utilizes network features extracted from parameters such as base station power control, bit rate, and frame rate to create virtual rate grid models. These models accurately predict changes in service rates and proactively optimize and adjust the network accordingly. On the live network, this solution boosts the perceived data rate for live streaming users by 5% to 10%.

### 4.2.2 IntelligentCore — Core Network ADN Solution

As core networks continue to evolve towards full convergence and NFV transitions from the VM era to the bare metal era, the scale and complexity of networks are increasing. The traditional O&M mode is no longer effective to meet the network O&M requirements of the new era, making O&M transformation a necessity. With the emergence of new 5G applications such as new calls, naked-eye 3D, and XR, operators want to adopt cloud-native best practices to enable the agile rollout of new services, improve user experience, and simplify network O&M. Automation and intelligence are crucial elements of the 5.5G core network, and have gained significant recognition in the industry as effective solutions for managing complex 5.5G networks. To address these challenges, Huawei offers the ICN Master solution, which is centered on O&M intelligence and part of the IntelligentCore solution. This ICN Master solution leverages advanced technologies, including digital twins, intent-driven systems, and large models, to empower operators in building an **intelligent and simplified, stable, and high-quality** L4 autonomous core network.






## Highlights

- **Intelligent and simplified:** Technologies such as intent-driven systems and CDCT are used to implement efficient and secure network changes. Before the events, change risks are identified in advance through staging and operational simulation. During the events, configurations are simplified through intent translation, and the automatic process is streamlined using CDCT to reduce misoperations. After the events, the effects of the changes are automatically monitored in real time through machine-assisted monitoring, and intelligent methods are used to provide assurance, eliminating the need for manual operations.
- **High stability:** Huawei provides customized solutions that target typical O&M scenarios, detect root causes of issues, boost the efficiency of routine O&M, and guarantee high network stability and reliability. The cloud-network topology is visualized to enable real-time monitoring of network status and potential bottlenecks are identified through online simulation evaluation, transitioning from reactive O&M to proactive prevention. Fault diagnosis is automated, reducing the troubleshooting time and minimizing the occurrence of faults.
- **High quality:** The ADN solution is focused

on delivering the ultimate service experience, particularly for VoLTE and 5G services. It monitors voice and data quality in real time, enabling early detection and prompt resolving of experience issues. This helps operators offer proactive customer care.

## Key UCs

- **Automatic NE upgrade:** The workflow orchestration engine's flexible scheduling eliminates the need for manual breakpoints and enables automatic upgrades of core network NEs. The unified operation interface allows for one-click downloads of core network software packages, automatic risk checks, and execution of upgrade operations. This reduces the number of man-machine interactions from over 100 to just 10, significantly reducing manual misoperations. During the upgrade, intelligent machine-assisted monitoring is used to automatically monitor and compare various counters and abnormal alarms. This identifies exceptions in advance and facilitates appropriate actions to prevent network faults. In addition, the rollback function allows for manual intervention in case of exceptions, enabling one-click suspension and ensuring dependable upgrade outcomes.

- **Intelligent DR assistance:** By utilizing automatic simulation evaluation, intelligent flow control parameter optimization, and switchover process visualization, risks can be eliminated during the switchover process to ensure successful DR switchover. (1) The manual mode has been replaced by the automatic mode. Prior to the switchover, the network is automatically simulated and evaluated online. The evaluation results can be presented to decision makers, allowing them to anticipate the signaling impact after the switchover and address any issues that may arise. (2) The optimization strategy has evolved from single-point to global optimization. Using the HEBO algorithm, an optimal flow control policy is created for the entire network and seamlessly distributed to each NE, ensuring quick convergence within 10 minutes. (3) The switchover process has been transformed from a black-box to a white-box process. As a result, the entire DR switchover process is now visible and manageable. This change allows operators to view the number of online subscribers in real time and monitor counters to detect exceptions and intervene in a timely manner, making switchovers more secure.

- **Signaling storm prevention and control:** Identifying potential risks is an effective way to prevent and control accidents. Technologies like digital twins, AI, and simulation are used to quickly and accurately evaluate networks. (1) By collecting multi-dimensional data in quasi-real-time, a high-precision digital twin network is constructed, which serves as the basis for evaluating network simulations. (2) AI-powered online learning of network behavior models, terminal behavior models,

and fault models guarantees the accuracy of evaluation models. Currently, support for 30 scenarios is provided, including holiday assurance models and live-network fault models. (3) Using advanced intelligent algorithms for surge simulation and flow control parameter optimization, automatic and routine online network simulations are performed to identify potential risks such as NEs and links with bottlenecks. This facilitates network capacity expansion and parameter adjustments to ensure a healthy network. Additionally, the topology traffic view provides a comprehensive overview of network-wide traffic and NE load. In the event of a traffic storm, the system performs network-wide traffic playback and automatic source tracing to quickly locate the source of the issue.

- **Intelligent fault diagnosis:** To address high-frequency link issues, alarms are aggregated to identify key abnormal links, gather information about faulty NEs at the local and peer ends, sort the NEs based on their fault probability, and ultimately locate the root NE that is faulty. This automated demarcation process reduces the troubleshooting time from hours to just 5 minutes, significantly enhancing O&M efficiency. In cases of high-risk KPI deterioration, the fault propagation path is determined online using the service process network model and periodic KPI data. This allows for quick identification of the root NE within 5 minutes. Extensive O&M experience is used to address NFV cross-layer issues. Intelligent analysis is supported by a built-in library of nine typical fault scenarios. Customers have the option to customize and orchestrate their experience rules online to include more fault demarcation scenarios. With the combined approach, NFV cross-layer faults can be automatically and efficiently identified within 15 minutes, significantly reducing in the time required to handle cross-layer issues.

- **Service experience optimization:** When a poor-QoE issue arises, our system collects CHR data and intelligently analyzes data samples to quickly drill down to the faulty unit and identify areas with typical issues. This enables proactive customer care, ultimately improving user experience. The system anticipates potential complaints up to three hours in advance and facilitates proactive actions to address poor-QoE issues, resulting in a 50% reduction in customer complaints.

### 4.2.3 IntelligentFAN — All-Optical Access ADN Solution

Huawei's all-optical access ADN solution addresses the challenges of intangible home broadband experience, complex home broadband experience operations, and high O&M costs. It comprises iMaster NCE, an intelligent management, control, and analysis system, and is designed for the intelligent distributed access network (FTTR/smart ONT, Digital QuickODN, and smart OLT). This solution offers the A-PRIME value framework for key roles (marketing, field engineers, call center/NOC, network departments, and end users) in broadband operations. It uses intelligent hardware and big data-based analysis capabilities to digitally model networks and user experience, offering a digital access experience platform and five scenario-based capabilities. It aims to deliver a PRIME quality experience, enable broadband quality experience operations, and help operators increase revenue, reduce OPEX, and improve user loyalty. The following figure shows the architecture of IntelligentFAN.

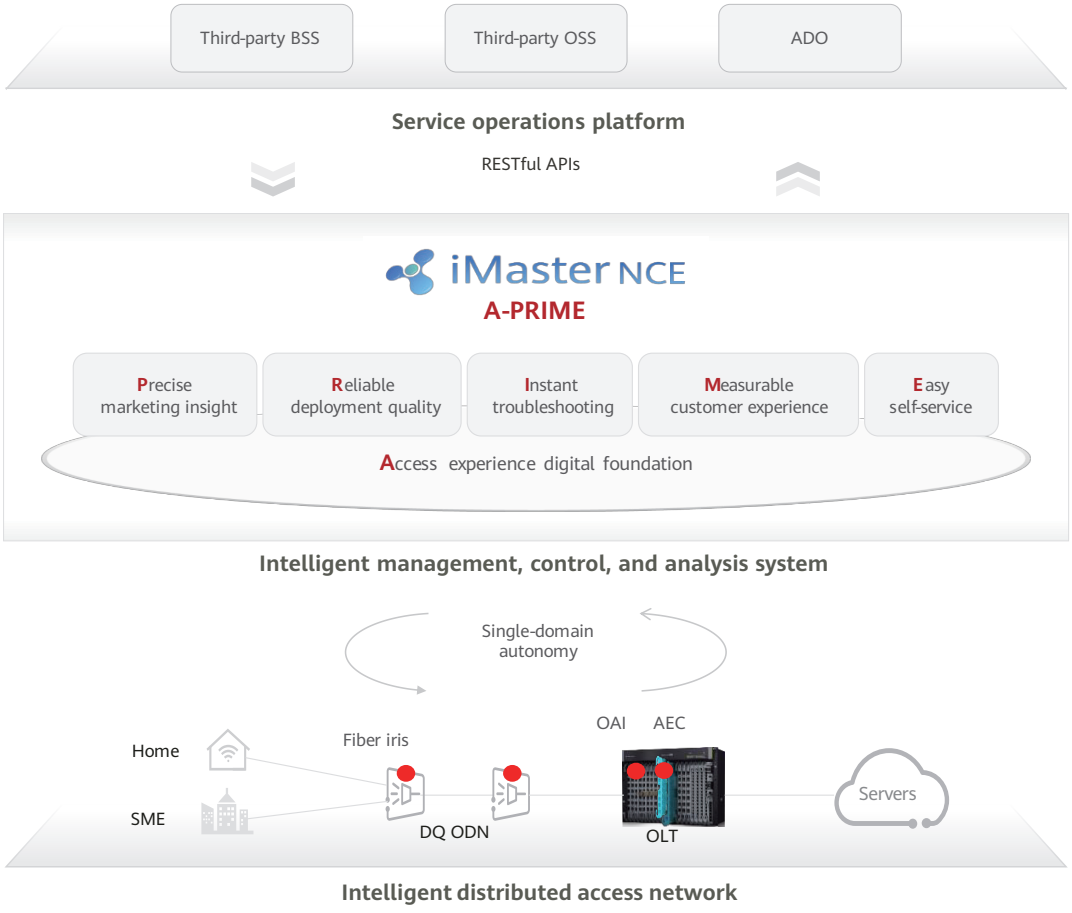



Figure 4-4 IntelligentFAN

## Highlights

- **Precise marketing insight:** The solution offers accurate insights into broadband user experience, experience bottlenecks, and networking. This enables marketing personnel to precisely identify potential users for package upgrades, home Wi-Fi networking/FTTR, and scenario-based broadband services. The solution significantly improves the marketing success rate and broadband service revenue.
- **Reliable deployment quality:** Field engineers can use the LinkHome Assistant app to complete acceptance of broadband and FTTR networking, including devices, connections, and user experience, within 5 minutes. The app generates acceptance reports, helping the engineers ensure successful deployments.
- **Instant troubleshooting:** The call center remotely performs a one-click diagnosis of common issues, segment-based speed test, STA-level application experience analysis, optimizes configurations, and quickly locates faults. This enables the NOC personnel to quickly handle issues such as low access speed, disconnection, and video freezing, reducing site visits and improving troubleshooting efficiency.
- **Measurable user experience:** Based on digital measurement scoring, ranking, diagnosis, and auxiliary optimization and rectification of network-wide broadband user experience issues, network departments can identify and resolve issues before users log complaints, maximizing user satisfaction.
- **Easy self-service:** End users can enable the youth mode and accelerate desired applications. They can independently perform speed tests and maintenance operations on the LinkHome app. This enhances user interaction and loyalty.

## Key UCs

- **ODN digital management:** Precise management of ODN dumb resources can improve the network resource utilization, one-time service provisioning success rate, and ODN management efficiency. For Huawei pre-connected ODNs, based on the code scanning and intelligent image recognition functions, the system quickly collects ODN information. It automatically restores the connection topology, implementing automatic resource input and maximizing resource accuracy. Traditional ODNs can be reconstructed to support fiber iris splitters and incorporate OAI optical intelligent test boards to implement automatic ODN topology restoration, improving resource accuracy.
- **Precise ODN troubleshooting:** Based on the OAI+fiber iris solution, the system automatically identifies optical path performance deterioration and interruption

faults, demarcates the fault scope (main optical path, branch section, or drop section), and locates faults in minutes with meter-level precision, shortening the optical path troubleshooting duration from hours to minutes.

- **Precise identification of potential home broadband users:** In the traditional mode, the marketing efficiency is low due to a lack of home broadband experience data. This function identifies potential requirements based on comprehensive and in-depth insights into broadband user experience, user experience bottlenecks, and home networking. More than 100 potential user tags are generated to help operators' marketing personnel identify potential business opportunities, including package upgrades, home Wi-Fi networking/FTTR, and scenario-based broadband services. This significantly improves the marketing success rate and home broadband revenue growth.

- **Home broadband deployment acceptance:** Field engineers perform acceptance of devices, connections, and experience (based on indicators such as rate, coverage, roaming, interference, and latency) on the LinkHome Assistant app. The app automatically generates acceptance reports to help field engineers implement standardized networking and ensure deployment success.

- **One-click fault diagnosis:** Once a call center performs one-click fault diagnosis, the system automatically analyzes network and broadband experience data to identify and diagnose potential risks. This helps the call center prevent faults from occurring. Additionally, the system supports remote optimization of Wi-Fi and software configurations.

- **Remote fault diagnosis:** It is challenging for NOC personnel to handle issues of video freezing and low access speed. This function automatically demarcates issues of low access speed in four segments (home, ODN, OLT, and bearer network and server) through segment-based speed tests. With a range of features, including as poor-QoE event identification, seconds-level data collection and analysis, playback of network KPIs and application experience data of 14 x 24 hours, and remote Wi-Fi/configuration optimization, NOC personnel can remotely and rapidly diagnose and rectify faults.

- **Home broadband CEI evaluation and optimization:** Due to the lack of effective methods, the home broadband user experience was intangible, and user experience issues were uncovered primarily based on complaints. To address this problem, this function models and analyzes issues of frame freezing, disconnection, and slow responses, performs digital evaluation, scoring, and diagnosis of network-wide user experience, proactively optimizes user experience, and resolves user experience issues. This way, the issues can be identified and resolved before users log complaints, significantly improving user satisfaction.
- **End-user self-service:** The LinkHome app allows users to manage their home networks independently. They can enable or disable the parental control and youth mode, configure a guest network, perform one-click diagnosis, speed tests, application acceleration, and view weekly experience reports. These self-service maintenance capabilities give users more control, increase user interaction, and significantly improve their network access experience.

### 4.2.4 IntelligentOTN — All-Optical Transport ADN Solution

The core components of IntelligentOTN — Huawei's all-optical transport ADN solution — comprise all-optical transport networks (such as OXC and OTN) and iMaster NCE, an intelligent management, control, and analysis system. Targeting key roles in optical networks and private line operations, including marketing, planning, network, maintenance, and IT, Huawei presents the T-AUTO framework. The solution integrates convergent awareness and big data-based intelligent analysis capabilities to abstract, model, and digitalize the physical-world optical network, building a digital twin that visualizes the optical network and services in a layered, multi-dimensional manner. The solution provides four scenario-specific capabilities: Agile Service Planning and Provisioning, Ultimate SLA Guaranteed, Time-Saving Ticket Journey, and Open to NaaS. These capabilities lay a high-efficiency and high-availability all-optical foundation and deliver premium private line service experience to various industries, helping operators increase revenue, reduce OPEX, and improve user loyalty. The following figure shows the architecture of IntelligentOTN.

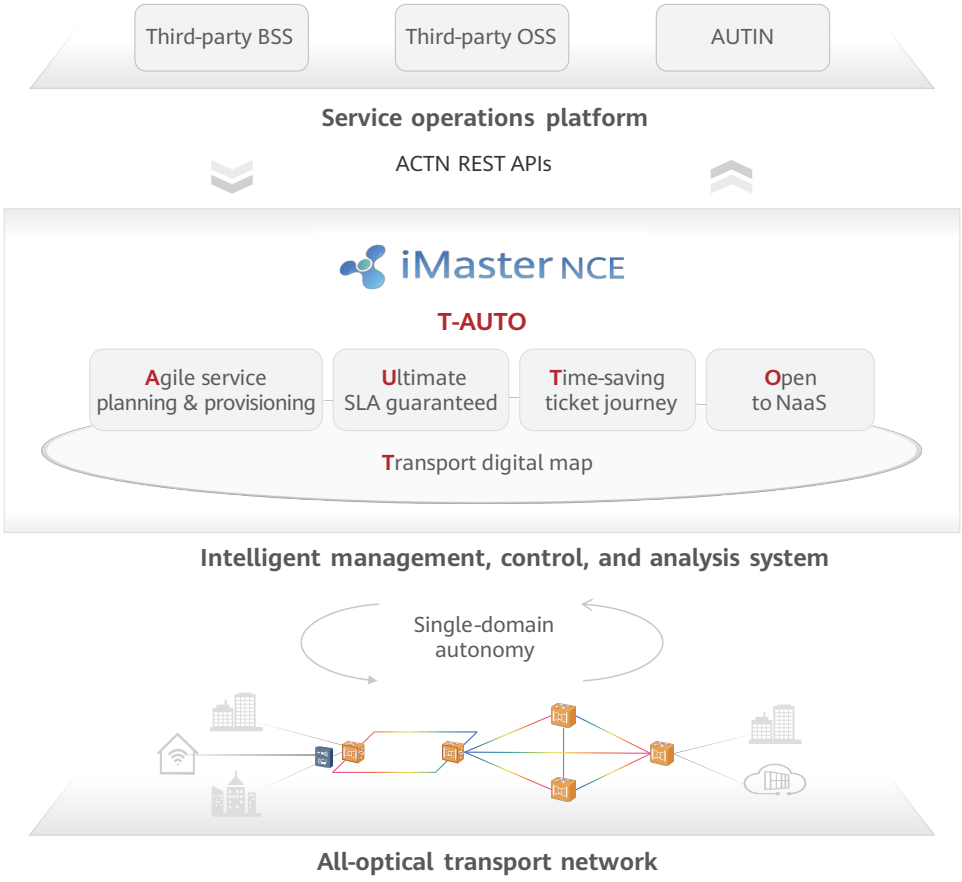



Figure 4-5 IntelligentOTN

## Key UCs

- **Online capacity expansion planning:** Traditionally, WDM OCh planning involved manually checking resources and confirming idle routes segment by segment. Offline service planning and manual deployment and commissioning made the entire process inefficient. The planning, engineering deployment, and live-network data were scattered and could not be automatically synchronized, leading to data conflicts and planning rework. The online capacity expansion planning function provides planning, engineering deployment, and live-network data with the same source. It supports minute-level E2E automatic resource check, online planning and design, and automatic OCh configuration. This eliminates resource errors and planning rework and reduces the planning and deployment duration from weeks to hours.

- **Multi-dimensional service recommendation:** This function meets differentiated SLA (bandwidth, latency, and availability) requirements across industries, including DCI, enterprise interconnection, enterprise service

cloudification, and computing. Based on the optical network digital map and Huawei's path computation algorithm StellarGo, multi-factor intelligent path computation and automatic recommendation of optimal service routes are performed to meet scenario-and customer-specific SLA requirements, enabling one network for multiple services.

- **Agile service provisioning:** E2E automatic path computation and provisioning based on SLA requirements are supported for all services (including Client, EoO, EoS, SDH, and MPLS-TP). Additionally, CPE plug-and-play implements automatic CPE go-online, automatic configuration, and remote acceptance, reducing the number of site visits required for CPE installation and deployment from 3 to 1.

- **Service SLA analysis:** Visualized playback and intelligent diagnosis and analysis are supported for service performance indicators (such as latency, bandwidth utilization, rate, jitter, packet loss rate/bit error rate, and availability) and service quality problems (such as interruptions, intermittent disconnections, SLA deterioration, protection degradation, and risks). This implements proactive O&M of private line services, ensures quality, provides SLA assurance, and improves customer satisfaction.

- **Optical network latency assurance:** Traditionally, latency in private line services was immeasurable. A microsecond-level, real-time, and dynamic network-level latency map makes private line latency perceivable and accurately measurable. Similar to map navigation apps, the latency map allows operator marketing personnel to evaluate the latency and bandwidth between sites or services and quickly find network resources to meet customer-specific SLA requirements for private line services. In addition, online evaluation of three-level latency coverage, latency matrix of primary/backup paths between cities or computing nodes, and latency detour analysis help proactively optimize latency in detour scenarios.

- **Optical network availability assurance:** Availability is guaranteed at the network and service layers. At the network layer, multi-dimensional visualization of NEs, wavelength, and fiber availability as well as automatic analysis and identification of network availability risks are supported. Optimization recommendations are provided to build highly reliable networks. At the service layer, statistics on the availability of services on the live network are automatically collected. Additionally, dynamic risks are simulated and evaluated in real time to identify potential service availability risks and provide optimization recommendations, facilitating proactive optimization of service availability and preventing customer complaints.

- **Alarm RCA:** Alarm filtering, aggregation, and root cause identification are used to intelligently compress alarms and identify root alarms from a massive number of

alarms with an identification accuracy higher than 95%. This significantly improves fault identification efficiency.

- **Intelligent fault diagnosis:** Based on the built-in eOTDR and convergent inference algorithm, the root causes of optical path faults are automatically located. Rectification suggestions help reduce the fault-locating duration from hours to minutes. In addition, hardware faults such as board, module, fan, and power supply faults can be automatically located to the unique physical fault source, improving troubleshooting efficiency.
- **REST NBI:** Designed for the IT integration department, the ACTN REST NBI exposes network capabilities, inherits the functions of the legacy CORBA and XML NBIs, and supports scenario-specific (such as E2E fault and service scenarios) northbound interfaces. This simplifies integration with the OSSs and BSSs, reduces the time required for integration, accelerates new service rollouts and closed-loop O&M automation, and protects investments.

### 4.2.5 IntelligentWAN — IP ADN Solution

Huawei's IP ADN solution comprises several essential components, including intelligent IP network routers like NetEngine, NE, ATN, and CX series and an intelligent network management and control system called iMaster NCE. iMaster NCE offers a path computation engine, intelligent O&M, and open programmability to implement full-lifecycle automatic scheduling of network traffic, helping operators build leading next-generation E2E intelligent IP networks.

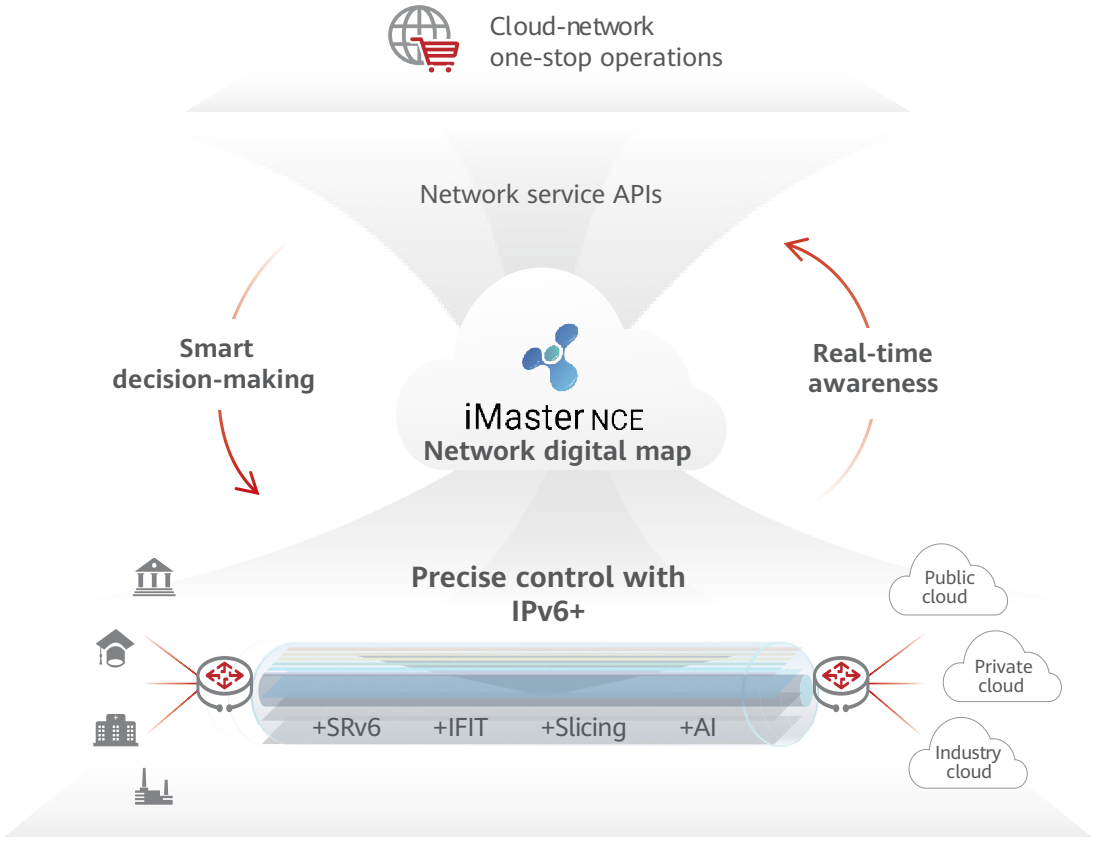



Figure 4-6 IntelligentWAN

## Highlights

**The "One NET one MAP" approach helps build "highly stable and reliable" and "elastic and ultra-broadband" IP networks for the intelligent era.**

**1. Building a highly stable and reliable IP network**

- **[N] No Configuration Error:** High-precision network simulation detects incorrect configurations in advance.
- **[E] Efficient Fault Removal:** Full-service real-time monitoring automatically rectifies "silent" packet loss faults.
- **[T] Traffic Congestion Free:** Automatic optimization covers all network traffic congestion scenarios, eliminating human intervention.

**2. Building an elastic ultra-broadband IP network**

- **[M] MUX Digital Express:** With multiple ultra-large bandwidth channels working in

full-duplex mode, it takes just hours to transmit TB-level data.

- **[A] Application-Level Elastic Guarantee:** Regarding application assurance, connections are established in seconds whenever calls are made. This is referred to as application-driven on-demand network assurance.

- **[P] Premium Deterministic Experience:** Milliseconds-level latency commitments can be fulfilled to ensure a high-quality service experience.

## Key UCs

- **Network Digital Map:** collects real-time data on physical resources, slices, tunnels, routes, VPN services, and applications on multi-vendor devices by using standard protocols such as BGP-LS and BMP. The map's distributed network performance collection framework provides real-time multidimensional indicators of ultra-large networks, including latency, bandwidth, packet loss, and power consumption. Network Digital Map functions like a navigation map, providing a holographic visualization of the entire network. This helps customers obtain a clear view of the network and identify service detours and other problems. Network Digital Map also uses an intelligent cloud-map algorithm that considers 20+ factors and computes optimal paths based on service intents in just a few seconds. Network Digital Map detects poor service quality in seconds, locates root causes in minutes, and rapidly completes automatic optimization to meet differentiated SLA assurance requirements.

- **Network Configuration Verification:** takes configuration changes, interconnecting routes, and traffic of network devices as inputs to simulate not only the statuses and behaviors of network protocols and traffic, but the routing and forwarding tables of network devices, thus providing an authentic and objective basis for assessing the risks associated with network changes. Based on the routing tables, forwarding tables, and traffic loads of devices, control plane verification/data plane verification (CPV/DPV) is conducted to assess network risks according to specific rules. CPV can formally solve and verify changes in the number of control plane routes (sudden surges and drops), route reachability, and route reliability (blackholes and loops). DPV can formally solve and verify network forwarding plane paths. These two verification techniques complement each other to identify potential risks from network configuration changes and detect incorrect configurations. By verifying the impact of network configurations in advance and preventing incorrect configurations from being applied, Network Configuration Verification makes configuration a worry-free task.

- **Digital Express:** builds an open, programmable, high-performance, high-reliability automation engine using YANG models. The engine makes programming as easy as stacking toy blocks,

allowing operators to quickly develop and roll out new services. As a result, the agile development objectives of prototyping in 1 week, providing a proof of concept (POC) in 1 month, and enabling commercial use in 1 quarter can be easily achieved. With built-in decomposition, orchestration, computing, and backtracking algorithms, the EasyMapping framework automatically decomposes network services into NE configurations and maps them to NE-level atomic APIs. In this way, E2E service provisioning is fully automated and takes only minutes to complete. The automation engine enables fast service provisioning on multi-vendor networks and addresses service automation challenges. It increases the efficiency of adapting to new devices by 90%, shortening the device adaptation and management periods from months to days. The rollout periods for new services are reduced by 80%, from 6–9 months to 1 month.

- **BGP Routing Analysis:** obtains BGP peer relationships and statuses in real time using BMP, and collects the Adj-RIB-In, Adj-RIB-Out, and the Loc-RIB routes of BGP peers to display statistics on BGP peers and their routes. When monitoring full BGP routes and key BGP routes, BGP Routing Analysis collects, analyzes, and displays route changes (including routing prefix advertisement/withdrawal and changes in route AS paths and source ASs) on each BGP peer in both temporal and spatial dimensions so as to detect route hijacks, route leaks, and other anomalies and report corresponding alarms. Regarding key routes, it collects real-time performance indicators such as reachability and latency and replays route path changes to facilitate quick detection and rectification of BGP route anomalies.

- **Network Congestion Analysis:** displays the distribution of traffic suppression on a heatmap, visualizes network congestion points, analyzes high-value areas on priority, drills down to the suppressed base stations, and provides precise capacity expansion suggestions. TWAMP and IFIT are employed to measure base station SLAs. Based on packet loss rates and actual traffic, Network Congestion Analysis calculates the suppressed traffic on base stations and determines whether the base stations are experiencing poor-QoS issues. The suppressed traffic is then visualized for the entire network and individual areas. Network Congestion Analysis also displays the packet loss distribution of base station services, restores the hop-by-hop path for individual base station services based on different time points, and analyzes the impact of link SLAs and bandwidth on packet loss to implement accurate fault demarcation and locating.

- **Intelligent Incident Analysis:** clusters network events/alarms and performs association analysis to reduce redundant alarms and tickets, consequently reducing O&M costs. Based on time or topology, the events/alarms triggered by the same fault are clustered as one incident to easily identify the root cause. The "one incident, one ticket" approach eliminates unnecessary tickets from being dispatched. Event/Alarm clustering and root cause identification are based on massive O&M data, extensive expert knowledge, and

AI algorithms. They can be automatically performed without experts (even for faults that are difficult to handle manually) and facilitate comprehensive and quick troubleshooting.

- **Intelligent Network Optimization:** uses BGP-LS to quickly detect network topology changes, including node and link faults and link bandwidth and latency changes. Intelligent Network Optimization combines IFIT with telemetry (seconds-level reporting mechanism) to accurately detect service SLAs and display network and service quality by layer. In the case of service quality deterioration, IFIT automatically starts hop-by-hop detection to identify poor-QoS points in service forwarding paths. The fault demarcation and location results are visualized in the network topology. If poor-QoS service SLAs are detected, the multi-factor cloud-map algorithm recomputes and re-optimizes network paths using technologies such as SR-TE and SR Policy. The new paths bypass the poor-QoS points, providing continued assurance for service SLAs.

- **Energy Saving:** provides an energy monitoring dashboard to display multidimensional power consumption data at the network and NE levels. Analyzing power consumption data from different dimensions, Energy Saving helps network departments demarcate and locate power consumption issues. In addition, its ability to forecast the benefits of energy-saving devices makes it easier to leverage the energy-saving potential of network devices, supporting the formulation of energy-saving policies based on statistics. With actual energy savings data collected from network devices, Energy Saving outputs a device-specific energy-saving benefit curve. History comparison ensures that the energy-saving benefits are evaluable and that energy-saving performance is quantifiable. Real-time visibility into the energy-saving status of network-wide resources and the forecast of energy-saving benefits help quickly identify the resources with the highest energy-saving benefits, enabling users to efficiently formulate energy-saving policies. Additionally, network-level energy-saving policy deployment using NETCONF/YANG and batch enablement of energy saving in a single click enable energy-saving policies to be delivered and applied seamlessly. The energy-saving statuses of devices are updated in real time.

### 4.2.6 IntelligentCampusNetwork — Enterprise Campus ADN

In Huawei's ADN solution for campuses, Huawei iMaster NCE leverages a four-dimensional network digital map that associates people, events, things, and networks. By doing so, iMaster NCE provides a network management platform that integrates management, control, and analysis functions for all scenarios, including the enterprise headquarters campus, production campus, and branch office spaces. This solution delivers full-lifecycle automated network management and intelligent O&M services.

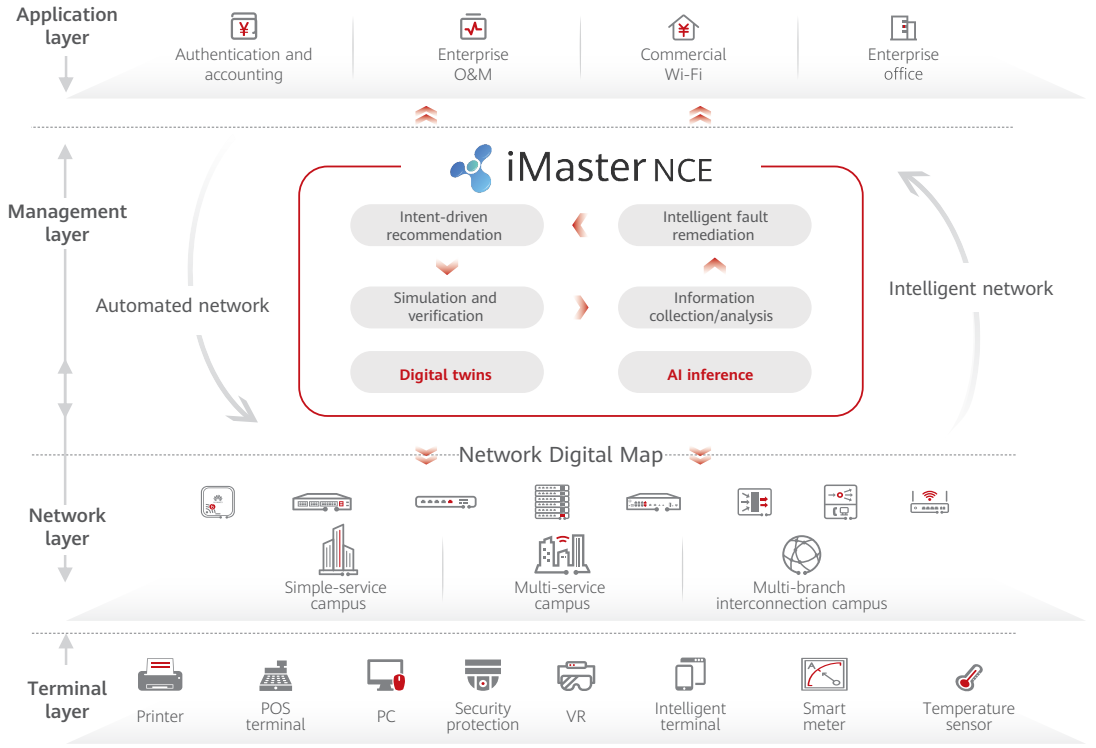



Figure 4-7 IntelligentCampusNetwork

## Highlights

- **Zero-wait:** With the network digital map, network management is automated, no longer relying on expert experience. This ensures zero wait time for network provisioning and reduces OPEX by 85%.
- **Zero-touch:** On traditional networks, terminal access needs to be manually controlled. In contrast, Huawei's ADN supports automatic terminal access, achieving seamless access and secure management in seconds.

- **Zero-interruption:** In terms of network O&M, passive response is transformed into automatic application experience optimizations in minutes and without service interruptions.

## Key UCs

- **Intent-driven deployment:** Using the scenario knowledge base and a collaborative recommendation algorithm, iMaster NCE accurately maps service scenarios with networking models and recommends the optimal network solutions by analyzing service intents. In this way, networks can be provisioned in minutes, without the need for deployment personnel.

- **Network digital map:** The digital map intuitively displays the network experience through four dimensions (NE, user, terminal, and application) and proactively analyzes over 200 typical issues. This facilitates one-click root cause locating and minimizes manual analysis and maintenance.

- **Intelligent verification:** iMaster NCE is much faster than conventional solutions at verifying network changes. Normally, a change takes just 10 minutes, but verification lasts for 4 hours; insufficient verifications could lead to many complaints. With iMaster NCE, verification takes just minutes and assures changes without errors.

- **Free mobility:** In Huawei's ADN solution for campuses, free mobility is orchestrated using natural language, achieving matrix-based simplified management, cross-vendor deployment through IP-security group mapping, and one-off policy configuration. This delivers a consistent service experience to users no matter where they are using all-wireless campus networks.

- **Intelligent terminal management:** iMaster NCE supports intelligent terminal management. It features a terminal fingerprint database along with innovative application AI clustering identification capabilities. These allow iMaster NCE to accurately identify networked terminals (≥ 98% of known types and ≥ 95% of unknown types), allocate them with the correct networks, and prevent access by spoofed terminals. This reduces manual intervention and assures secure access.

- **Application and VIP user assurance:** The digital map and in-band flow measurement functions comprehensively measure the experience of key applications, spanning the wireless air interface and wired network. They can also rapidly demarcate and locate faults based on the time and space dimensions and perform intelligent optimization in real time. This ensures the ultimate experience for applications and VIP users and improves network performance by 58%.

### 4.2.7 IntelligentFabric — Data Center ADN Solution

Huawei's Data Center ADN Solution is built on CloudEngine data center switches and iMaster NCE — an ADN management and control system. It implements an all-IP architecture for computing, storage, and service networks, delivering consistent network experience. The solution also supports IPv6 and is the first to offer L4 ADN capabilities. And with support for full-lifecycle automation and network-wide intelligent O&M of DCNs, this sophisticated solution reduces the operational expenditure (OPEX) by 30% and enables intelligent upgrade of enterprises.

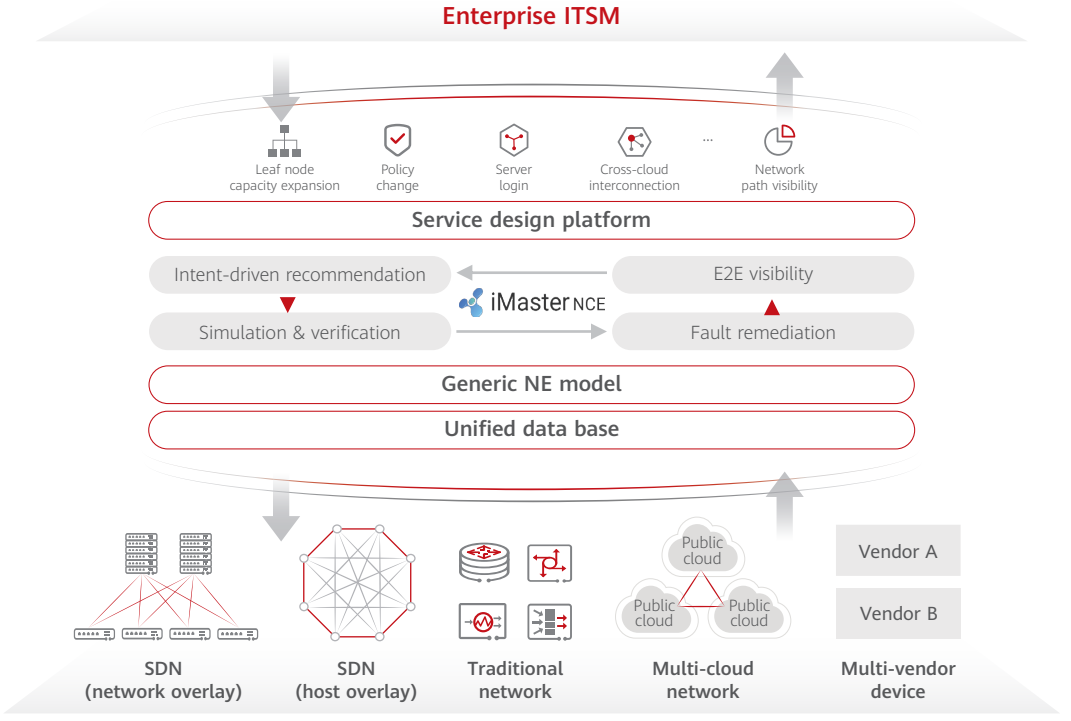



Figure 4-8 IntelligentFabric

## Highlights

- **Zero-wait:** The service deployment and rollout time is slashed to minutes, greatly reducing the O&M workload and improving the O&M efficiency.
- **Zero-error:** Evaluating network change risks helps prevent faults caused by manual errors for maximized productivity.
- **Zero-interruption:** Network trend prediction prevents network quality deterioration and

failures, minimizing the possibility of faults. Even though a fault occurs, it can be quickly and accurately demarcated and located.

## Key UCs

- **Intent-driven planning and deployment:** By understanding and translating customers' service and network intents, iMaster NCE automatically selects the optimal network deployment solution, enabling E2E automated service provisioning and automated closed-loop management of intents throughout the lifecycle.
- **Network change simulation and evaluation:** Based on the device configuration, topology, and resource information on the live network, iMaster NCE uses network modeling and formal verification algorithms to evaluate network change risks and eliminate design logic defects and configuration errors, thereby ensuring 100% configuration correctness.
- **"1-3-5" intelligent O&M:** Telemetry technology is used to collect network performance data and comprehensively evaluate network health based on service experience to proactively identify more than 60 potential risks and over 90 typical faults within 1 minute. Based on knowledge graphs and Huawei's unique AI algorithms, fault aggregation and source tracing are performed, locating root causes within 3 minutes. And thanks to the intelligent decision-making system, the impact of faults is analyzed and the optimal remediation solution is recommended, rectifying typical faults within 5 minutes.
- **Open industry ecosystem:** Huawei's ADN is seamlessly integrated into enterprises' O&M systems, becoming a key part of the O&M process. This helps achieve automated closed-loop management on the entire data center network. In the northbound direction, iMaster NCE uses the runbook service designer to flexibly orchestrate service flows and seamlessly interconnect with enterprises' O&M systems. In the southbound direction, AOC — Huawei's open programmability platform — implements fast adaptation of devices from multiple vendors, achieving automated provisioning of heterogeneous multi-vendor and multi-cloud networks in minutes. On top of that, full open network data services facilitate integration with the service performance monitoring system, implementing unified O&M of services and networks.
- **Diversified computing network acceleration:** The network scale load balancing (NSLB) algorithm performs global path calculation and identifies the optimal path based on the traffic congestion status of network-wide switches as well as the network topology to assign paths for computing tasks. This eliminates path conflicts, maximizes the throughput of diversified computing networks (including general-purpose computing, storage, and AI computing networks), and improves the foundation model training efficiency by 20%.

- **Unified O&M of applications and networks:** The xFlow intelligent full-flow analysis solution offers full-path, full-flow, and full-packet application analysis capabilities across DCs, vendors, fabrics, and heterogeneous networks. Leveraging technological innovations such as the digital twins of applications and networks, the solution provides more than six key technologies, such as network-wide application exchange relationship sorting, application performance profiling and exception detection, real flow-based full-path restoration in DCs, intelligent demarcation of application faults, hop-by-hop network node troubleshooting, and unified root cause tracing for applications and networks. All of these combine to enable one-click diagnosis of service faults, rapid fault locating and demarcation in minutes, and real-time quality awareness for key applications.
- **FinOps:** By introducing the cost concept into the network domain, the solution offers digital support for fine-tuned operation management from the network perspective, as well as assisting cost accounting, investment decision-making, cost reduction, and efficiency improvement for better operations. In addition, the solution can intelligently detect the utilization of network-wide infrastructure resources and analyze whether the service resource utilization is high or low based on a resource heat map, helping to assist decision-making of service scaling. It also recommends solutions, automatically executes service changes, and completes service configuration and deployment with just one click.

### 4.2.8 IntelligentServiceEngine — Intelligent O&M Solution

The fast-paced growth of 5G networks and home broadband (HBB) services have resulted in large and complex networks and a diverse range of emerging services. This has presented many challenges for operators regarding cost, efficiency, quality, and talent development. As a result, operators are exploring and implementing digital intelligence transformation of operations to improve efficiency, enhance customer experience, and add value to operations. Huawei offers a comprehensive cross-domain collaborative intelligent O&M solution, which includes AUTIN, SmartCare, and ADO.

#### AUTIN: Intelligent O&M

AUTIN, Huawei's intelligent O&M solution, meets three key O&M requirements: quality improvement, efficiency improvement, and talent development. The solution enables operators to

quickly implement digital intelligence transformation on their journey toward Zero-X network O&M.

- **Quality improvement:** In 5GC scenarios, major faults have a significant impact, and fault demarcation and troubleshooting can be time-consuming. Huawei AUTIN intelligently predicts service impacts and risks and automatically diagnoses faults within minutes, significantly reducing the mean time to repair (MTTR).

- **Efficiency improvement:** Over 70% of daily operations in a network operations center (NOC) are repetitive, inefficient, and depend heavily on expertise. Huawei AUTIN helps NOCs streamline operations through integrated, automated monitoring and maintenance, intelligent diagnosis, and closed-loop management of onsite operations via mobile devices without relying on external assistance. This enables automatic diagnosis and closed-loop management of faults, reducing the number of tickets per network element (NE) and significantly improving operational efficiency.

- **O&M talent upskilling:** As O&M operations become increasingly automated, O&M personnel must upgrade their skills to keep up with the changing landscape. Huawei's open platform and abundant O&M knowledge assets enable orchestratable, low-code O&M application development, simplifying O&M talent upskilling. The systematic Accompanying Service and enablement service for talent upskilling are provided to shorten the O&M application development period from months to weeks. AUTIN continuously integrates expertise and iteratively optimizes domain-specific automated, digital, intelligent engines to improve its level of automation and intelligence.

## SmartCare: Ultimate Experience

The SmartCare service experience solution is designed to enhance the net promoter score (NPS) and decrease the number of complaints per 10,000 users on operators' networks. It builds an intelligent data engine with the convergent data capability and offers operator-focused experience management service solutions that encompass all aspects of their business. This enables operators to shift from network-centric to customer-centric digital operations transformation, thereby enhancing the value of customer journeys throughout their full lifecycle.

**Three collaborations for further improving user experience and helping operators monetize their data value:**

- **Experience-optimization collaboration:** Using advanced geographic technologies at the POI, grid, and 3D building levels, SmartCare leverages experience and performance data to establish user experience standards towards future ADNs with the collaboration between experience and optimization. It offers precise visualization and management of service quality, accurate fault demarcation, and troubleshooting capabilities. These features enhance the NPS on operators' networks.

- **Experience-O&M collaboration:** Service experience management enables the transformation of network operators from Network Operations Centers (NOC) to Service Operations Centers (SOC). This transformation allows collaboration between experience and O&M, streamlining the user experience and fault-handling flows. The collaboration facilitates efficient identification and quick resolution of network quality issues, ultimately improving network NPS.

  SmartCare provides E2E service capabilities from complaint prediction and prevention to quick complaint resolution. It achieves this through AI-based quality detractor analysis and automatic massive fault identification before complaint filing and automatic fault analysis with a fault tree that associates multiple data sources in different domains during complaint handling, helping operators decrease the number of complaints per 10,000 users.

- **Experience-business collaboration:** SmartCare enhances the collaboration between experience and business by creating accurate and adaptable AI big data models using data from OSS, BSS, and Social domains. This improves the marketing success rate of mobile operators and helps them monetize their network products. For instance, during live-streaming events featuring internet celebrities, SmartCare accelerates user acquisition.

**Service experience DataOps capability:**

- **One-stop data integration, development, governance, and visualization:** The low-code tool chain lowers the threshold for data asset development and data consumption, integrates service experience data with wireless and BSS data, offers cross-domain Data DevOps capabilities, and supports quick and low-cost customized development and rollouts across multiple business scenarios.

- **Various threshold data model assets for multi-scenario business analysis and agile development of report preparation:** SmartCare provides metadata-driven solutions for data management, data quality management, data lifecycle management, and data security management, facilitating transparent, high-quality, efficient, secure, and open domain data implementation.

## ADO Premium Home Broadband

The ADO Premium Home Broadband solution is designed to enhance users' internet access quality and satisfaction, with a focus on two key scenarios: improving home broadband (HBB) internet access quality and acquiring new users.

Proactive optimization helps operators accurately identify users experiencing poor quality of experience (QoE) and resolve issues related to the home, network, and resources. This helps to improve network quality, reduce the number of poor-QoE users, and enhance overall customer satisfaction. The solution provides the following actions to resolve poor-QoE issues:

- Perform poor-QoE modeling based on minute-level, user-level, and app-level experience data to implement poor-QoE awareness and identify users with poor Internet access experience.
- Based on experience data and PON NMS performance and alarm data, analyze the root causes of poor-QoE issues, demarcate and locate device-pipe-cloud faults segment by segment, and diagnose poor-QoE issues.
- Contact poor-QoE users by phone to proactively inform them of the status and dispatch work orders to rectify the issues onsite.
- Achieve poor-QoE closed-loop through auxiliary operations and trace the effect of poor-QoE issue rectification.

The solution uses OSS and BSS data to support potential user identification and smart marketing, helping implement value-added operations and increase revenue.

To identify potential high-value users, such as gigabit and FTTR users, and increase ARPU, the solution can leverage OSS data for modeling and analysis. This helps to identify users with poor QoE, strong broadband requirements, and a high willingness to upgrade their bandwidth. By improving the accuracy of identifying potential users and increasing the success rate of marketing efforts, the solution can effectively explore and target these valuable user segments.

# 05

# Prospects and Suggestions

We are on the cusp of an intelligence era with all things connected and intelligent. This also poses higher requirements on network management. We are seeing exponential growth in service diversity, network scale, O&M complexity, and network energy consumption, yet the number of O&M personnel of operators hardly increases at all. To address these challenges, we urgently need to systematically introduce AI to the communications network and gradually build a self-configuration, self-healing, and self-optimizing AN based on the closed-loop control and knowledge management of network digital twins. In addition, by building digital employees in the communications field and reconstructing the O&M mode, we can systematically improve the productivity of the communications industry.

Standards and industry organizations, operators, suppliers, research institutes, and industry management departments need to work together to evolve towards High Autonomous Networks. In this regard, we propose to:

**Accelerate the definition of industry generations.** We are looking forward to working closely with all industry partners to define the L4 objectives and clarify the AN level characteristics and key experience indexes (KEIs) to guide the industry development.

**Accelerate the development of industry standards.** Alongside all industry players, we jointly promote the development of L4 AN standards, define high-level capability interfaces, and promote efficient industry collaboration.

**Accelerate technological breakthroughs in the industry.** We recommend that all industry partners work together to promote the breakthroughs in core AN technologies, such as converged sensing, digital twin, foundation model, and intelligent decision-making to advance technologies in the AN industry.

**Accelerate industry innovation practices.** We recommend that all industry partners explore the commercial application scenarios of L4 AN, focus on value creation, and carry out E2E innovation to expedite the closure of business value.

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