HUAWEI

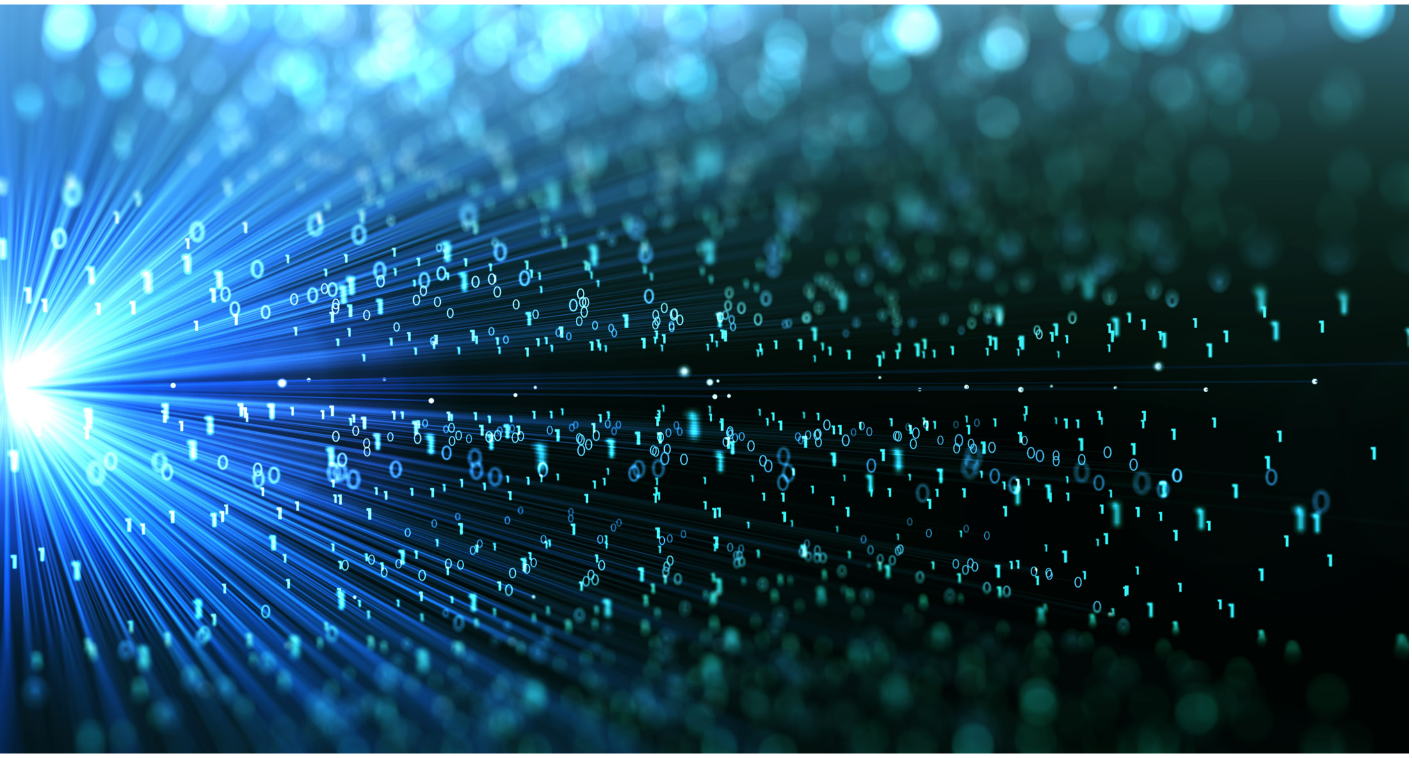
Huawei
Intent-Driven Network
White Paper

CONTEBTS

Introduction

After more than 30 years of development, the telecom network has laid a solid network connection foundation for the future intelligent society. According to Huawei Global Industry Vision (GIV), by 2025 the number of global connections will reach 100 billion, the Internet will cover 77% of the population, broadband will be used as infrastructure to reach 75% of families and mobile communications will cover 80% of the population. The enterprise digitalization process is accelerating. According to Gartner's analysis report, 83% of enterprises will start or complete the digitalization process by the end of 2019.

Global operators, large and small, realize that end users are pursuing better service experience. They hope that services can be quickly provisioned, network faults can be rectified in a timely manner, and service quality can be guaranteed in an end-to-end manner. Therefore, they raise more explicit requirements for the intelligent operations of networks. Currently, the device-centric network O&M mode is difficult to support. Only a user-experience-centric network can effectively meet end users' experience requirements and support operators' business success. Thanks to the innovative advancement of cloud computing, big data, and artificial intelligence technologies, Huawei launches the Intent-Driven Network (IDN) solution to deliver full closed-loop automation and network intelligence, and at the same time, forming the foundational element toward the autonomous driving network in reach. This solution is driven by the users' business logic and service policy intent, builds a digital twin world between physical networks and business intent, and a user-experience-centric network based on intelligence, simplicity, ultra-broadband, security, and openness, and maximizes business value.



01 There Is an Urgent Need for Architecture Innovation to Cope with Structural Issues Facing Telecom Networks

The intelligence era, especially the rise of 5G and cloud, brings structural challenges to telecom networks. First, 5G will not only enable traditional 2C services, but also provide private line and home broadband services for 2B and 2H respectively. Therefore, 5G will bring about 100 times of connection growth and low latency requirements for networks. In addition, the control plane and user plane are separated on the 5G network, and the user plane is moved downwards, leading to the requirements of multi-level DC networking. 5G will increase the bandwidth 10 fold in the new 3.5GHz+mmWave spectrum. The exponential growth of 5G network scale and service complexity will make network O&M more complex. In addition to 5G, 4K/8K/VR video services drive CDN to the network edge and CO cloud convergence, and migrate enterprise applications and services onto the cloud. Both need to build a DC-centric simplified network. These structural issues need to be dealt with using architectural innovation.

1.1 Explosive Traffic Growth Requires Optimal Network Cost per Bit

With the wide use of emerging services such as 4K/8K, ultra-HD video, and VR, the data traffic of the entire communication network increases 10 fold every 5 years. In the 5G era, Internet of Everything (IoT) will increase the traffic by 6.7 times. It is estimated that by 2022, there will be more than 6 billion smartphones worldwide, and the monthly traffic per person will exceed 12 GB. In the face of such explosive traffic growth, maintaining the network construction cost per bit to a reasonable level is the first issue that each operator faces.

1.2 Increasing Complexity of Telecom Networks Leads to Low O&M Efficiency and Increasing OPEX

The current operator network relies heavily on human expertise and skills. An operator needs 384 individuals to operate and maintain a network with 10,000 devices, while OTT O&M only requires 249 individuals to maintain a network with 1 million devices. The high efficiency of OTT vendors is related to the advanced network design. However, telecom networks are becoming increasingly complex due to historical causes. In the 5G and cloud era, the network scale has increased tenfold. Future services and the necessary network traffic are uncertain, and beyond the professional knowledge and capabilities of individuals. As a result, 70% of major network faults are caused by human factors. In the future, a large number of real-time services are more difficult to human response, and must be implemented by machines. The chief wireless architect of an operator in Canada says, mechanical manufacturing has been automated, but the telecom industry is still in the phase of manual operation.

All these issues have led to OPEX increases year-over-year. The revenue growth of the telecom industry between 2005 and 2016 has not outrun the OPEX, but the CAPEX has decreased from 17% to 12% in the past 10 years. Considering that the OPEX accounts for more than 70% of an operator's revenue, there are few opportunities for TCO optimization unless structural optimization is performed first.

1.3 Passive Management of the Customer Experience Needs to Be Improved in the Experience Era

The telecom service experience is invisible, and the operation process does not have full lifecycle management based on user experience. As a result, the current user experience management is driven by a user complaint initiated system. In addition, the private line SLA is invisible and difficult to manage. In the tender documents for a financial customer, the requirements for an operator's private lines are as follows: The monthly rental is reduced by 25% each time services are interrupted for 2 minutes, and it is decreased to 0 when the accumulated service interruption duration is 8 minutes or more. An operator in the UK was fined £50 million each year because the SLA of the private line does not meet the commitments made to the enterprise customer.

It should be emphasized that, to solve the structural issues faced by telecom networks, product innovation is not enough. Innovation of the entire system architecture and business model is necessary to solve the structural issues and improve the competitiveness of operators.

02 Learning from the Advanced Experience of Other Industries and Thinking About the Key to the Structural Issues

2.1 OTT Industry: Modular Simplified Network, High Automation, and Closed-loop Operation Centered on User Experience

Agility and good experience have always been the competitiveness of OTT. The root cause is that OTT network construction has no historical burdens. In the first place, all-IP networks and centralized O&M are used, which focuses on modularization, standardization, and automation. Even if OTT services and networks are rapidly expanding, the total number of O&M personnel is small and the efficiency is high. Therefore, OTT can quickly respond to user requirements and provide high-quality services and products.

2.2 Manufacturing Industry: Digital Twin Construction, Data Driven, and AI Enablement

Industry 4.0 has three characteristics to support product automation: agile equipment, intelligent control, and intelligent analysis systems. These three characteristics are also suitable for the telecom industry. In addition, the manufacturing industry first proposed the concept of Digital Twin, using data drive and AI to realize intelligent manufacturing throughout the lifecycle.

2.3 Automobile Industry: Standard Definition and Industry Collaboration

Through industry collaboration, the industry standards of five-level autonomous driving are defined. Through the industry's most influential organizations, high-level planning and system design are performed from multiple dimensions, such as policies, laws, regulations, roads, vehicles, and operation and maintenance, to propel automatic driving into accelerated development. For example, Society of Automotive Engineers (SAE) International released a six-grade autonomous driving classification system in 2014, and the National Highway Traffic Safety Administration (NHTSA) began to follow SAE classification standards in 2016.

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To sum up, the simplified architecture, closed-loop automation, data drive, AI enablement, and industry collaboration are key enlightenments for telecom networks. Huawei has proposed the vision and goal of the telecom networks towards automatic driving. Unlike autonomous driving in the automobile industry, the telecom industry has its unique complexity: A telecom network carries multiple services such as mobile, home broadband, and enterprise services. The autonomous driving system needs to accurately understand the differentiated intents of services and adapt to different operating environments (road conditions), such as data center "high ways" and broadband access "country roads". The autonomous driving system also needs to adapt to different stages throughout the operation lifecycle, such as planning, O&M, and service provisioning. Therefore, the evolution of the autonomous driving network needs to be gradually promoted based on scenarios and complies with the three principles: (1) Consider the main conflicts of the network. OPEX. (2) Gradually form a closed-loop system from a single domain to multiple domains. (3) Build a unified data model and sharing capability from top to bottom based on service experience.

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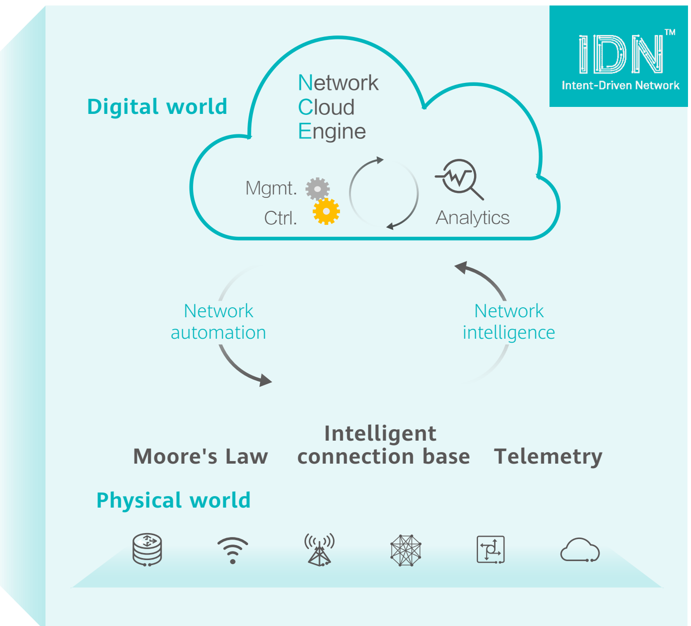
03 Solution: Constructing a Digital World on the Physical Network to Implement Digital Transformation Based on User Experience

Requirements

- **Intelligent O&M**
  Automation in the full life cycle
  SLA assurance
  Predictive maintenance
- **Intelligent connection**
  Massive connections
  Super large networking
  Cross-domain one-hop access to the cloud
- **Ultra-large capacity**
  10 times bandwidth and
  100 times connections



对策

- **Smart brain of the network**
  Integration of management, control, and analysis
- **Intelligent connection base**
  New-generation simplified protocol stack
- **Moore's Law**
  Non-blocking network
  Simplified physical network

The structure of telecom networks has become the biggest bottleneck that restricts the development of the telecom industry. We can solve this problem by constructing a digital world on the physical network, and by systematically building a new generation network architecture centered on user experience, driven by business logic and the service intent of users.

The network architecture innovation mode of Internet enterprises is of great significance to telecom networks. The core competitiveness of Internet enterprises lies in user-experience-centric operation, highly automated O&M, simplified network architecture, and the latest technologies. These advantages enable Internet enterprises to effectively ensure user experience.

For the telecom industry, the construction of the digital world is the key to improving user experience. By building a digital world between physical networks and business intent, Huawei IDN empowers operators to transform their past discrete network architectures into user experience-centric ones.

The digital world builds a smart brain that integrates management, control, and analysis for physical networks to implement full-lifecycle automation and intelligent O&M based on AI. The digital world creates a close-loop automation system to accurately identify users' business intent and closed loops. Driven by data, building digital twins, and introducing AI, Huawei IDN solution implements proactive O&M, performs predictive analysis, identifies network faults in advance, proactively optimizes networks, and closes loops based on commercial intent.

Physical networks need continuous innovation to lay the foundation for the digital world. The innovation of physical networks will focus on two dimensions: Moore's Law and simplified architecture. Moore's Law drives continuous improvement of bandwidth capabilities of IP networks and promotes continuous network innovation. The Fabric network architecture separates network services from the bearer network to reduce the cost per bit.

At present, operator requirements have shifted from communication to informatization, and from connection/traffic operation to data operation. Network openness is becoming a trend. To help operators build a more flexible and open network, focus will be placed on providing network capability exposure. By abstracting network capabilities and scheduling resources, Huawei IDN solution allows application developers to conveniently invoke and flexibly assemble various network capabilities to implement continuous and rapid innovation of services and applications.

At the same time, to cope with the increasingly severe cyber security and privacy protection situation, Huawei has designed a complete set of cyber security methods to provide customers with more secure and reliable products/solutions based on the "trusted" principle. Based on the assumption that the network environment is insecure and network attacks are common, the system helps customers quickly identify and respond to threats and ensure service continuity and personal data security.

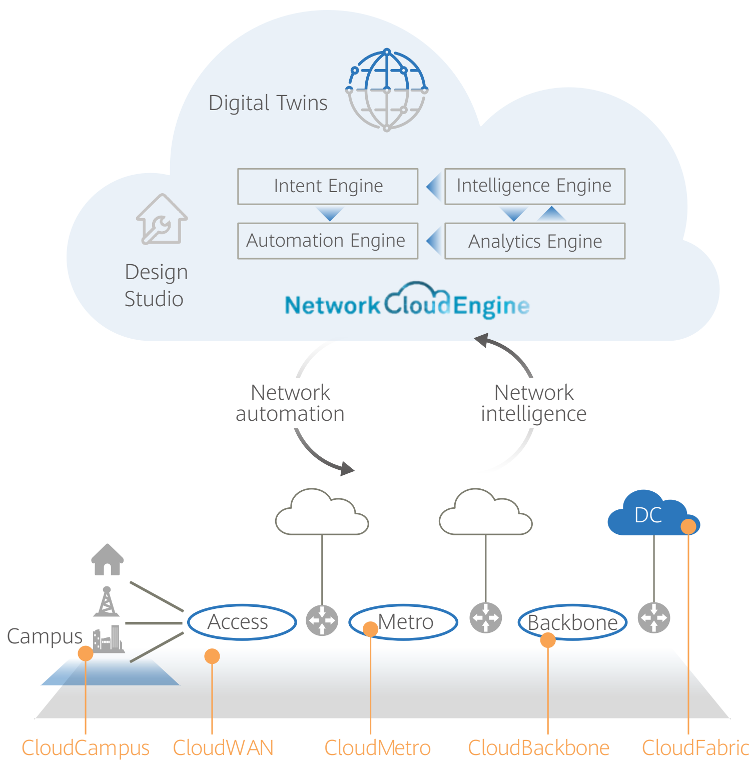
04 Huawei IDN: Driven by Users' Business Logic and Service Intent, Maximizing Business Value

The IDN aims to build a new-generation network with full lifecycle automation, intelligent O&M, and loop-closing based on business logic and service intent, realizing digital transformation of networks and eventually leading to an autonomous driving network. The IDN builds a smart bridge between business intent and basic physical networks to quickly deploy business intent, shorten TTM, and improve user experience and network agility. In addition, the IDN effectively reduces OPEX and maximizes operators' business value.

The IDN consists of the smart brain layer constructed by NCE and the ultra-broadband simplified infrastructure layer driven by Moore's Law.

Smart brain: implements intelligent network management and control. It interconnects with operators' business intent, implements accurate understanding and translation, automatically implements translation results on specific physical devices, and ensures that the network meets service requirements. It detects the health status of physical networks in real time, detects exceptions, sends warnings in a timely manner, provides exception handling suggestions, quickly rectifies network exceptions or optimizes networks based on the experience library, implements real-time service SLA visualization, and enables predictive maintenance based on the AI technology. Through continuous modeling, behavior learning, and training, it predicts component failures and sends warnings so that the components can be replaced efficiently. In addition, transient congestion points can be identified in advance so that important services can be migrated or scheduling policies can be improved in advance.

Ultra-broadband infrastructure: is the cornerstone of IDN networks. It follows Moore's Law. Through continuous innovation and breakthroughs in key communications technologies, node capacity doubles every 24 months to meet the bandwidth requirements brought by new services such as 4K/VR, 5G, and cloud computing. The network architecture is continuously reconstructed and optimized. The simplified fabric architecture is implemented by modularization and standardization, enabling elastic scalability and plug-and-play capabilities of the network, and providing deterministic low latency for future 5G services and industrial special applications. In addition, the E2E SRv6+EVPN unified bearer protocol simplifies network protocols, reduces network complexity, decouples services and network connections, implements fast service provisioning, and improves network programmability to meet different service requirements.



NCE as the network smart brain

- Full-lifecycle automation of the existing network and new network
- Real-time service SLA awareness and proactive O&M
- AI enabling forecast maintenance

Simple architecture and protocols

- Simplified fabric network architecture to separate services from networks

E2E SRv6+EVPN unified protocol

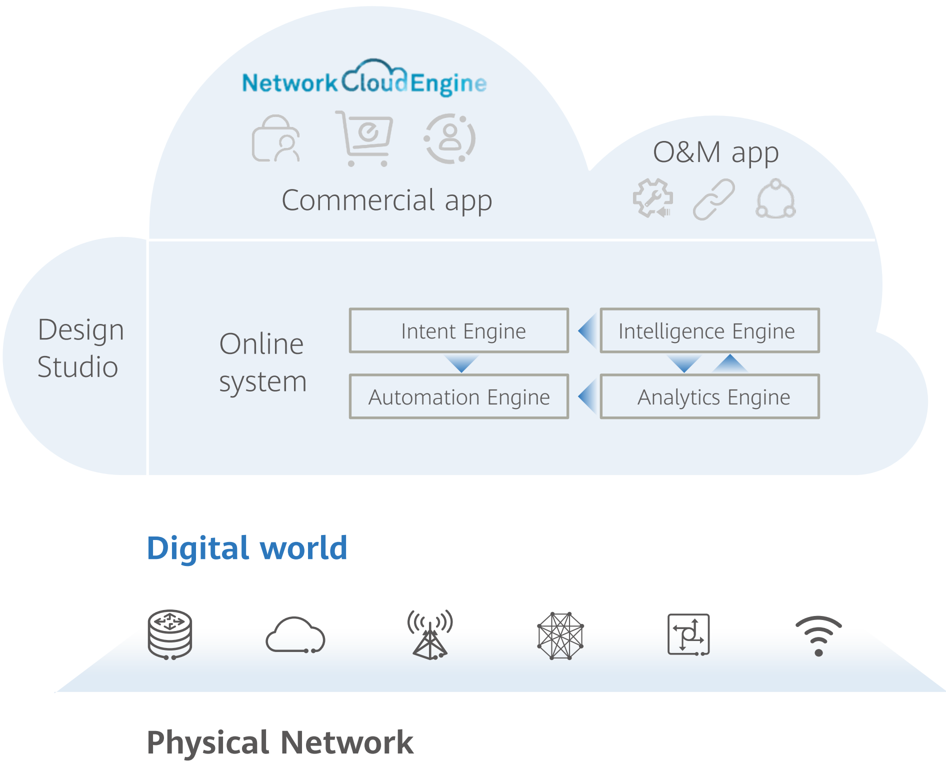
Network Moore's Law with network capacity doubled in 24 months

- 6.4 Tbit/s NP chip
- 10GE to site, 50GE PAM4 access ring, 400GE backbone network&DCN
- Optimal power consumption: 0.3 W/G, which has been decreased by 30%

4.1 NCE Building IDN Smart Brain

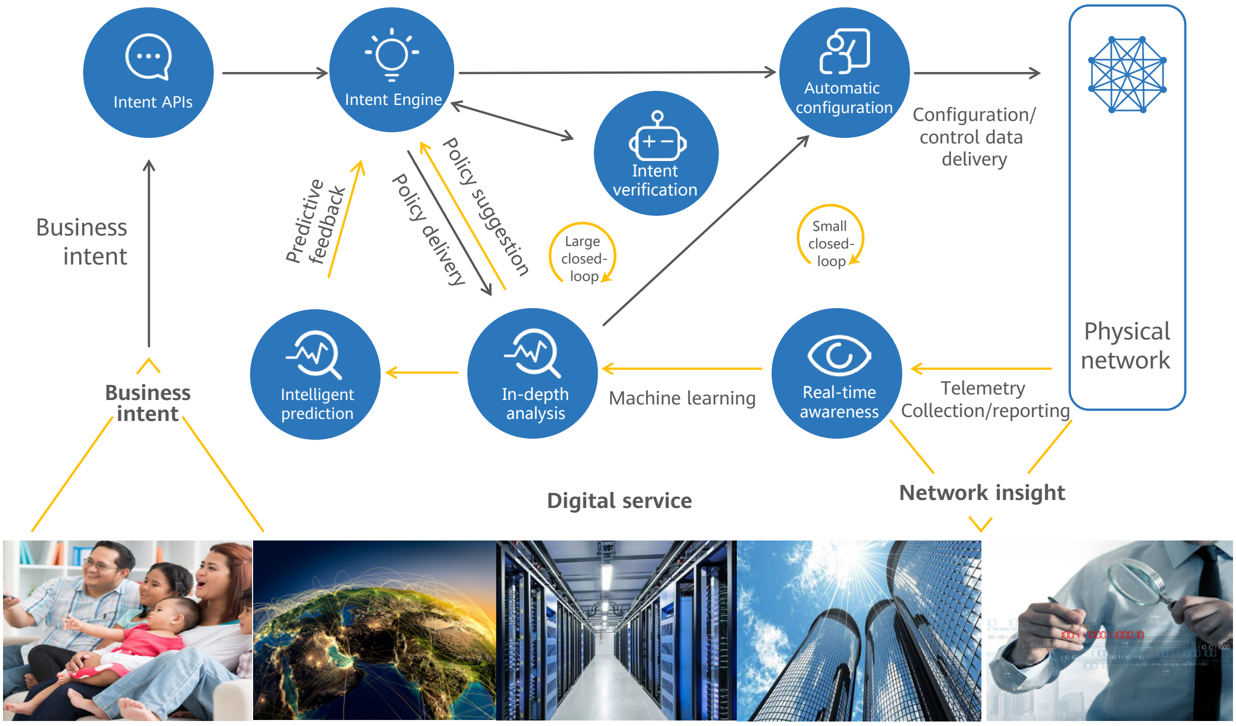
Huawei IDN network architecture provides smart capabilities for networks through Network Cloud Engine (NCE). NCE is the central nervous system of the IDN network and plays the role of the smart brain. By constructing a unified network brain, NCE implements centralized management, control, and analysis of global networks, and provides open network APIs and IT integration. NCE enables operators to construct automated and intelligent networks centered on the user experience.

Based on the Digital Twin technology that has been successfully verified in traditional industries, NCE creates a precise digital simulation model based on historical data and real-time running data to display the running status and health status of network infrastructures, including physical network devices, logical network devices, ports, and connections. Based on the AI, big data, and cloud technologies, NCE analyzes the precise measurement data and service behavior collected in the entire lifecycle of network O&M management to implement continuous predictive maintenance. NCE integrates the traditional NMS, SDN controller, and analyzer system into a unified IDN architecture to enable network data synchronization and sharing among these systems. This simplifies and improves collaboration among different systems, maximizing service agility and network programmability.

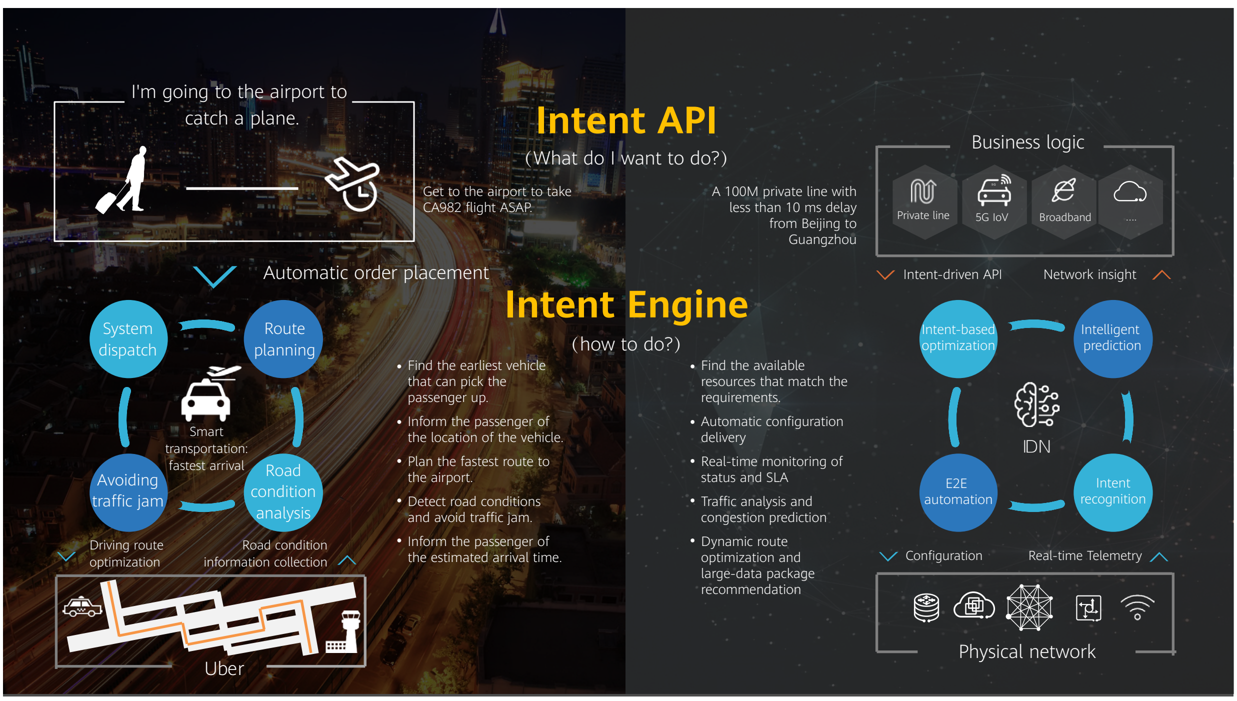


NCE has four main functional modules: Intent Engine, Automation Engine, Analytics Engine, and Intelligence Engine.

- Intent Engine: receives and understands business intent, translates business intent to network strategies, and simulates and verifies network design and planning.
- Automation Engine: converts the network design and plan data into specific network commands, and enables network devices to automatically execute these commands through standard interfaces (such as NETCONF).
- Analytics Engine: uses technologies such as Telemetry to collect and analyze network data of users, including Wi-Fi uplink and downlink rates, delay, and packet loss rate, but not any user privacy data.
- Intelligence Engine: provides risk prediction and handling suggestions using AI algorithms and the continuously upgraded experience library on the basis of Analytics Engine. Alternatively, Intelligence Engine provides optimization suggestions to the Intent Engine to implement automatic and intelligent optimization for network exceptions.



For example, a company headquarters (located in Beijing) and a newly established Guangzhou branch need to enable a 100M private line (15-ms delay) to meet office requirements such as video conferences. After receiving the requirement, the telecom service provider finds the available resources that match the requirements, breaks down the resources into network parameters, delivers the configuration automatically, and monitors the SLA status in real time. The telecom service provider predicts congestion based on traffic analysis and historical experience and proactively optimizes routes to ensure that services are not affected. In addition, the telecom service provider recommends more suitable packages based on the service usage.



NCE's four engines and underlying physical networks form a large network closed-loop. The analysis algorithm continuously learns from the behavior of network services so that this network evolves into an autonomous network that is self-adaptive and self-optimized to achieve self-healing.

NCE provides network programmability and openness.

NCE provides customized programmable automation capabilities in the network model (NBI&SBI), service model, analysis model (data analysis pipe), and closed-loop model through the integrated development environment (IDE). Development activities in the design phase and operation activities in the running phase are combined to support the DevOps development mode and implement quick release of new services. The Design Studio tool provided by NCE uses powerful rule-based experience programmable engineering methods to support programming in the design phase. NCE also provides open southbound APIs for interworking with controllers of other vendors. Openness and programmability enable NCE to meet service requirements of operators and enterprises, and help build an open ecosystem, achieving business success.

4.2 IDN Infrastructure: Complying with Moore's Law, Ultra-Broadband Simplification Without Blocking

With the rapid development of cloud computing and ultra-HD video services, such as 4K and VR, network traffic keeps increasing. According to the research, the capacity of IP bearer networks needs to be doubled every 24 months. This is Moore's Law of the network. Through continuous R&D investments, Huawei has made continuous innovations and breakthroughs in key communications technologies, such as Solar series NP chips, 50GE/400GE optical modules, high-speed interconnection based on the orthogonal architecture, and minimum power consumption in the industry.

Huawei constructs a non-blocking fabric network based on E2E SRv6. This network supports flexible service expansion, protocol simplification, and one-hop direct transmission. SRv6 simplifies over 10 MPLS protocols to one protocol and improves the configuration efficiency by 60%. SRv6 also supports application-based network path programming to implement more flexible path planning and optimal traffic engineering, ensuring deterministic latency. Service and network decoupling is enabled to support on-demand NE capacity expansion. Services on the live network are not affected.

05 IDN Implementation in Various Business Scenarios

5.1 5G Transport

Trend

In the 5G era, eMBB, URLLC, and mMTC are three new typical application scenarios that bring new challenges to networks. Bandwidth is fundamental to mobile communication and, for 5G applications such as HD video live broadcast, Cloud XR, cloud access anytime and anywhere, and artificial intelligence, higher bandwidth is a basic requirement. Therefore, 3.5 GHz and millimeter-wave new spectrum are required to meet high bandwidth requirements, leading to a 10-fold increase in bandwidth. The mMTC scenario, which includes environment monitoring, intelligent metering, and intelligent agriculture, is targeted at sensing and data collection. Characterized by small data packets and massive connections, this scenario requires a connection density of millions per square kilometer. As a result, the number of connections increases by hundreds of times. To meet requirements in the Internet of Vehicles (IoV), industrial control, and vertical industries, URLLC needs to provide millisecond-level end-to-end deterministic latency. In addition, as the density of 5G gNodeBs increases, the scale of networks on which O&M is performed also increases. Furthermore, networks carry many different services that have many different requirements on the networks. SLA assurance for the massive number of services will become a basic requirement of users in the future, which will increase the O&M complexity exponentially. Therefore, it is imperative to introduce automatic and intelligent O&M capabilities.

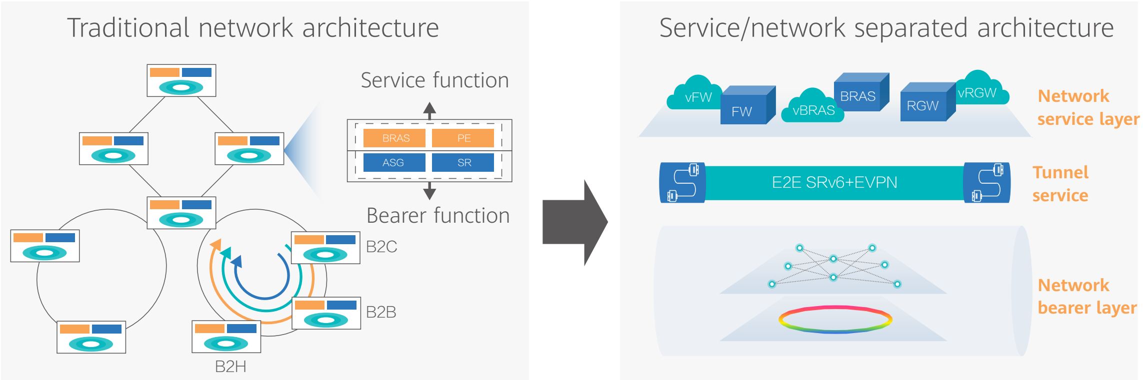
As bearer networks continue to evolve, carrying all services on one network will be the inevitable trend. In addition to carrying traditional 2C services, the 5G transport network will also carry 2B services (such as intelligent manufacturing) and 2H services (such as cloud gaming) and be able to meet the requirements of different types of services. Because 5G services, 2B services, and 2H services will be migrated to the cloud, the service flow directions will remain the same. Networks in the future must be DC-centric bearers. As the scale at which 5G gNodeBs are deployed increases, 5G gNodeB access points will gradually be moved downward to form integrated 2B/2C/2H all-service access points. Constructing independent networks is wasteful in terms of investments. Therefore, in the future, one network will bear all types of services.

Challenges and Requirements

How to meet the requirements of large bandwidth, deterministic low latency, automation, and intelligence in addition to full-service bearing and massive SLA customization through one physical network is the major concern for the transport network. Specifically, issues that need to be resolved are as follows:

- **Non-blocking networks driven by network Moore's Law:**In the 5G era, the access rate of a single gNodeB will exceed 5 Gbit/s. Therefore, the access and aggregation networks must support larger bandwidths. After the 2B/2H services are migrated to the integrated transport network, the bandwidth requirement will increase significantly. The network Moore's Law drives the capacity of IP devices to double every 24 months in order to meet bandwidth requirements.

- **Simplified network architecture with separated services and networks:** After wireless and core networks become cloud-based, connections between core networks and between gNodeBs and core networks will become more complex. In addition, NEs on the cloud-based wireless and core networks will need to be quickly deployed, generally within several minutes. Therefore, the corresponding transport network must also be agile and provide automatic connections within minutes. In the traditional network architecture, the network is coupled with services. A single device integrates service functions (such as BRAS) and forwarding functions. When services change, the network changes accordingly. As a result, the service deployment efficiency is low and network expansion is difficult. In addition, the network needs to support more than 30 complex protocols and over 6000 configuration commands, and network maintenance requires highly skilled personnel.



To facilitate agile service connection and provisioning, services are decoupled from network connections. For example, control and user plane separation (CUPS) is implemented for the BNG. The service system is interconnected with the control plane (CP) device, and the service configuration is performed in a centralized manner. In addition, the new user plane (UP) device requires only basic configuration, resulting in a much faster service rollout. The CP can centrally manage UP devices, which can be scheduled on demand to meet the differentiated service requirements. In addition, to meet deterministic ultra-low latency requirements, a simplified fabric architecture needs to be enabled based on the simplified SRv6 protocol to achieve one-hop direct transmission.

- **Full-lifecycle automation and intelligence enabled by the network smart brain:** The inefficiency of traditional O&M is a major factor that contributes significantly to high OPEX for operators. In the future, the 5G transport network will be a comprehensive transport network for 2B/2C/2H services, leading to increased complexity of services and O&M. Take service provisioning as an example. The deployment of private line services depends on manual planning and configuration. In cross-AS and multi-vendor scenarios in particular, cross-department management and coordination and cross-vendor service interconnection are involved, resulting in low deployment efficiency of private line services. Therefore, operators are considering network smart brain for fast service provisioning, fast fault locating, and predictive maintenance.

IDN-based 5G Solution

10GE to site, providing 50GE access ring and 100/200GE aggregation on demand

For areas with optical fibers, it is advisable to create or upgrade to a 50GE access ring to access 3G/4G/5G services. The cost of a 100GE optical module is 10 to 15 times that of a 10GE optical module. Due to the high costs, upgrading directly to a 100GE access ring is costly for operators. The 50GE optical module based on the PAM4 technology implements the 50GE capability with one 25G optical module. The 100GE optical module is formed by combining four 25G optical components. Therefore, the per-bit cost of the 50GE access device is 30% lower than that of the 100GE optical module, effectively saving operators' investment.

For areas without optical fibers, 5G microwave is used to provide supplementary coverage. Huawei has industry-leading 5G microwave technologies and can provide 10 Gbit/s bandwidth in any conventional band. In addition, Huawei proprietary 2+1 architecture allows one antenna to support two ODUs of any frequency band and each ODU to support four carrier channels. In this way, hardware installation can be completed in a single visit, and bandwidth adjustments can be implemented flexibly through software. Compared with other vendors' site visits, OPEX is reduced by 50%.

E2E on-demand SRv6 deployment to simplify the configuration of 5G service protocols

The E2E 5G service uses the SRv6 protocol, which simplifies protocol configuration. SRv6 works with NCE to implement configuration on the source node for all protocols running on the path, thereby achieving fast service provisioning. In addition, Huawei devices support MPLS/SRv6 dual stack. For 4G services, the MPLS protocol is still used, which has no impact on existing services. Mixed bearer of 4G/5G services is also supported.

All Huawei IP devices are based on the NP programmable chip. The software can be upgraded to smoothly support the SRv6 protocol, reducing the hardware replacement costs caused by protocol upgrades.

Unified management, control, and analysis platform, enabling intelligent O&M throughout the lifecycle

NCE smart brain based on the cloud platform can implement network automation and open network capabilities. NCE is oriented to network planning simulation, network service deployment and provisioning, and network monitoring, assurance, and optimization. Based on the unified software orchestration and workflow engine, NCE can construct differentiated service packages for different services and business scenarios both quickly and flexibly, achieving the full-lifecycle automation of physical and virtual network functions. NCE aims to accelerate provisioning of network connection services from months to days or even minutes, through user-friendly and real-time online consumer service portals or applications. The unified, simple, and clear administrator workbench implements intelligent operation of planning, deployment, monitoring, maintenance, and assurance, thereby improving O&M efficiency by 10 times and greatly reducing OPEX. In addition, predictive maintenance based on AI and big data is introduced to identify potential faults several days or even months before they have an impact and handle them in a timely manner, greatly reducing O&M costs.

IDN Use Case in 5G Scenarios

Use case 1: automatic 5G new site deployment and service deployment

In the past, the deployment of 4G CSG required phone-based communication between onsite technical personnel and remote NOC engineers. The NOC engineers manually performed configuration on the NMS. Basic configuration and service provisioning required 20 steps and involved more than 100 parameters. The entire process required an average of 30 minutes to complete, which is inefficient. And with the error rate reaching 2%, rework usually required an extra two hours.

With the zero-touch provisioning function, NCE automatically delivers network and service configurations after CSG installation and QR code scanning. This does not require any manual intervention, preventing operation errors.

NCE uses a small number of parameter sets to simplify and automate the configuration process, shortening the software commissioning delivery time from 30 minutes to 3 minutes.

Use case 2: automatic fault demarcation and intelligent troubleshooting

Currently, networks run in a reactive maintenance mode. Approximately 90% of faults are driven by complaints or NMS alarms. No quality of experience (QoE) measurement method is available for detecting packet loss or latency. In addition, existing technologies support sampling at a minimum interval of only 15 minutes, which is insufficient for troubleshooting. Therefore, troubleshooting takes an average of 90 minutes to complete and requires an additional 2 hours to optimize per day. For example, operator L experience a forwarding fault in device chips on the transport network. On the operator's network, a fault caused packet loss and resulted in a large number of complaints. However, no alarms were generated on the NMS. After receiving thousands of complaints, the operator manually investigated the fault, requiring many hours of labor to identify the fault point.

Huawei IDN implements proactive O&M, minute-level fault locating and self-recovery, SLA commitment, and zero service impact to reduce complaints by 90%.

Real-time SLA awareness: Telemetry achieves second-level monitoring on the SLA of all base stations and a large number of device KPIs. Faults are visible and corrected before users are aware of them.

Minute-level fault demarcation and locating: With Telemetry-based iFIT inband flow detection in collaboration with ML-based fault locating algorithms, monitored points are extended to every hop and sampled at intervals of seconds to provide hop-by-hop diagnosis so that problems can be identified within 10 minutes.

Automatic service recovery: According to SLA requirements, NCE can calculate a new service path through SRv6, isolating the faulty node and enabling automatic fault rectification.

5.2 Enterprise Campus

Trend

With the rapid development of various ICT technologies, such as cloud computing, big data, AI, and IoT, the digital processes of various industries are accelerating. The government, enterprise, university, retail, and manufacturing industries are building their own digital spaces to improve production efficiency and customer experience. These digital spaces exhibit a number of common characteristics:

- Ubiquitous connections: Not only are people connected, but also people, machines, things, and services are fully connected anytime and anywhere.
- On-demand services: Network users can quickly obtain services, greatly improving production efficiency.
- Focus on experience: A network does not only provide connections, but also continuously improves user experience through digital means.

Digital space brings new challenges to campus networks:

Challenge 1: Static preset campus networks can hardly implement on-demand services.

Traditional campus networks are statically preset based on command lines. However, fast growing connection requirements increase the network scale exponentially, and digital services are changing much faster than before. Traditional command line configuration by device cannot meet service change requirements.

Challenge 2: Service experience is difficult to manage, and operators can only respond to faults passively.

In existing network O&M, personnel cannot proactively identify faults. Instead, they respond passively only after faults occur. This is because current network O&M focuses on devices. O&M personnel monitor device, link, and port faults but cannot identify and monitor differentiated connection requirements of different terminals, users, and applications, especially in a wireless network environment. Digital space (especially digital production and digital services) requires continuous improvement of service experience, and has increased urgent demand for visualized management of service experience.

IDN-based Campus Solution

Based on the IDN concept, Huawei IDN campus network solution introduces big data analysis, AI, and cloud technologies to build a campus network featuring ultra-broadband connections, automatic deployment, intelligent O&M, and threat self-defense. This solution continuously drives compatibility and openness standards, and helps customers enable digital transformation in the industry.

The IDN campus network uses the cutting-edge Wi-Fi and wired network technologies. Based on customers' differentiated scenarios, the IDN campus network builds a wired and wireless converged network that features fast connection, IoT converged access, ultra-low latency, and high reliability. In this way, the IDN campus network meets the increasing requirements for IoT access, all-wireless office, and ultra-high bandwidth applications, such as AR/VR/4K video, in various industries.

How does IDN implement simplification and on-demand services on campus networks? An IDN campus network uses SDN and automation technologies to implement the underlay physical network, overlay virtual network, and automation and policy provisioning at the service policy layer. Cloud management technologies are used to provide centralized cloud O&M and cloud inspection, reducing the OPEX by 80%. Big data and AI technologies are used to implement intelligent O&M, visualize service experience, identify 85% of potential faults, detect root causes, detect and defend against unknown advanced threats, and reduce threat detection and response time by 90%.

IDN Use Cases in the Campus Network Scenario

Use case 1: minute-level service provisioning for campus networks

In traditional service network deployment, manual planning and design are used. The service configuration is performed by command lines on site, which is inefficient and prone to errors. As a result, the service delivery period is long. Based on the IDN architecture, the campus network introduces NCE's Automation Engine, which integrates traditional network management and user policy management. It provides centralized planning, deployment, and management for underlay networks, overlay networks, and policies, improving campus network deployment and management efficiency.

For example, a customer adds a set of security monitoring services to provide security protection and video surveillance in office areas and at the campus entrance and exit.

As is: The chimney architecture is used for service deployment. One new physical network needs to be deployed. Skilled personnel plan and configure services one by one on each device. The service network rollout takes 4 to 6 weeks.

To be: The VXLAN virtualization technology eliminates the need for new physical networks. IT personnel can complete virtual network planning and requirement design through only a dozen or so clicks on the Automation Engine's graphical user interface (GUI), and then network devices can be automatically deployed. It takes only 5 minutes to deploy the security monitoring service, which is isolated from existing services.

Use case 2: using AI and big data technologies to detect over 85% potential faults and implement minute-level network fault identification and automatic optimization

Traditional network O&M is centered on devices and cannot detect user service experience. Network faults are detected only after user complaints are received. Fault locating and troubleshooting are performed by device, leading to low troubleshooting efficiency and prolonged fault recovery. Based on the IDN architecture, the campus network introduces NCE's Analytics Engine (Campus Insight), which not only uses Telemetry to collect network data in real time, but also uses big data and AI technologies to mine and analyze network data to detect more than 85% of potential faults. Faults can be automatically located and rectified within minutes. In the future, network faults can be predicted and rectified in advance, improving network O&M and troubleshooting efficiency.

For example, a company's R&D department noted that a laptop was working properly in the morning. However, by the afternoon, frequent frame freezing and call drops occurred when a PC voice conference is held in the conference room.

As is: The IT personnel check the AP, access/aggregation device, and conference system of the conference room through the NMS. The test results indicate that everything is normal. In the conference room, the handheld terminal software is used to test the Wi-Fi performance. Again, the test results indicate that everything is normal. Then it is found that the terminal has weak Wi-Fi signals. The terminal is connected to the AP in the adjacent office. The fault is caused by sticky roaming. In this case, after more than 4 hours of troubleshooting, smart roaming is manually enabled to solve the problem.

To be: The Analytics Engine is used to quickly view the entire network service experience of the user throughout the day. The GUI shows that the user is connected to the same AP all day. The service experience is normal in the morning. In the afternoon, the packet loss rate is high, the average delay is long, and the data traffic is low. Specifically, the Wi-Fi signal strength and negotiation rate are low. The Analytics Engine determines that the user is a sticky roaming user and automatically provides suggestions on enabling smart roaming. The problem can be solved in minutes.

5.3 Data Center

Trend

Almost all enterprises are currently undergoing digital transformation. To address the challenges of digital transformation, cloudification, AI, and big data become the development trend. The ABC technology is accelerating enterprise digital transformation and reshaping the core competitiveness of enterprises. Data centers of enterprises are the key.

As the core service center of an enterprise, data centers have passed the virtualization stage and are moving from the cloud phase to the AI phase. Virtualization aims to improve resource utilization through pooling, and cloud computing improves the business transmission speed through services. The value of AI data centers is to mine data in order to achieve business value. In this way, a cross-generation data center has the following development trends:

- **Multi-cloud:** Edge computing brought by IoT drives the rapid development of edge clouds. Therefore, how to implement multi-cloud collaboration and unified deployment of edge clouds and central clouds becomes a major requirement of more and more enterprises.
- **Explosive growth:** Data centers need to be built or expanded frequently. Take large Internet companies as an example, where servers for data centers increase by 50% to 100% every year.
- **Second-level elastic scaling:** Rapid application rollout requires that the network be deployed in seconds. The service scheduling based on multi-clouds and container clouds changes network configurations more than 200 times per day.

Challenges and Demands

As the carrier of AI applications, data centers (especially data center networks) play a critical role in the connections of AI applications, clouds, and big data. They face new challenges and higher requirements. The major requirements are as follows:

Multi-cloud collaboration:

- The hybrid cloud is preferred by medium- and large-scale enterprises due to its advantages. Therefore, how to implement interconnection, collaboration, and free switchover between private clouds and public clouds of carriers becomes a major requirement of more and more enterprises.

Simplicity experience:

- As data centers grow rapidly in scale, data center networks need to be reconstructed every two to three years, leading to an urgent need for simplified automation of network deployment and expansion.
- Starting from the initial proposal of a data center service requirement to network deployment, complex workflow tickets and manual intervention are required. This is time-consuming and prone to errors. As a result, the ultra-fast requirement for the full digital service environment cannot be met.

Intelligent O&M:

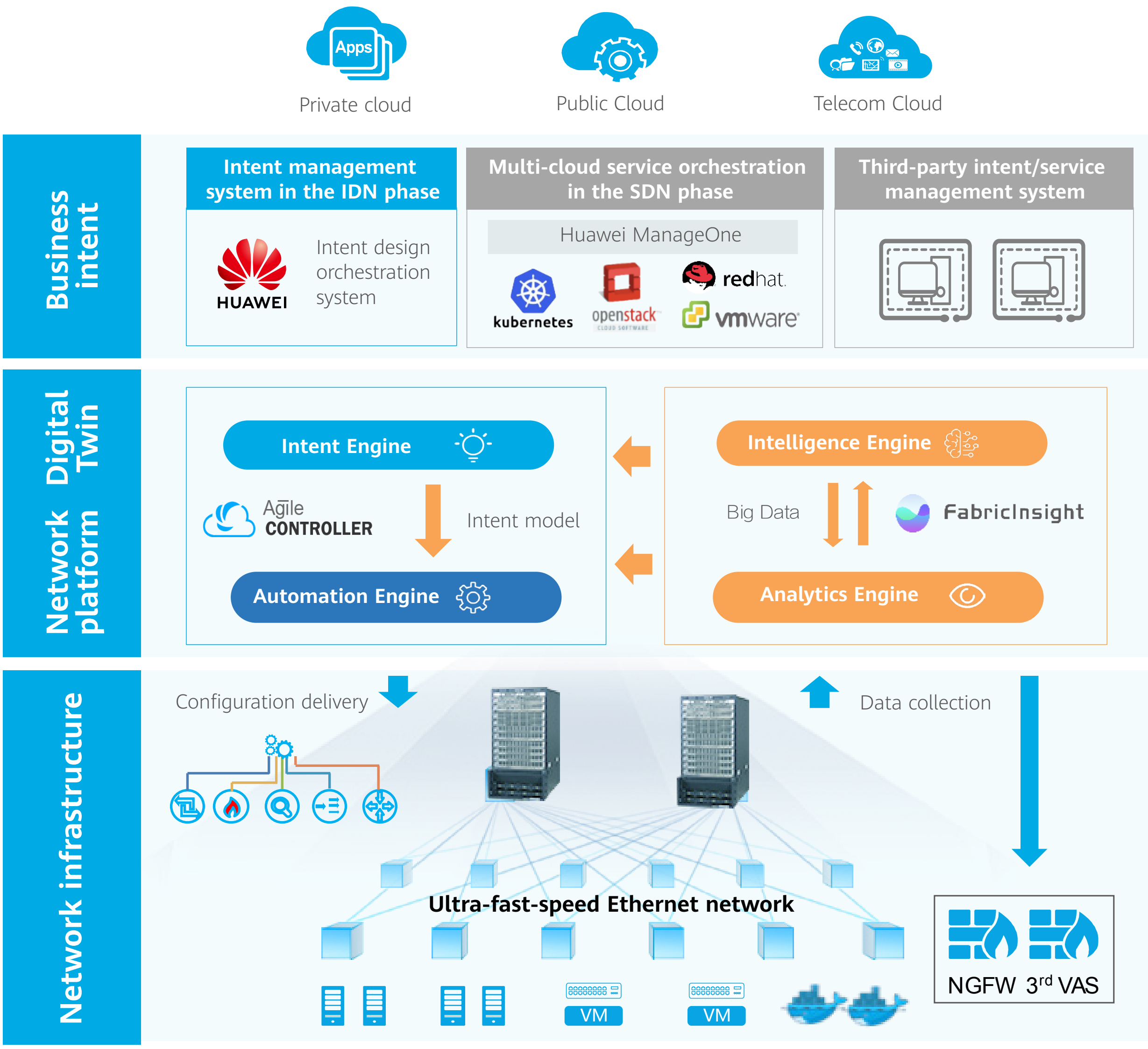
- For network configuration changes, the current network lacks a verification mechanism. Evaluating service delivery or change impact and checking whether configurations are correct depend on professional experience and manual check of O&M personnel. It takes two or more days to bring an application online.

- The application status is related to customer experience. Real-time application status awareness, adaptive optimization, and predictive operation are effective paths for enterprises to improve their competitiveness and operation efficiency. NE-centric traditional networks cannot be aware of the application status in real time and do not support dynamic fault diagnosis and processing. Additionally, no preventive measures are available.

As data centers become increasingly large and complex, the complexity of network deployment, network capacity expansion, fast service rollout, frequent adjustment, and quick troubleshooting has exceeded the limit of manual processing capabilities. Existing networks have become the bottleneck in accelerating the digital transformation of enterprises. These networks are urgently required to keep pace with ICT transformation.

IDN-based Data Center Solution

The following figure shows Huawei IDN data center network architecture, including business intent, digital twin network platform, and simplified UBB cloud network infrastructure.



Huawei IDN data center network architecture

Business intent is the business logic or decision-making of enterprise users. With the evolution from SDN to IDN, the platform of the business intent layer evolves from the SDN phase to the IDN phase. The business intent can be classified as follows:

- Multi-cloud service orchestration system in the SDN phase
- Intent management system in the IDN phase
  Data center intents can be classified into business/service intents and network intents according to the organization structure and operation of different enterprises and industries.

Intent Category	Example 1	Example 2
Business/service intent	I'm going to launch a secure distributed application today.	I want to expand my application database.
Network intent example	I want to expand the capacity of 100 servers.	I want to quickly upgrade the 10GE network to the 25GE network and replace switches and servers in a batch.

Huawei's business intent platform supports both types of intents to meet diversified requirements of different customers and helps networks smoothly evolve to intent-driven autonomous data center networks.

The **digital twin network platform** is the core of an intent-driven data center network and a key component of an autonomous network. This platform is required to process business intents and convert business intents into implementation of the network infrastructure.

The digital twin network platform includes four engines: Intent Engine, Automation Engine, Analytics Engine, and Intelligence Engine. These four engines collaborate to receive business intent from the upper layer and use the intent-driven automation service to implement this business intent on network infrastructure at the lower layer. The engines also work together to detect network status in real time and perform predictive maintenance.

The **network infrastructure layer** includes an underlay network (composed of various physical and virtual devices) and an overlay network.

In terms of underlay networks, Huawei creates a next-generation intelligent lossless and low-latency AI Fabric based on the open Ethernet technology. Relying on two levels of AI chips and unique intelligent congestion scheduling algorithms, the AI Fabric implements zero packet loss, high throughput, and ultra-low latency of RDMA service flows. It also accelerates computing and storage efficiency in the AI era, delivers private network performance at Ethernet prices, and improves the overall ROI by 44 times.

IDN Use Cases in the Data Center Scenario

Use case 1: intent-driven automatic service deployment for data centers

Business requirements usually consist of one or more business intents. Currently, a large number of manual operations, and cooperation between service departments, network departments, among others are needed for a data center to fully implement a service. This is a time consuming process in which the service intent needs to be manually identified and understood and then converted into a policy that can be applied to the network. Take China Merchants Bank (CMB) as an example. It is the largest retail bank in China and has hundreds of millions of retail customers. In the future, CMB is proposing the strategic reconstruction of the customer operation plane using big data. In simpler terms, they plan to reduce the bad loan rate through real-time risk control, and develop more customers through precision marketing. The current data center, lacks effective collaboration for multiple service systems. Traditional data mining platforms cannot interact with service systems in real time. As a result, risks such as bad loans are decided offline and cannot be effectively controlled. Credit evaluation takes an extended length of time (3-5 weeks). In addition, services are separated from the network, and the network needs to be manually configured.

Huawei intent-driven data center network is connected to big data services through the cloud platform to implement elastic scaling and flexible scheduling of infrastructure and achieve second-level automatic network deployment. This greatly shortens the time spent by network engineers in network planning, design, deployment, verification, and troubleshooting, and reduces the network OPEX.

Users intuitively express service intents, and the intent engine can understand and convert users' intents into model-based policies, and perform consistency and integrity check to ensure consistency between policies and intents. Intents and policies can be reused, for example, intents expressed previously can be reused to extend the applications again.

Model-based policies are automatically converted into standard and specific network configurations, and can be deployed on the network in one-click mode to implement network provisioning in seconds. In addition, the intent-driven data center network supports ZTP deployment and capacity expansion to implement automatic setup of the initial network.

Through the closed-loop design, the intent-driven network continuously verifies the consistency between network configurations and intents to identify potential problems or quickly provide root causes of network faults, ensuring normal service operation when the data center network frequently and dynamically adjusts.

Through understanding and converting user intent, implementing fully automatic network deployment, and continuously ensuring consistency of networks and intents, Huawei's intent-driven data center network aims to make services more agile, identifies service intent, and implements automatic service provisioning based on service intent in minutes. By underpinning the efficient running of big data-powered financial service systems, Huawei IDN helps reduce risky cases by 50%, improve the conversion rate of small and micro loan customers 40-fold, and decrease credit card evaluation time to minutes.

Use case 2: closed-loop intent verification to ensure network and intent consistency

SDN achieves automatic network deployment, but lacks verification mechanism. After a logical network model is defined and the deployment key is clicked, the system automatically delivers the network model to the network, but does not guarantee the delivery result or the impact of the delivery on the existing network. In other words, the system delivers the model no matter whether the delivery succeeds.

During loop closure, Huawei's intent-driven data center network verifies the network to ensure proper service operation. After intents are converted into network configurations, the system configures a model to pre-verify the consistency between configurations and intents, whether the remaining resources of the physical network infrastructure are sufficient, and whether the current configurations have any impact on the original configurations. For example, users on the current data center network have a common problem. The number of configured ACLs increases with time. Each time services are adjusted, a large number of experts are required to manually analyze and verify whether the new ACLs conflict with those on the existing network. However, the intent verification mechanism can automatically solve this problem, and minimize the impact of this problem before the network is provisioned.

By reducing the workload of overloading engineers, the manual error rate will decrease from 35% to 0%. This has a significant impact on network reliability and service operation. In the fully-connected world, networks means services. It is crucial to ensure the consistency between networks and services and accurate execution of intents.

06 IDN Collaborating with Operators in NetCity

NetCity is an innovative platform for Huawei and operators to practice IDN. NetCity innovates in DevOps mode, sets up a joint team to jointly define use cases, iterative development, market verification, and service design, and fully utilizes Huawei's technical advantages in development capabilities, algorithms, and solutions over the past three decades. In addition, operators have advantages in business case design, operation and maintenance, and business service capabilities. Huawei and operators collaborate to jointly build leading technical and business solutions, shorten the period from technical verification to business realization, help customers improve their social image and brand value, and build strategic mutual trust in joint business innovation.

In 2018, Huawei started over 25 NetCity projects with more than 20 customers worldwide, jointly designed and developed 63 use cases, and deployed 37 use cases. The IDN concept and NetCity project have been widely influential in customers and the industry.

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