A WHITEPAPER ON

autonomous networks

SEPTEMBER 2022

Empowering digital transformation – from strategy to implementation

Objective(s): to share the latest updates of business requirements, architecture, capabilities, collaborative activities, best practices and reference implementations in the Autonomous Networks industry.

Contributing companies

Editors and contributors

EDITORS

TM Forum	**Aaron Boasman-Patel**
Futurewei	**Dong Sun**

CONTRIBUTING COMPANIES & INDIVIDUALS

AIS	**Wasit Wattanasap, Suphachet Phermphoonwatanasuk, Boonchoung T. Verawongse**
AsiaInfo	**Ye Ouyang, Duozhi Zhu, Sen Bian**
Beyond Now	**Andreas Polz**
Broadtech	**Ren Li, Yin Ming, Ran Bin**
BT	**Andy Corston-Petrie**
BUPT	**Wenjing Li**
CAICT	**Junfeng Ma, Qiang Cheng, Zhirou Liu, Zishan Liu, Yuhua Zhang**
CCSA	**Shizhuo Zhao, Ying Zhao, Yan Zhang, Xin Guo, Xu Qi**
CCSSOFT	**Lan Yinghua, Zhang Zehua**
China Mobile	**Ninglun Gu, Liwei Liu, Yuan Yao, Lingli Deng, Kaixi Liu**
China Telecom	**Sun Qiong, Zhang Le, Yanqin Wu, Jingjing Yuan, Zhang Ke, Linjun Liu**
China Unicom	**Ren Fei,Wan Yuhai,Wang Lei, Qiao Zizhi, Yang Jianjian, Zhao Yongjian, Zhao Zhanchun**
China Unitechs	**Lu Yunyang, Hao Liguang, Song Gang, Zhou Huadong, Wang Han**
Chunghwa Telecom	**Tse-Han Wang, Hao-Yu Kao, KAI MING TENG**
Cognizant	**Arun VS, Pramathesh Bhurangi**
Clarity Global	**Ali Mozaffar, Seyed Zoee, Mohammad Reza Anbiyaei, Adel Hosseiny**
CloudBlue	**Doug Migliori**
Dialog Axiata	**Ravi Kamalendiran**
Eastcom	**Jianping Duan, Hongpeng Yi**
Ericsson	**Ignacio Más, Jörg Niemöller, Muhammad Rehan Raza**
ETIYA	**Thierry Reynard, Ali Durmug**
Etisalat	**Abakar Abdelmalik,Salem Alnuaimi**
Futurewei	**Dong Sun, Min He**
GuoChuang	**Zhao Long, Li Fei**
HKT	**Derek Chen**
Huawei	**He Huang, Yongming Lin, Yuzhou Hou, Yining Wang, Ji'ang Li, Jian Wang, Hui Li, Guangying Zheng, Xiaolin Song, Chen Chen, Jing Hao, Kevin McDonnell, Fernando Camacho, Qing Yu, Lexun Wang, Chen Feng**
Infosys	**Anuroop Awasthi, Ankur Goel, Ankur Goyal**
Inspur	**Chang Chengyang, Huang Jing, Chu Yufei, Shen Linjiang, Xu Bingjian**
Intraway	**Diego Ambuhl, Mark Abolafia, Santiago Gonzalez**
MTN	**Mohamed Salah, Lloyd Mphahlele, Steven Hill, Nkosinathi Nzima, Brite Devassy, Daniel Smith, Thembinkosi Ndebele**
NBNCo	**Brad Peters**
Netcracker	**Andrei Chekalin, Manoj Nair, Abinash Vishwakarma**
Nokia	**Xihai Xu, Kailing Luo,Tao Zhi**
NTT	**Takayuki Nakamura, Kenichi Tayama, Shingo Horiuchi, Hiroaki Kikushima, Chao Wu**
Orange	**Christian Maitre, Sophie Nachman, Frederic Desnoes**
Sparkle	**Dario Serra**
stc	**Khalid Mohamed Attia**
Reliance Jio	**Ankit Murarka**
Robi Axiata	**Mohammed Fahim Momen, Mohammad Rubbyat Akram**
Telecom Argentina	**Gaston De Arriba, Eduardo Panciera Molanes, Miguel Fernandez, Ruben Delgado, Claudio Righetti**
Telecom Italia	**Massimo Banzi**
Telenor	**Hanne-Stine Hallingby, Knut Johannessen, Min Xie**
Telkomsel	**Deasy Apriani, Henry Ganda Purba, Novi Faldian Alfianto, Laode Muhammad Ramadhan**
TEOCO	**Yuval Stein**
TM Forum	**Aaron Boasman-Patel, Dave Milham, Dawn Bushaus**
UBiqube	**Hervé Guesdon, Naveen Kumar M J**
UltraPower	**Wang Xiaojun, Wang Chao, Chen Zhen**
Universita degli Studi di Milano	**Marco Anisetti**
Verizon	**Pranab Das**
Vodafone	**Lester Thomas**
Whale Cloud	**Guo Yihua, Shi Zhiwei**
Wipro	**Vinay Devadatta, Dharmendra Misra**
XL Axiata	**Muhammad Sufyan Masood**
ZTE	**Manchang Ju, Hao Wang, Zhiqiang Chen, Yong Wang**
Zznode	**Chen Dan, Wang Hao, Wan Zhusheng**

contents

Executive summary

1.

Digitalization, intelligence and the need to reduce carbon to combat climate change are driving technological revolution and transformation in many industries. In the ICT industry, these changes demand automation of networks and operations. Communications service providers (CSPs) have responded quickly. In just three short years since TM Forum's first Autonomous Network (AN) white paper explaining the concept, operators around the world have developed strategies and are now deploying ANs, with plans to quickly accelerate to the highest levels of automation.

Globally, CSPs are leveraging their investments in 5G, network-as-a-service (NaaS), service agility and platform-based OSS, cloud, and AI to increase innovation, improve customer experience and reduce costs. They aim to give enterprises and consumers fully automated networks and ICT infrastructure, with goals of delivering a Zero-X service experience and facilitating new partner ecosystem business models. Operators also are deploying automatic and intelligent operations and maintenance (O&M) capabilities to improve efficiency in their increasingly complex networks.

These efforts are in step with global digital transformation initiatives. Around the world, more than 170 countries have developed digital strategies, and enterprises are accelerating their use of technologies like 5G, IoT, AI and cloud. Consider these data points:

- In 2030, we will enter the yottabyte era. General-purpose computing power will have increased 10-fold, and AI computing power will have increased 500-fold when compared with 2020.
- According to GSMA, the number of global IoT connections will reach 25 billion by 2025, among which 14 billion will be industrial IoT connections.
- Gartner predicts that by 2025, more than half of enterprise IT spending in key market segments will shift to the cloud and their IT expenditure on cloud access will reach $1.8 trillion.
- A survey from Deloitte shows that 54% of enterprises have deployed more than five AI applications on average.

This is TM Forum's fourth Autonomous Networks (AN) whitepaper. Since the release of the third, Autonomous networks: Empowering digital transformation, one year ago, the industry has witnessed unprecedented development. Global standards-development organizations (SDOs) have been refining AN standards, researching key technologies and determining how to evaluate AN levels (ANL) to facilitate evolution towards the highest levels.

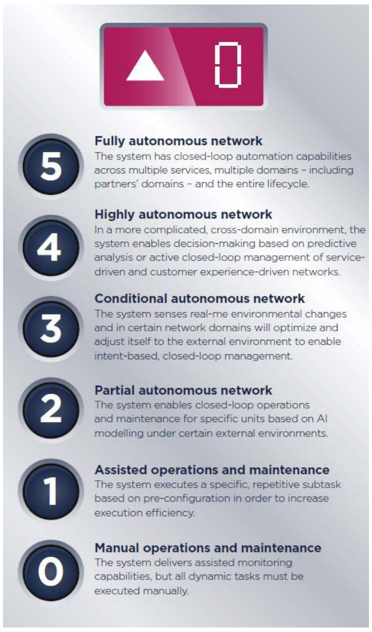
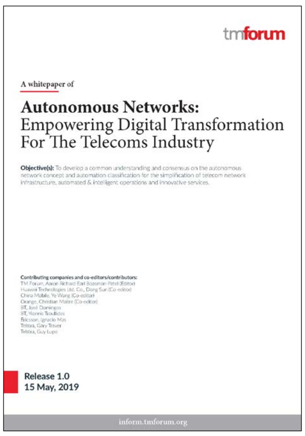
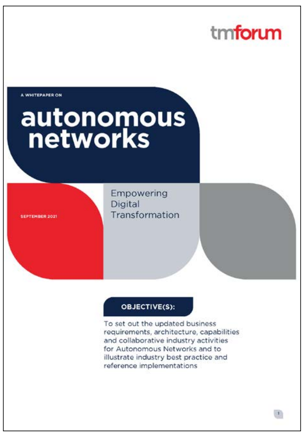


Figure 1: AN levels

TM Forum, 2022





Indeed, a key piece of the work from the TM Forum Autonomous Networks Project is a six-level AN autonomy that CSPs can use to measure their progress. Each AN level (ANL) has a set of characteristics describing the evolutionary stage of the CSP's journey from fully manual to fully autonomous operations. The model progresses from Level 0 to Level 5, with degrees of operations autonomy.

Many other SDOs are now supporting these definitions of the ANL, and nearly two-thirds (63%) of CSPs surveyed by TM Forum in May and June 2022 said they intend to be operating at Level 3 or 4 by 2025. That is substantial progress.

Nearly a dozen industry partners, including CSPs and equipment and systems vendors, have released their own AN white papers to describe their visions and strategic plans for AN. An increasing number of CSPs are focusing on best practices for a systematic approach to AN, which includes four key elements:

- Creating **a vision and target architecture**
- Adopting the **AN levels**
- Using **effectiveness indicators** to measure the business value and service effectiveness of ANs
- Establishing **operations practices** to develop automated and intelligent capabilities for networks and support systems efficiency.

With that as background, the AN industry partners jointly release the fourth AN whitepaper. The goals are to guide the development of the AN industry, strengthen industry consensus, accelerate standards, and facilitate network planning and deployment for CSPs and their innovation partners.

In the paper, we describe the latest AN trends and achievements and update the six challenges to large-scale deployment. We also explain the four key elements to implementation and describe the technical features of AN Level 1 to Level 5. We discuss the meaning and boundaries of autonomous domains, and the positioning of and correlations between generic ANL and domain-specific ANL. In addition, we look at the positioning and value of effectiveness indicators and how to evaluate and certify AN implementations.

The paper also describes CSPs' new best practices for AN planning and deployment, formulation of domain-specific ANL and formulation of effectiveness indicators, along with the best ANL evaluation practices carried out by industry organizations. Importantly, we showcase 20 select high-value business solutions using AN best practices, out of more than 40 contributions received. All the use cases are available in TM Forum's Autonomous Networks Realization Studies (IG1218C).

We hope to enable more CSPs to embark on the journey to AN and improve their ANL. We also hope to collaborate with all industry partners to develop a healthy and prosperous ecosystem for AN.

"CSPs aim to give enterprises and consumers fully automated networks and ICT infrastructure, with goals of delivering a Zero-X service experience and facilitating new partner ecosystem business models."

The need for ANs, their development and challenges

2.

2.1 THE NEED FOR AUTONOMOUS NETWORKS

Several key trends in the communications industry, and the upgrade from communications networks to production networks for various industries, are requiring more advanced automatic and intelligent network capabilities, including:

- **5G-Advanced –** as the new core infrastructure of a digital intelligent society, the 5G-Advanced standard will further promote digital transformation. Innovative 5G-Advanced technologies and a whole new industry are being explored, posing new requirements for high-level AN.

- **Computing network –** as a new business scenario for enterprise cloud access, the purpose of a CSP's computing network is to allocate and flexibly schedule computing, storage and network resources on demand among the cloud, edges and devices to meet the cloud access requirements of enterprises. Computing networks require carriers to better orchestrate and schedule their networks and clouds in an autonomic and intelligent manner.

- **Low-carbon emissions –** In 2030, digital services traffic is expected to be 13 times that of 2020. The increasing energy consumption caused by traffic growth has made carbon neutrality a global challenge. It is CSPs' responsibility to figure out how to use automated and intelligent technologies to deploy green and low-carbon networks in order to conserve energy and reduce emissions in various industries.

- **Ubiquitous 10 Gbit/s, ultra-low latency, ultra-high availability and other advanced requirements –** users constantly demand more immersive experiences that connect the virtual and real worlds, which requires a network speed of 10 Gbit/s or higher. Use cases such as telemedicine, autonomous driving and smart manufacturing require end-to-end latency of 1 to 10 milliseconds (ms) and reliability of 99.999% or higher. By 2030, businesses and individual consumers will require 100-fold greater core capabilities on communications networks, including bandwidth, latency and availability.

- **Scenario-based slicing, elastic bandwidth, deterministic SLAs, and other new requirements –** digital transformation of core production scenarios in various industries requires scenario-based private networks and slices. For example, large manufacturing enterprises need scenario-based slices for offices, production control, quality inspection, security management and marketing services. They want to adjust application traffic in real time, allocate bandwidth on demand and use services with deterministic service level agreements (SLAs).

- **Zero-wait provisioning, preventive maintenance, visualized management, and other experience requirements –** timeliness, stability and visibility of network services will become more important as key production scenarios in various industries are migrated to the cloud. For example, enterprises require delivery of a zero-wait experience based on e-commerce subscription, self-configuration provisioning and one-stop access to multiple clouds. When using and managing networks and services, enterprises want delivery of a zero-trouble experience based on preventive and predictive maintenance, and independent and visualized management.

To overcome these challenges, operators have been accelerating the transformation of network automation and intelligence. AN has become the preferred choice for many and is expected to drive the digital, intelligent and green development of ICT networks.

It is CSPs' responsibility to figure out how to use automated and intelligent technologies to deploy green and low-carbon networks.

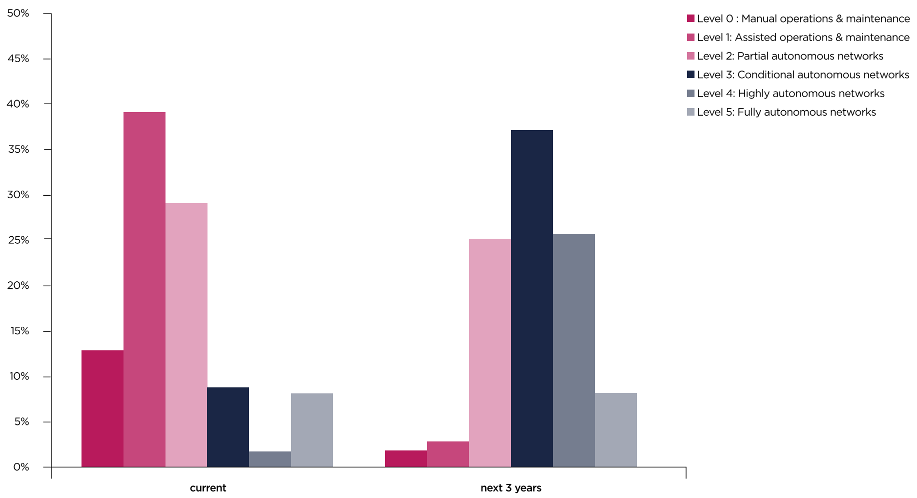
2.2 AN INDUSTRY DEVELOPMENT – CSPs

Industry consensus is developing around AN, and the trend is for CSPs to move toward intelligent network automation. Compared with last year, AN practices have improved in terms of scale (number of participating CSPs) and depth (ANL approach, APIs and effectiveness indicators).

The graphics below from TM Forum's latest AN survey and report show that CSPs believe they will make significant progress toward L3 and L4 automation by 2025, and that the majority of operators have a vision and strategy for automation.

> **"CSPs believe they will make significant progress toward L3 and L4 by 2025, and most have an AN vision and strategy."**

CSPs' AN level now and in 3 years



CSPs' AN visions

9% We have **no specific vision** apart from a continued commitment to cutting costs

54% We have **a vision that involves the continual improvement** and automation of operations with increased investment

37% We have **an ambitious automation strategy** with significant investment planning that will result in a full transformation of our operations

TM Forum, 2022

Figure 2: CSPs' AN progress and strategy

Some pioneering CSPs like China Mobile, which is widely recognized as the most advanced AN-enabled CSP in the world, have formulated their overall strategies and plans for AN in a top-down manner based on service strategies and operational requirements, proposing the goal of achieving L4 in some or all scenarios by 2025. Many operators are also dedicated to taking the bottom-up path to simplify networks and enable agile service innovation. They are continuously incorporating new solutions to evolve Self-X capabilities on their networks and deliver a Zero-X experience, enabling new business opportunities and improving operational efficiency. Following are examples of how some leading CSPs are approaching their AN strategy.

"CSPs are continuously incorporating new solutions to evolve Self-X capabilities on their networks and deliver a Zero-X experience."

AIS is dedicated to providing distinctive customer experience through its Cognitive Telco Strategy, which is based on AN and IT intelligence in a "Dual Technical Engine" to realize zero-touch operations through network, customer, and partner data and insights to support L4 automation.

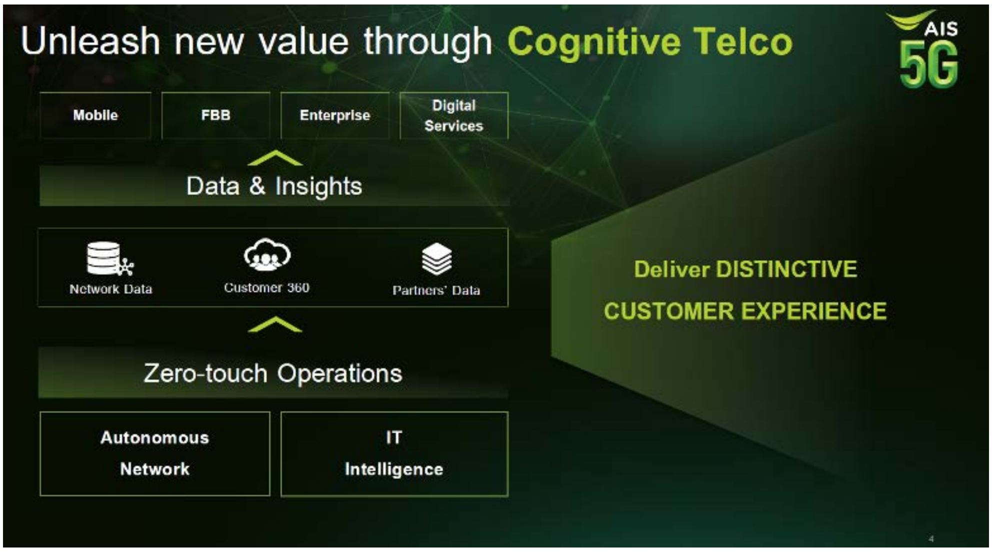


Figure 3: AIS Cognitive Telco Strategy

China Mobile has been continuously improving the digital intelligence level of network management systems (NMS) and network elements (NEs) and encouraging industrial collaboration at the same time. As the leading CSP in practicing AN, China Mobile is the first in the industry to put forward a systematic level evaluation model, focusing on five domains of radio access network (RAN), core, transmission, IP and network cloud, combing out more than 200 core capabilities and more than 1,000 specific scenarios around key services including individual services, home services and 2B services.

Technical assessment principles are well defined, together with 24 end-to-end effectiveness indicators, to measure the effectiveness and practical results brought by AN. This methodology has been contributed into TM Forum assets such as Autonomous Network Levels Evaluation Methodology (IG1252) and Autonomous Networks Business Requirements and Framework (IG1218) to promote common agreement.

In the past 2 years, China Mobile has actively initiated more than 10 whitepapers and over 30 standards on AN in standards organizations such as 3GPP, ETSI, CCSA, NGMN and GTI. After two years of ANL evaluation and autonomy enhancement, China Mobile's network was upgraded from L1 in 2020 to L2 at the end of 2021 and is planned to be fully L3 in 2023. The upgrade includes the following enhancements:

- **Digital experience improvement from users' perspective with zero waiting, zero failure and zero contact service.** Now home broadband services can be provisioned in hours and individual services in minutes, and provisioning times for business services are further shortened, with 5G private network services being provisioned in days and cloud network private line in minutes.

- **Digital transformation promotion from an operations, administration and management (OAM) perspective with self-configuration, self-healing and self-optimization network.** OAM efficiency has improved by 10% to 20% in general. Innovative energy-saving schemes are piloted and largely promoted in key scenarios such as 4G/5G base stations, Internet data centers (IDC), slicing packet network (SPN), etc., which aims to help China Mobile realize the goals of reducing energy consumption and carbon emissions by 20% in 2025 compared with 2020 and achieving energy savings of over 40 billion kilowatt hours (kWh). AI breakthroughs are realized in key scenarios with 244 mature capabilities and applications deployed on the Jiutian AI platform, and average daily API calls total more than 6 billion. These improvements are accelerating the value transformation of the innovation achievements of Autonomous Network.

"China Mobile aims to reduce energy consumption and carbon emissions by 20% in 2025 compared with 2020 and achieve energy savings of over 40 billion kilowatt hours (kWh)."

中国电信 CHINA TELECOM

"Ultra-premium customer experience, ultra-fast telecom services and ultra-intelligent cloud network operations" are all part of China Telecom's Autonomous Cloud Network Operations vision. With the goal of achieving L4 by 2025, the company is focusing on all production scenarios of cloud network operations. In particular, China Telecom is accelerating evolution of the next-generation cloud network operations service system to the cloud network operating system, continuously building native autonomous capabilities for network+cloud and streamlining end-to-end service flows, all of which increase service growth and improve operations efficiency.

In 2022, China Telecom released the China Telecom Cloud Network Operations Autonomy White Paper and is comprehensively promoting autonomous cloud network operations. Based on the concept of "cyclic evolution in four dimensions and five steps", China Telecom started formulating cloud network operations autonomy standards and operations practices. Based on 300 evaluation tasks, level evaluation standards have been developed for two products: 5G Customized Network and Cloud Private Network 3.0. Standards have also been established for four professional networks: 5G, all-IP network, all-optical network and e-Cloud. In addition, three categories of effectiveness evaluation indicators have been proposed.

China Telecom actively participates in the formulation of international and industry standards for AN and is playing a leading role in defining more than 20 standards with standards organizations such as TM Forum, ITU-T and CCSA. The operator is also piloting level evaluation at the provincial level, optimizing the evaluation standards, improving their feasibility and integrity, and promoting level evaluation and autonomous cloud network operations in the group and all 31 provincial subsidiaries across China.

In March 2020, China Unicom formally proposed the vision of moving toward AN and released the China Unicom Autonomous Network White Paper 1.0, which proposed the first AN level evaluation system in the industry. In 2021, China Unicom further defined the systematic AN implementation approach "Tri-in-one" to accelerate the AN evolution, and deployed the digital management platform. At the end of 2021, China Unicom summarized the AN practice experience in group and provinces and released its second white paper, China Unicom Autonomous Network White Paper 2.0, further proposing the AN vision, objectives and level characteristics, which have been incorporated into TM Forum's ANL work (**see page 6**):

- **L1: System assist –** system-assisted sensing and execution
- **L2: Intelligent awareness/automated execution –** static, rule-based awareness and analysis
- **L3: Intelligent analysis –** policy-based intelligence awareness and analytics
- **L4: Autonomous closed-loop –** implement intent-driven closed-loop control under human supervision
- **L5: Self-learning and adaptive decision-making –** self-awareness, self-analysis, self-decision and self-execution.

Leveraging the systematic approach, China Unicom injects the capabilities of AI and intelligent automation (IA) into the full lifecycle of network planning, construction, maintenance and optimization. It has already applied the capabilities to more than 1 million network elements. By promoting the solution for improving AI and intelligent automation levels to all operating companies, China Unicom is achieving outstanding outcomes from the view of the whole network operations O&M including:

- Enterprise service provisioning efficiency improved by 69%
- Intelligent capacity allocation saves more than 5.7 million RRC (radio resource control) licenses
- Broadband network quality complaints reduced by 30%
- AI intelligent energy savings of 200 million kWh per year.

Chunghwa Telecom (CHT) views autonomous networks as a key technological enabler to deliver better customer experience and improve business agility. Since 2019, CHT has developed several data-driven operations automation solutions in production to realize closed-loop automation for specific network scenarios. Here are some highlights of the measurable impacts:

- After applying the supervised machine learning algorithm to automatically assess and recover dormant 4G/5G mobile cells, service dispatch has been effectively reduced by around 11%, and the availability of base stations has reached at least 99.2%.
- By implementing the closed-loop automation mechanism for traffic engineering practice (e.g., congestion mitigation & rerouting) across the fixed-mobile converged transport network, AN operation has been optimized to be five times faster than the previous non-autonomous process, such that the CapEx of the company's transport network is effectively saving 16% per year.

CHT will evaluate AN maturity for the entire lifecycle of network and service management across different network domains, then prioritize its work to create a comprehensive roadmap that considers customers' needs, business strategy and technology readiness. The goal is to achieve L4 in key selected scenarios by 2025.

HKT continues to strengthen its quad-play platform and enhance synergy across services to offer one-stop shopping to customers. HKT assists enterprise and public bodies in navigating the digital transformation journey by harnessing its integrated fixed-mobile network and the latest technology like Autonomous Network. HKT further develops its digital ecosystem by integrating a loyalty program and a host of online services to meet customers' health, financial services and other needs, further extended with the company's presence in the Metaverse.

MTN has updated its practice of building a target architecture and ANL evaluation and has added more innovative use cases in its "Autonomous Network Framework 2022", which is in line with the company's Ambition 2025 Strategy

MTN completed a proof of concept (POC) and commercialized five AN use cases in 2021 and plans 10 additional use cases in 2022 based on the AN framework. All MTN operating companies are aligned with the AN strategy and target architecture and are using standard ANL definitions and evaluation methodology provided in TM Forum's Autonomous Networks Levels Evaluation Methodology (IG1252) plus use cases and effectiveness metrics to measure the business values.

MTN will put the AN framework into practice focusing on the five key scenarios below, which will help the company evolve to intent-aware operations based on experience-driven automation and achieve its L4 target goal by 2025.

1. One-stop cloud-network service
2. Transport for 5G readiness
3. AI for smart operation
4. Premium home broadband experience
5. Fifth Generation Fixed Network (F5G) AN standardization deploying solutions including optical premium private line, AI-driven network assurance, congestion-free network, DQ ODN, cell outage analysis, intelligent battery backup, and 4/5G user migration and development.

An approach that extracts intent from natural interactions is key to rapidly delivering overlay solutions that meet the requirements of NTT Group's IOWN-CF (Innovative Optical and Wireless Network – Cognitive Foundation) concept. While discussions based on business use cases are extremely useful for realizing concepts, standardization is also key to the expansion of B2B2X businesses. As such, NTT is grateful to TM Forum for providing the opportunity to work with its many partners.

Orange is the champion and co-founder of the AN Hyperloops concepts and Catalyst (**see page 36**). The company has long had a role of structuring telco markets with innovation concepts and operational frameworks. A couple of years ago, the need for autonomous systems arose, and Orange was one of the initiators of TM Forum's AN Project, signing [the first AN whitepaper.]

Orange created the AN Hyperloops Catalyst with NTT, and today the companies are co-leading it, exploring new telco business cases. As key partner of the 2024 Olympic Games and other big events, Orange is volunteering to study and build the framework of a new type of platform and services. This year the company is looking at smart stadium/smart tourism use cases as an opportunity to propose business solutions through Orange's B2B brands: Orange Events and Orange Business Services.

Telecom Argentina (Telecom) has defined the following drivers to move towards Autonomous Networks:

- Optimize workflows, reducing human error optimizing the processes
- Improve time to market, CapEx and OpEx
- Operate more dynamic and complex networks efficiently
- Expose networks and platforms as a service to build new services for B2C, B2B and B2B2X in general.

Telecom has built a network automation framework that unifies the standard operation processes that different networks teams use to automate tasks and process. This provides only ANL 1, not autonomy. So, now the company is starting to build a plan to go forward with higher ANL. Since it is not feasible to provide autonomy in all the domains at once, Telecom proposes a methodology, shown in Figure 4, for selecting autonomy based on the value of the use cases. By using this methodology, the company can identify use cases and domains as well analyze the autonomy impact (effort/benefits) on them.

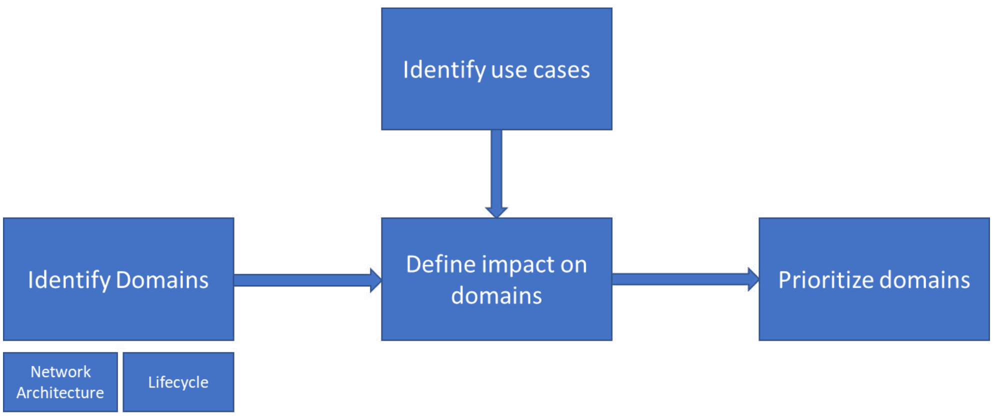


Figure 4: Telecom Argentina's AN methodology

To achieve the long-term vision, Telecom will develop the strategy and framework for the cloudification and closed-loop automation of the network infrastructure using a four-step process:

- Discovery of the present mode of operations
- Build an AN strategy and architecture framework
- Design an AN operational framework
- Align the high-level roadmap for adopting an Autonomous Network and operations.

2.3 AN INDUSTRY DEVELOPMENT – STANDARDIZATION

AN standards have experienced rapid and vigorous development over the past year. As of July 2022, several SDOs including TM Forum, 3GPP, ETSI, CCSA and IETF have researched and formulated standards based on their focuses and fields of expertise, launching more than 40 AN projects.

Preliminary cross-organization collaboration has been established, with TM Forum taking the lead in organizing a multi-SDO collaboration platform joined by GSMA, 3GPP, ETSI, CCSA, IETF, ITU-T and IEEE. The group started an in-depth discussion about technological collaboration in 2022. The table below shows five standard directions defined for AN.

SDO	Requirement and Use Case	5 Standard Directions of Autonomous Networks				
		ANL	Evaluation System	Architecture	Interface	Key Technology
tmforum	General requirements and cases Best practices of carriers	Generic ANL	Generic ANL evaluation	Autonomous Networks reference architecture	General intent models and Autonomous Networks API map	Closed-loop technologies
GSMA	Wireless requirements and use cases					
3GPP A GLOBAL INITIATIVE	Wireless and core network requirements and cases	Wireless- and core network-specific ANL	ANL evaluation for wireless and core networks	Layered, domain-based, and service-oriented architecture for wireless and core networks	Intent models and interfaces for wireless and core networks	SON and MDAS
ETSI				Service-oriented architecture of the Zero-touch Network & Service Management (ZSM) resource layer F5G E2E management and control architecture	ZSM resource intents NFV intent management interfaces and information models	ZSM closed-loop management, digital twins, and AI enablement ENI policy-based automation NFV MDAF interfaces
IETF	IBN: network measurement intent use case			ACTN architecture OPSA: level-based automation architecture based on the YANG model	SBIs in the ACTN transport domain OPSA: L2NM, TE, and northbound performance reporting models TEAS: slice service intent interfaces	IBN: intent classification and digital twins OPSA: service assurance closed-loop architecture and root cause locating NetMod: closed-loop automation, policy management, and configuration management
IEEE	Autonomous Networks O&M management principles					
CCSA	Autonomous Networks requirements and use cases	Generic ANL +domain-specific ANL	Generic ANL evaluation+domain-specific ANL evaluation	Autonomous Networks technical architecture, functional architecture, and data architecture		Intent management and knowledge management
ITU-T SG13	Technical Specification Use cases for Autonomous Networks	Framework for evaluating intelligence levels of future networks including IMT-2020		Architecture Framework for Autonomous Networks		Machine Learning, closed-loop control, and trust in Autonomous Networks

Table 1: Defining AN standards

Meanwhile, various industries and SDOs have started to explore new technologies in popular projects focusing on intent interfaces, ANL evaluation and API maps in order to facilitate the evolution towards higher-level ANs. For example:

- **Intent model interfaces –** TM Forum is defining a unified intent metamodel, and 3GPP and ETSI's Zero-touch Network and Service Management (ZSM) team are also defining intent models for resource domains in various network domains. Multiple SDOs have started to coordinate intent model standards, hoping to develop models compatible with different domains and interoperable interfaces.

- **ANL evaluation –** TM Forum is developing generic ANLs, while ANL evaluation use cases, and requirements for the wireless domain are defined in 3GPP Release 17. The ANL evaluation in specific use cases is further researched in 3GPP Release 18.

- **API maps –** to facilitate the evolution towards higher-level ANs in different service scenarios, APIs need to be abstracted and decoupled from network technologies and evolve towards intent APIs. Many SDOs have taken initiatives to explore API maps. TM Forum has launched an Autonomous Networks API Map project to study the framework and method for mapping ANLs to the API system and to examine the kind of API system required for L4 and L5. 3GPP Release 18 is also working on the mapping between ANLs of different service scenarios in the wireless domain and APIs.

In China, CCSA TC7 held an initial AN joint meeting in July 2021 and by July 2022 had held five. The SDO has initiated 25 related industry standards and 10 research topics, and developed a generic ANL and domain-specific ANL system. Multiple standards will be released in 2022. In an effort to accelerate industry development, CCSA TC610 has set up an AN industry collaboration platform focusing on requirements research, standards formulation, experimentation platform construction, and evaluation and certification.

> **"Multiple SDOs have started to coordinate intent model standards, hoping to develop models compatible with different domains and interoperable interfaces."**

2.4 CHALLENGES TO LARGE-SCALE DEPLOYMENT OF ANs

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

1. How to measure the business value and O&M effectiveness of ANs?
Can L3 or L4 ANs help CSPs provide new services and expand the digital markets in various industries? How can L3 or L4 improve service quality and experience? What benefits can L3 or L4 offer to improve network resource usage, lower O&M costs and improve O&M efficiency? These key problems need to be considered when carriers formulate AN strategies and evolution paths.

2. How to implement a level-based autonomous closed loop and finally enable agile services and business closed loops?
The implementation of ANs requires cross-layer collaboration between networks and operations systems, and cross-domain streamlining of core, bearer, transport and wireless domains. How can operators develop autonomous capabilities from bottom to top and implement a level-based autonomous closed loop? How can they quickly integrate underlying capabilities to enable agile services? How can they facilitate AN construction based on business value in a top-down manner to achieve a business closed loop? These problems are yet to be resolved by CSPs.

3. How to develop the L4 target profile for each network domain and set the evolution path?
What is the L4 target profile of each network domain? What new digital services, business models and service capabilities can be provided? What are the technical features? What is the target architecture? What specific technical capabilities need to be developed? What new operations changes will emerge? What are the evolution paths and how to select them? These are the questions to be answered by CXOs of CSPs and all industry partners.

4. How to deploy full-stack AI and leverage the collaboration between cloud-based centralized AI and network-based distributed AI?

Introducing AI to communications networks in order to upgrade highly complex networks to ultra-intelligent systems has become the industry consensus. However, what is the target architecture for ultra-intelligent systems? Is it a centralized ultra-intelligent brain that commands the entire network? Or is it an efficient and collaborative distributed cerebellum? How will operators deploy full-stack AI in a coordinated manner? How can they leverage the collaboration between cloud AI and distributed AI? The entire industry needs to jointly explore these questions and find win-win answers.

5. How to enable industry partners to collaborate and innovate, build a healthy ecosystem, and upgrade and evolve at the same time?

The implementation of ANs involves theoretical research and technological breakthroughs in multiple sectors including communications, IT, AI and automation. Many concepts and technologies are still being defined and verified. How can the positioning and collaboration of all parties be standardized? How will the sectors strike a balance between return on investment and developing cutting-edge technologies? How to design a schedule for upgrades and evolution is a challenge that must be overcome.

6. How to establish process mechanisms and develop skills for ANs?

Tremendous efforts have been made to use machines to equip employees with O&M capabilities and transform the troubleshooting mode from ticket forwarding, which is a long process, to device self-healing or one-hop closed-loop processing. How will operators upgrade employees' skills to implement automatic and intelligent O&M? How will they inject O&M knowledge, train, and supervise machines in a low-code manner? Answering these questions is key to the successful implementation of ANs.

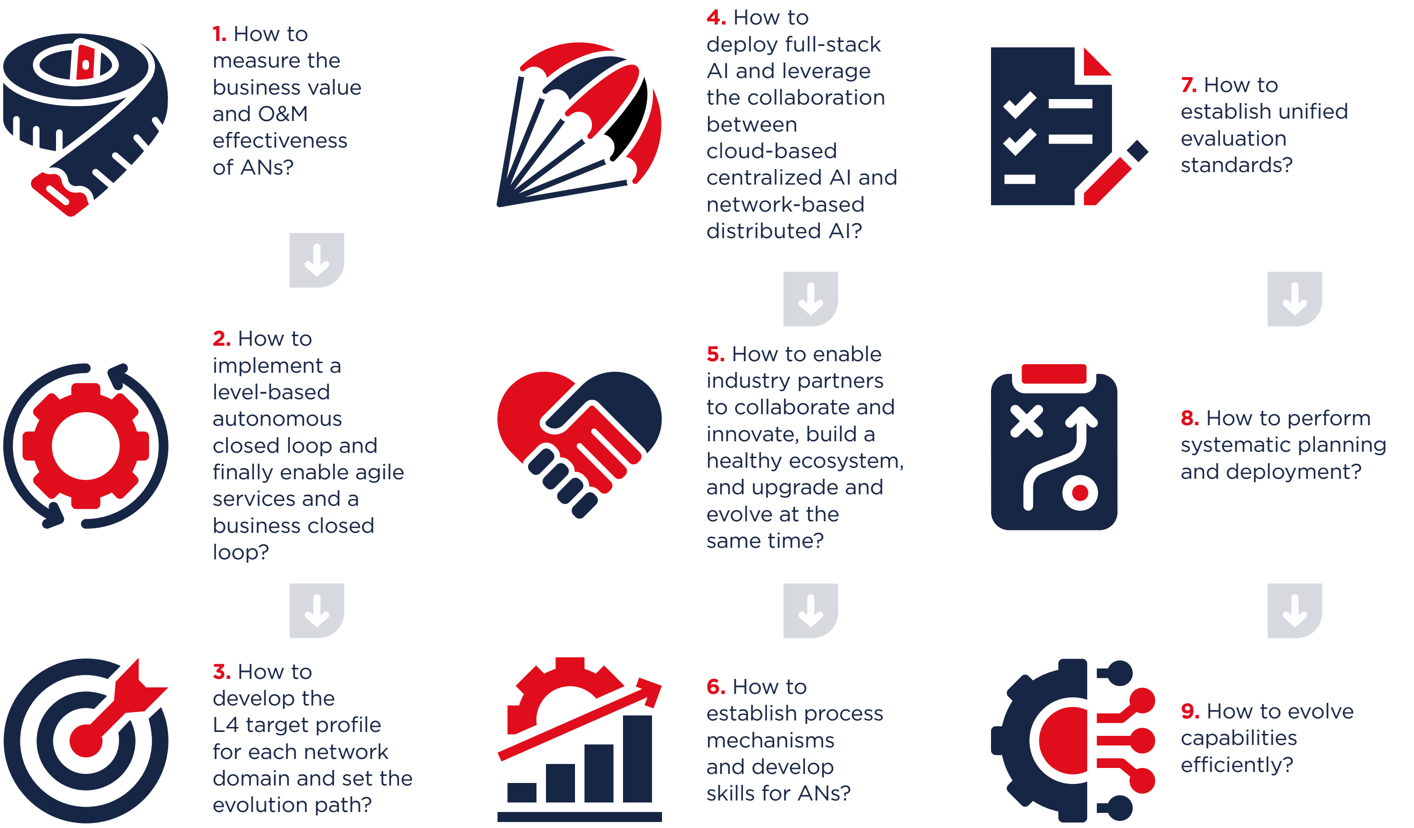


Figure 5: Challenges to deploying ANs

7. How to establish unified evaluation standards?
Many CSPs and suppliers have been working on the objectives of L3 and L4 autonomous capabilities. However, due to different methods of evaluation, multiple evaluation scopes and varying degrees of understanding, it is difficult to compare and evaluate the ANL of industry players. Therefore, it becomes necessary to jointly define unified evaluation standards.

8. How to perform systematic planning and deployment?
It is challenging for CSPs to perform ANL evaluation on all products, services and domains. Plus they must, correlate standards at the domain level and promote cloud network operations autonomy for the entire network based on the unified goal, planning and strategies.

9. How to evolve capabilities efficiently?
It is difficult to build the mapping between ANL evaluation results and effectiveness evaluation results based on business and service objectives. It is also challenging to effectively identify weaknesses of autonomous capabilities, coordinate the autonomous capabilities of the system with those of network+cloud, and adopt agile iteration to evolve to the higher levels of ANs.

"It is difficult to compare and evaluate the ANL of industry players, so it becomes necessary to jointly define unified evaluation standards."

Vision and framework of Autonomous Networks

3.

This chapter summarizes the baseline of Autonomous Networks, from the vision to the overall framework and key capabilities, which are based on TM Forum publications such as Autonomous Networks – Business requirements & framework (IG1218) as well as others (see the full list of TM Forum AN publications).

3.1 VISION

Autonomous Networks aim to provide zero-wait, zero-touch and zero-trouble customer experience for vertical industry users and consumers through intelligent infrastructure, agile operations and all-inclusive services of fully automated networks and ICT (see Figure 6). This makes them simpler for users to consume and leaves implementation complexity with the providers using cutting edge technologies. In addition, ANs need to support self-service, self-fulfilling and self-assuring telecom network infrastructures for internal users across various departments including planning, marketing, operations and management.

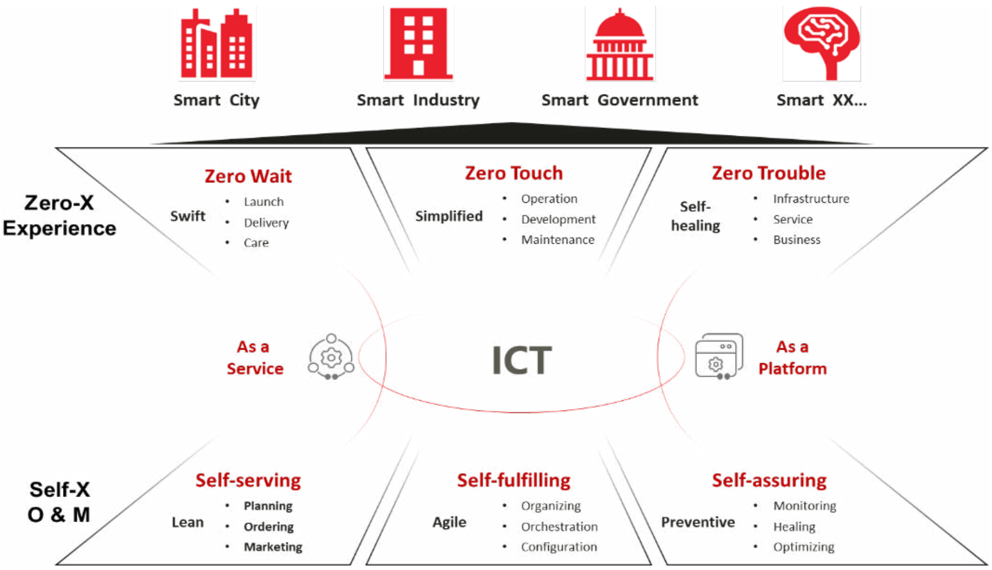


Figure 6: Autonomous Networks vision

3.2 AUTONOMOUS NETWORKS FRAMEWORK AND CAPABILITIES

The TM Forum framework that members are building identifies three layers and four closed loops to deliver Autonomous Networks. The three layers are common capabilities of operations that can be utilized to support all scenarios and business needs:

1. **Resource operations layer –** provides automation of network resources and capabilities in each autonomous domain level
2. **Service operations layer –** provides the capabilities for IT services and network planning, design, rollout, provisioning, assurance and optimization of operations across multiple autonomous domains
3. **Business operations layer –** provides the capabilities for customer, ecosystem and partner business enabling and operations for AN services.

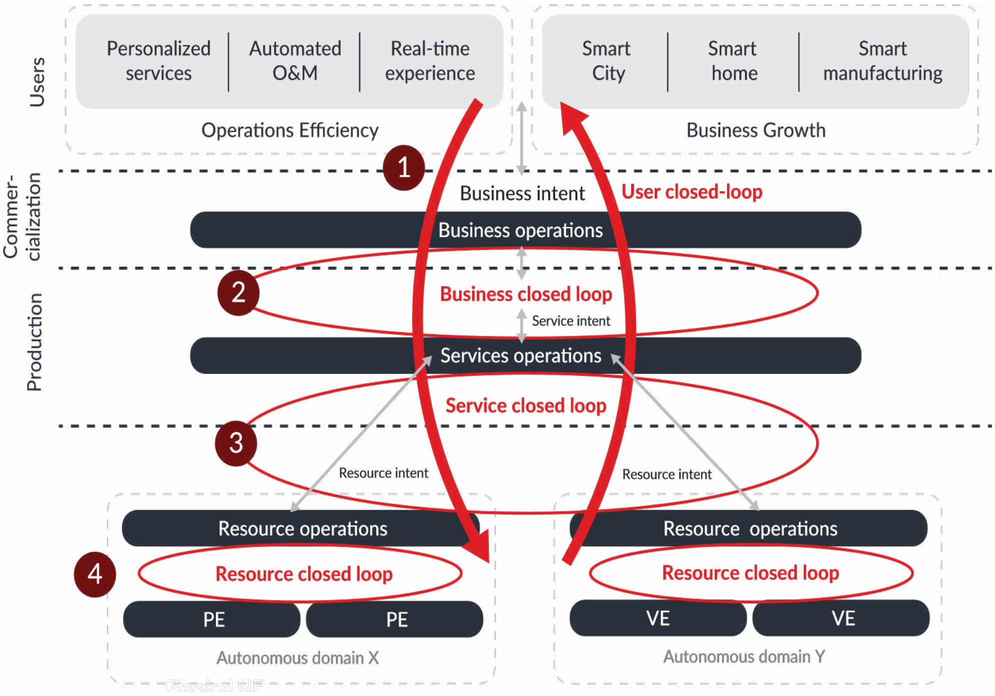


Figure 7: Autonomous Networks framework

The four closed loops identified to fulfill the full lifecycle of the inter-layer interaction are:

1. **User closed loop –** the interaction across three layers and three closed loops to support fulfillment of the user's service
2. **Business closed loop –** the interaction between business and service operations may trigger related service and resource closed loops in its fulfillment
3. **Service closed loop –** the interaction between service and network resource operations may trigger related resource closed loops in its fulfillment
4. **Resource closed loop –** the interaction of network resource operations is in the granularity of autonomous domains.

Autonomous Networks are characterized by autonomous domains and automated intelligent business, service and resource operations for the closed-loop of digital business, which offer the best-possible user experience, full lifecycle operations automation/autonomy and maximum resource utilization.

This framework is driven by business value from top to bottom and features bottom-up Autonomous Networks capabilities, with network intelligence as the foundation. Intent is a must for implementing ANs (**see page 23 for more about intent.**)

Figure 7 illustrates the rationale of correlation and interaction among the closed loops of different layers. The user closed loop is the main thread to streamline the business/service/ resource closed loops, while each of the business/service/ resource closed loops addresses the interaction between adjacent layers. The interaction between adjacent layers is simple, business driven and technology/implementation independent, i.e., communicating and fulfilling the intents (business/ service/resource) rather than technology-prone commands based on the intent mechanisms and interfaces. The different intents are used for the interactions of different layers, i.e., business intent, service intent and resource intent.

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

P People (manual) **S** System (autonomous)

Table 2: Autonomous Networks Levels (ANL)

AUTONOMOUS NETWORK LEVELS (ANL)

To fulfill and measure customer experience and SLAs, ANLs are defined to guide network and service automation and intelligence, evaluate the value and benefits of AN services, and guide the intelligent upgrade of CSPs and vendors. The technical work of ANL evaluation methodology is published in Autonomous Network Levels Evaluation Methodology (IG1252), which describes the ANL evaluation approach and operation flows, tasks evaluation criteria, scoring method, etc. The table above shows the levels in more detail.

- **Level 0 – manual management:** The system delivers assisted monitoring capabilities, which means all dynamic tasks must be executed manually.
- **Level 1 – assisted management:** The system executes a certain repetitive sub-task based on pre-configuration to increase execution efficiency.
- **Level 2 – partial Autonomous Networks:** The system enables partial automatic O&M for certain units based on predefined rules/policy under certain external environments.
- **Level 3 – conditional Autonomous Networks:** Building on L2 capabilities, the system with awareness can sense real-time environmental changes and in certain network domains optimize and adjust itself to the external environment.
- **Level 4 – high Autonomous Networks:** Building on L3 capabilities, the system enables, in a more complicated cross-domain environment, analysis and decision-making based on predictive or active closed-loop management of service and customer experience-driven networks.
- **Level 5 – full Autonomous Networks:** This level is the goal for telecom network evolution. The system possesses closed-loop automation capabilities across multiple services, multiple domains and the entire lifecycle, achieving Autonomous Networks.

"Intent is a must for implementing Autonomous Networks."

Autonomous domains

AN services involve multiple layers and closed loops. Autonomous domains serve as the basic unit that can fulfill the closed loop automation of the lifecycle of specific network operations of ANs based on the business disposition of network functions and operations (see Figure 8). This reduces technical complexity and conceals the variations of different vendor implementations, thus supporting end-to-end business requirements of AN services.

The boundary of autonomous domains is based upon the network operation requirements and business decisions of each CSP. The instantiation of autonomous domains can be defined by CSPs based on factors such as service types, network technologies, deployment locations and maintenance organization relationships. Examples of autonomous domains could be the closed loops of access, metro backbone, core, edge and the customer's network from an infrastructure perspective, or SD-WAN, VoLTE, CDN, etc., from a service perspective.

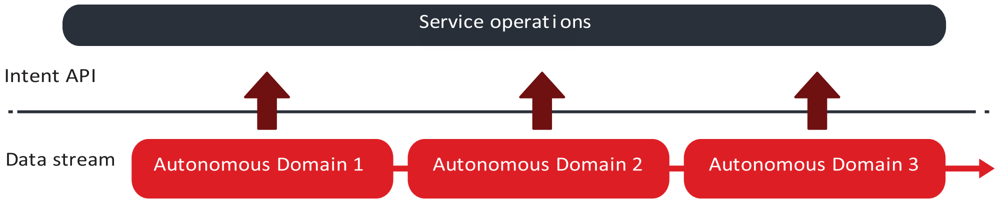


Figure 8: Example of the principles of autonomous domains

The basic principles of the operations of autonomous domains are:

- **Autonomy of individual autonomous domains –** each autonomous domain runs in self-operating mode per business objective and hides the details of domain implementation, operations and the functions of the domain elements from the users of the autonomous domains by using an abstraction layer of service APIs.
- **Collaboration of a cross-autonomous domains –** multiple instances of autonomous domains can be collaborated on by upper layer service operations using the intent-driven interaction to fulfill the lifecycle of network/ICT services.

The technical work of the AN reference architecture is published in Autonomous Networks – Reference Architecture (IG1251).

Intent-driven interactions

Autonomous networks are systems that are governed according to specified objectives or expectations known as "intents". Intents comprise the requirements, goals and constraints in a simplified manner that is abstracted from the technical inner workings. Put more simply, intents are the "what" not the "how" – meaning, you can tell the system what it should do without having to tell it how to do it.

At L0 to L3, users' requirements, goals and constraints can be reached using policy-driven operation, and requirements are carried over existing interfaces. At L4 and L5, systems will be able to adapt their own behavior with reduced need for human adaptation through intent-driven interaction. This capability will translate into business flexibility by introducing new and customized services without human intervention.

The high-level descriptions of intent are defined in TM Forum's Autonomous Networks Business Requirements and Framework (IG1281), and the technical work is published in Intent in Autonomous Networks (IG1253). The descriptions, which include Responsibilities, Intent Expression, Model Federation, Lifecycle, Interface and Interaction, aim to support use at L4 and L5, while allowing the subsequent introduction of the respective capabilities.

SELF-X OPERATING CAPABILITIES

To support the full lifecycle of user closed loop, the key capabilities are categorized in a tiered manner. Although those capabilities may be applied to the operations within a single layer/domain, they are mainly considered in support of the cross-layer closed loops in the context of Autonomous Networks.

Categories	Sub-categories
Self-serving	**Self-planning/capability delivery:** provides the customization (DIY) capabilities of network/ICT service planning, design and deployment
	Self-ordering: provides the online, digitalized and/or one-click ordering capabilities of network/ICT services
	Self-marketing: provides the automated marketing activities for general and/or personalized campaign/promotion
Self-fulfilling	**Self-organizing:** provides the collaboration of business/service/resource intent delivery on demand
	Self-managing: provides the orchestration of business/service/resource intent delivery on demand
	Self-governing: provides the governance of business/service/resource intent delivery on demand
Self-assuring	**Self-monitoring/reporting**: provide the automatic, continuous monitoring and alerting in real time
	Self-healing: provides the recovery of SLA (e.g., performance, availability and security) in real time
	Self-optimizing: provides the optimization of SLA (e.g., performance, availability and security) in real time

Table 3: Self-operating (Self-X) capabilities requirements

Full-stack AI in Autonomous Networks

In ANs, AI can be used anywhere as needed. Similar to a human brain in terms of perception, training, inference, decision-making and execution processes, AI capabilities need to be provided at different layers of ANs. Autonomous Networks are developing towards full-stack AI.

- **Business operations layer:** customer- and business-oriented AI focuses on implementing intelligent applications for various business processes, including precision marketing, customer intent translation, customer experience, and flexible combination of products and offerings.
- **Service operations layer:** AI oriented to service intents and cross-domain collaboration focuses on implementing intelligent applications for various service processes, including service intent translation, end-to-end resource orchestration and scheduling, SLA policy production, and end-to-end fault and performance management.
- **Resource operations layer:** AI in an autonomous domain is responsible for local lightweight development, model retraining and AI asset management, efficiently implementing generalization and iterative optimization of local intelligence, and supporting intelligent perception, analysis, decision-making and execution on local networks. NE AI can comprehensively detect network status in real time and perform inference, improving device-level autonomous analysis and processing.

Effective collaboration of AI at each layer can complete more complex AI tasks. This will support AI-based, automated closed-loop network operations and implement intelligent automation in different service scenarios to reach higher Autonomous Networks levels.

> **"At L4 and L5, systems will be able to adapt their own behavior with reduced need for human adaptation through intent-driven interaction."**

Method and practices for AN evaluation

4.

4.1 FOUR ELEMENTS KEY TO IMPLEMENTING ANS

Implementing Autonomous Networks requires an all-around, systematic and continuous network transformation. TM Forum has aggregated industry best practices and summarized four elements key to AN implementation:

- Creating a **vision and target architecture**
- Adopting the **AN levels**
- Using **effectiveness indicators** to measure the business value and service effectiveness of ANs
- Establishing **operations practices** to develop automated and intelligent capabilities for networks and support systems efficiency.

These elements are expected to help more CSPs plan and implement AN in a faster and more systematic manner. Figure 9 illustrates how the four elements fit together, and a more detailed explanation follows.

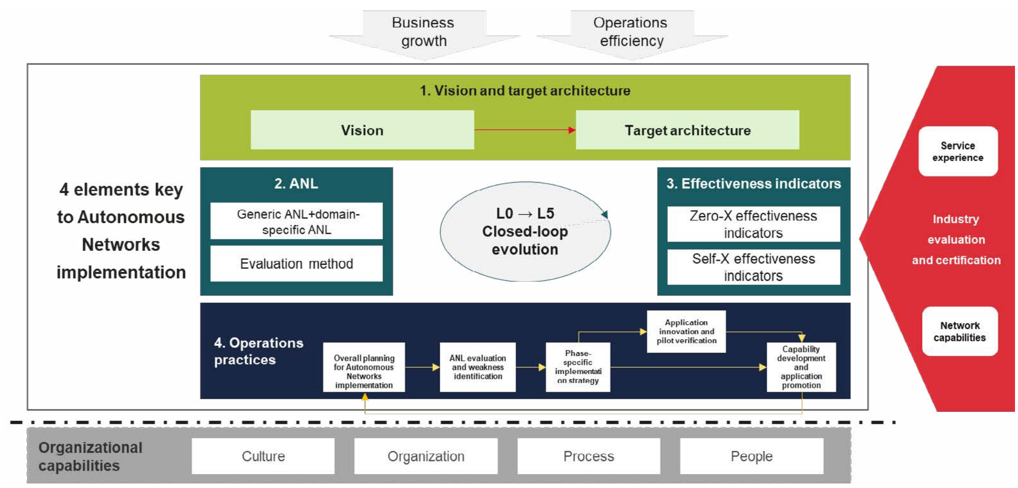


Figure 9: Four elements key to AN implementation

1. **Vision and target architecture –** the AN vision and objectives are defined to improve business growth and operations efficiency based on the overall corporate strategy and industry trends (for example, business scenarios like computing power network). Based on the live network architecture and running status, key trends (for example, 5G-Advanced, cloud-network synergy and digital symbiosis) are considered to develop a mid- and long-term target architecture in order to guide AN construction.

2. **AN Levels –** CSPs must also adopt generic ANL, domain-specific ANL and the corresponding evaluation methods to fully and objectively measure the ANL. The evaluation process requires setting up baselines and identifying weaknesses to formulate phase-specific objectives and improvement strategies. Then, CSPs can launch technical research and develop innovative applications to meet the autonomous capability requirements at each level. Finally, CSPs can verify the results, optimize strategies in real time and improve resource utilization.

“Implementing Autonomous Networks requires an all-around, systematic and continuous network transformation.”

3. **Effectiveness indicators –** it is important to measure the business value and service effectiveness of AN in terms of service growth, customer experience and operations efficiency. The value of these indicators lies in two aspects: 1) visualizing and quantifying the effectiveness and benefits of AN evolution and 2) aligning the development of autonomous capabilities with the enterprise strategy and service development trend. Effectiveness indicators are selected based on the Zero-X and Self-X visions. Effectiveness indicators and ANL are two key AN evaluation factors that jointly facilitate the fulfillment of the AN vision.

4. **Operations practices –** improving autonomous capabilities for networks and operations systems is also key. From the network (including NE) perspective, the focus is on improving converged sensing, self-configuration and native intelligence. From the operations system perspective, the focus is on improving requirement translation, end-to-end resource orchestration and cross-domain O&M optimization. In order to accelerate large-scale AN deployment, the industry has summarized a five-step operations practice method for reference:

1) AN implementation planning;
2) ANL evaluation/weakness identification;
3) strategy and direction selection;
4) application innovation/pilot project verification; and
5) capability development/application promotion.

"Authoritative evaluation and certification increase credibility, help CSPs better serve industry customers and promote win-win industry development."

Organizational capabilities and industry evaluation

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

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

The following sections provide several best practices to help readers better understand the four elements key to AN implementation, evaluation and certification.

4.2 METHODS AND PRACTICES OF AN LEVEL EVALUATION

Correlations between generic ANL and domain-specific ANL

AN levels have witnessed rapid development. A generic ANL+domain-specific ANL system has been developed. To improve industry collaboration and ensure consistent ANL concepts, principles and methodologies, TM Forum has partnered with CCSA to define the positioning of and correlations between generic ANL and domain-specific ANL, as shown on the next page.

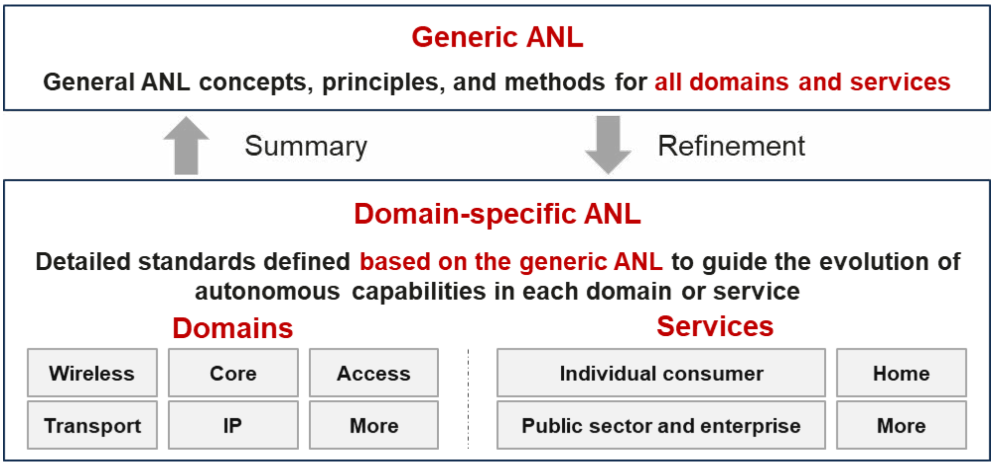


Figure 10: Generic and domain-specific ANL

- **Generic ANL is designed for all domains and services.** The core value of generic ANL is to ensure consistent O&M tasks among different domains and services in terms of dimension, granularity and terminology in order to facilitate centralized evaluation and certification, and horizontal analysis. Generic ANL measures the overall ANL across all domains and services. Operation task baselines are defined based on industry consensus (including the definitions of L0 to L5, cognitive closed loop and man-machine division of labor) from the perspective of the entire O&M process (planning, construction, maintenance, optimization and operations). For each operations task, generic technological requirements and level evaluation rules are defined from the domain and service perspective, providing a reference for defining and instantiating domain-specific ANL.

- **Domain-specific ANL is applicable to a specific domain or service.** It defines the detailed rules for the domain or service based on the generic ANL, including the specific technological requirements at all levels and baseline scenarios. Domain-specific ANL can be used to evaluate the domain or service, identify the weaknesses of autonomous capabilities in the domain or service, and guide the evolution of autonomous capabilities in the domain or service.

CHINA MOBILE'S ANL PRACTICE

First company to target L4 at scale for production by 2025

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

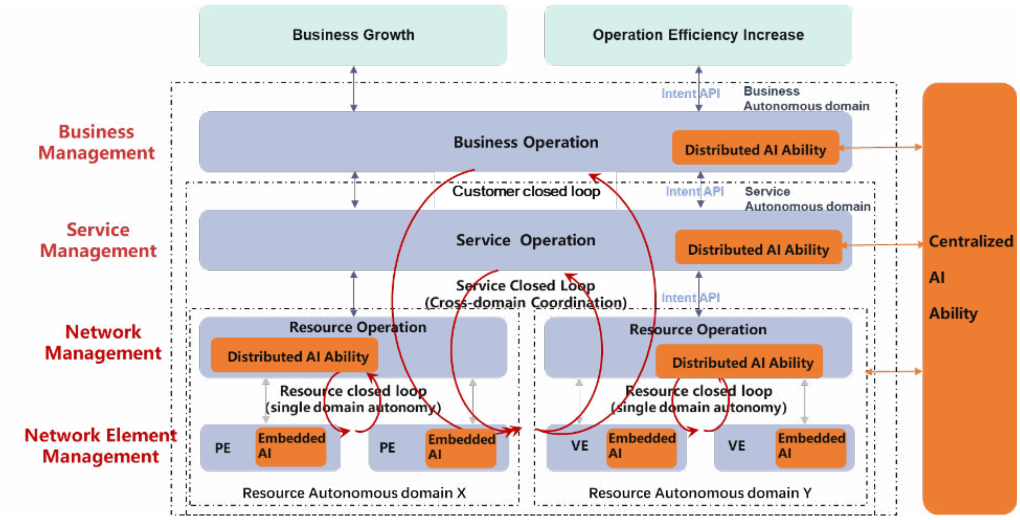


Figure 11: China Mobile's target architecture

First systematic level evaluation methodology and practice

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

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

China Mobile has defined a maturity model as shown in Table 4 to guide the system implementation. It refers to the DIKW (data, information, knowledge, wisdom) system and aims at the step-by-step construction of system cognitive ability.

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

Table 4: China Mobile's AN maturity model

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

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

CHINA TELECOM'S PRACTICE: AN CHARACTERISTICS ACROSS ANL

China Telecom accelerates the construction of cloud-network operation autonomy; focuses on closed-loop operations; faces customers, partners, products, and network + cloud; matches the development stage of cloud-network integration; and defines the intergenerational characteristics of cloud-network operation self-intelligence. The company is defining these characteristics across ANL as shown in Figure 12.

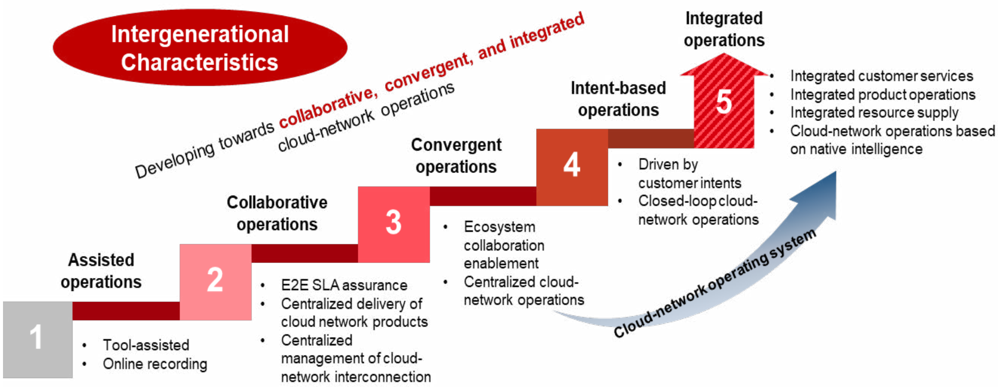


Figure 12: AN characteristics across ANL

CHINA UNICOM'S PRACTICE: ANL EVALUATION

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

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

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

Table 5: L4 ANL example

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

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

MTN'S PRACTICE: DEFINE THE DOMAIN-SPECIFIC ANL AND EVALUATE PER SUB-SCENARIO

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

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

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

Table 6: Transmission network operation task example

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

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

Table 7: Sub-scenario list example

4.3 PRACTICES OF AN EFFECTIVENESS INDICATORS

CHINA MOBILE'S PRACTICE FOR DEVELOPING EFFECTIVENESS INDICATORS

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

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

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

- **User value indicators** are designed to fulfill the Zero-X vision and improve the experience of users including industry customers, individual consumers, and partners. For example, zero-wait (average service provisioning duration), zero-touch (user self-service rate) and zero trouble (service availability).
- **O&M value indicators** are designed to fulfill the Self-X vision and reduce network O&M costs and improve O&M efficiency such as self-configuration (automatic configuration rate), self-healing (proportion of preventive and predictive O&M tickets) and self-optimizing (energy efficiency improvement rate). For details about Self-X, **see page 24.**

Step 2: List effectiveness indicators based on the service development and network maintenance objectives.

China Mobile selects the core capability automation rate as a generic indicator, which measures the proportion of L2 core capabilities. In addition, 24 detailed indicators and an indicator model are defined. Table 8 provides an example:

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

Table 8: China Mobile's effectiveness indicator example

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

Based on the effectiveness indicator list, develop and deploy corresponding IT systems. Define effectiveness indicator baselines based on the status quo. Set phase-specific targets (which can be continuously optimized). Table 9 provides an example.

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

Table 9: China Mobile's effectiveness indicator target example

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

CHINA TELECOM'S PRACTICE FOR EFFECTIVENESS INDICATORS

To measure the business value of cloud network operations autonomy, China Telecom defines the effectiveness evaluation standard framework, which includes ultra-premium customer experience, ultra-fast telecom services and ultra-intelligent cloud network operations. This framework, shown in Figure 13, can evaluate the contribution of improving the autonomous level to product services, customer experience and operations efficiency.

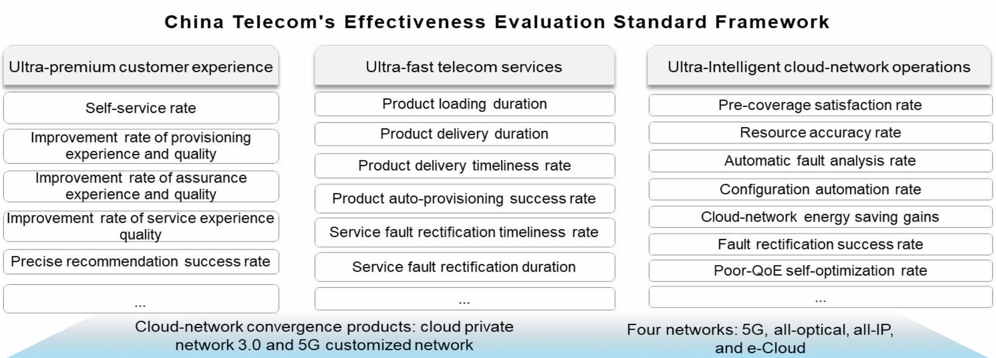


Figure 13: China Telecom's evaluation framework

China Telecom maps the operations phase and products used in this phase with the effectiveness evaluation standard framework and breaks down the end-to-end indicators for cloud-network convergence products into system and professional network indicators. The name, formulas and data sources of each indicator are defined. The indicator baselines and the year-by-year improvement goals (absolute values) for the next three years are also defined based on live network data analysis. These indicators will drive the development of autonomous capabilities and level evolution. Table 10 on the next page describes some of the indicators and targets.

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

Table 10: China Telecom's effectiveness indicator targets example

4.4 COMPREHENSIVE AN PRACTICES

CHINA MOBILE: FIRST LARGE-SCALE OPERATION PRACTICE

China Mobile's AN operation follows the closed-loop method of "industrial standard promotion, top-level design, digital intelligent capability building and application, evaluation and analysis", and systematically promotes the capability improvement and autonomous evolution of the whole network. Figure 14 shows the process.

Figure 14: China Mobile's closed-loop method

1. **Industrial standard promotion –** China Mobile has been actively contributing to the industry standards and guide all parties in collaborative deployment. Practices are summarized and shared as multiple TM Forum assets to promote shared growth.

2. **Top-level design –** China Mobile has put forward the target architecture of "2 objectives, 3 layers and 4 closed loops". Thirty-seven key capabilities have been defined, covering the full lifecycle of network operation. Autonomy evaluation has been evaluated from both the technical side and application side to better reveal the deployment effect of autonomous network.

3. **Digital intelligent capability building and application –** vendors are guided to improve built-in automation and intelligence of network elements, centralized data acquisition and control of OMC. The company continuously optimizes the OAM process, rules and policies, and data model to improve single-domain autonomy and cross-domain collaboration, vigorously promoting AI innovation.

4. **Evaluation and analysis –** 31 provincial branches are organized together to carry out capability evaluation around key domains and services. The best innovative products are selected and deployed on the whole network. Through the evaluation, shortcomings are identified and improvement plans are formulated to promote future ANL enhancement.

AN INDUSTRY EVALUATION PRACTICE: SERVICE EXPERIENCE OF SITE-TO-CLOUD PRIVATE LINE

The AN industry evaluation proposed by CCSA TC610 covers service experience and basic network capabilities. CCSA TC610 hopes to use evaluation as a starting point to enable all industry partners to deploy high-quality site-to-cloud private lines and deliver a Zero-X service experience. This will help more enterprise customers implement intelligent and agile cloud access.

“The Best Practice of Level Evaluation for AN Service Experience – Site-to-Cloud Private Line” is a level evaluation defined based on the autonomous features of site-to-cloud private lines in order to meet the SLA requirements of industry customers across all service processes for private lines.

1. Level evaluation framework for AN service experience
Based on TM Forum’s Customer Experience Lifecycle Model (GB962C), a level evaluation framework for AN service experience is developed according to the different focuses of industry customers and individual consumers in terms of service experience. This framework includes four phases:

1. **Subscribe –** includes service consultation, selection, ordering (agreement signing), renewal, and change
2. **Provision –** refers to end-to-end configuration and testing of networks and services, including those caused by network changes
3. **Use –** includes service usage, usage review, and value evaluation
4. **O&M –** includes service status monitoring, troubleshooting, quality optimization, and network and information security.

2. Level evaluation indicator list for AN service experience of the site-to-cloud private line service
Research shows that five autonomous features of site-to-cloud private lines are most important to industry customers: e-commerce subscription, elastic bandwidth for intelligent cloud access, deterministic SLA, customer-level assurance, and security and trustworthiness. Figure 15 shows 13 level evaluation indicators for AN service experience that have been developed based on the level evaluation framework to fulfill the Zero-X vision of AN.

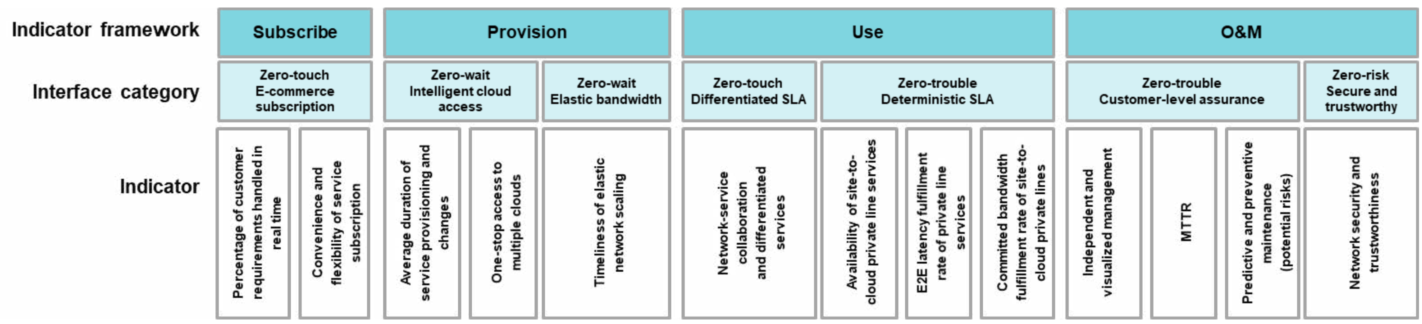


Figure 15 : Evaluation indicators for AN service experience

3. Definitions of level evaluation indicators for AN service experience of the site-to-cloud private line
Each level evaluation indicator is defined in detail from the aspects of its meaning, key evaluation points, application scope, formulas and data sources. For example:

- **Timeliness of elastic network scaling –** this indicator is used to evaluate how fast site-to-cloud private lines can adjust based on industry customers' changing requirements. This indicator focuses on two aspects. The first is how elastic scaling is initiated and performed. At advanced levels, the system automatically predicts traffic changes and initiates and completes scaling. The second aspect is the average duration of elastic scaling, which is calculated as:

Average duration = ∑(Scaling completion time – Scaling initiation time)/Number of services x 100%

Improving the experience management for site-to-cloud private lines or other 2B services, as well as the level evaluation for both service experience and basic capabilities in ANs, will become an main focus for CSPs and their suppliers. To further improve the level evaluation for AN service experience, three suggestions are offered:

- Optimize the evaluation indicators
- Define technical requirements for the level evaluation
- Launch evaluation projects.

"Improving the experience management for site-to-cloud private lines or other 2B services will become an main focus for CSPs and their suppliers."

AN reference solutions

5.

5.1 ENABLING VERTICALS

AUTONOMOUS NETWORKS HYPERLOOPS ENABLING SMART-X INDUSTRIES – SMART TOURISM/STADIUM

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

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

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

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

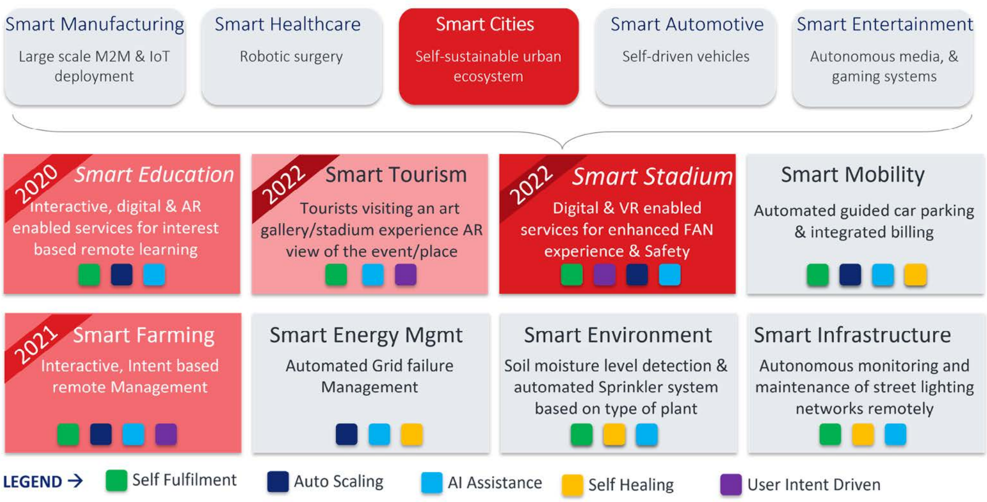


Figure 16: Examples of vertical use cases that benefit from ANs

"Deploying massive, dedicated networks dynamically and flexibly, while ensuring sustainability and efficiency is a big challenge."

> "One of the key questions CSPs are exploring is how they can improve fans' experience with autonomous drones and cameras to enrich game experiences."

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

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

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

1. Solution architecture powering ANs

To achieve ANs for vertical use cases, maturity is required across several loops including resource, service, business and user. The simplified architecture to achieve this maturity is shown in Figure 17, followed by an explanation of each level of operations.

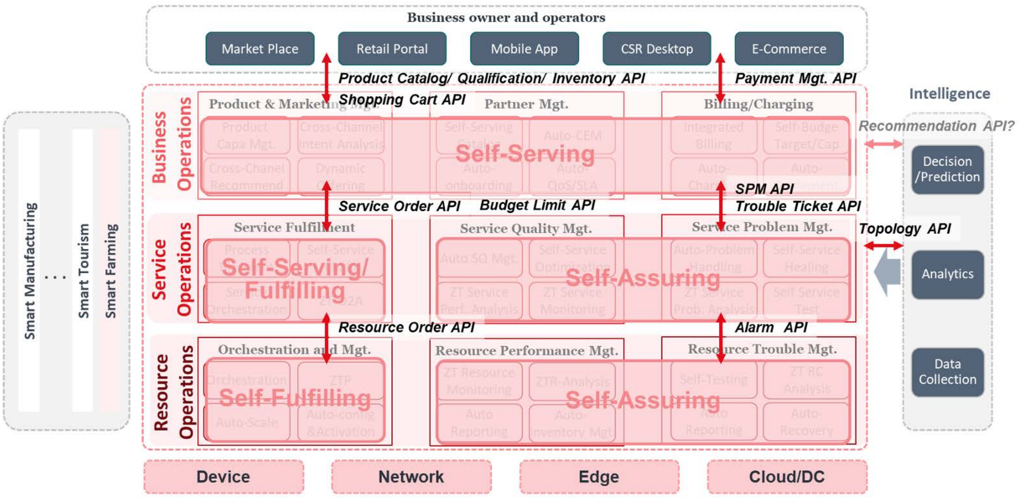


Figure 17: Simplified solution architecture of ANs

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

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

Governance and business limits of autonomous operations

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

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

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

> "One of the key elements of providing seamless autonomous services to fans is zero-friction service fulfillment."

2. Enabling smart stadium/tourism

CSPs can monetize the smart stadium/tourism use case to empower stadiums and sports clubs and to enrich fans' experience with experience and safety. They can also enable cost- and time-efficient management of stadiums by leveraging Zero-X experiences based on the AN business and technical architecture across the layers including edge cameras and drones, video capability, edge containers, virtualization, automated to autonomous operations, AI and insights analytics, and 5G. The reference architecture to achieve AN for smart stadiums or tourism is depicted in Figure 18.

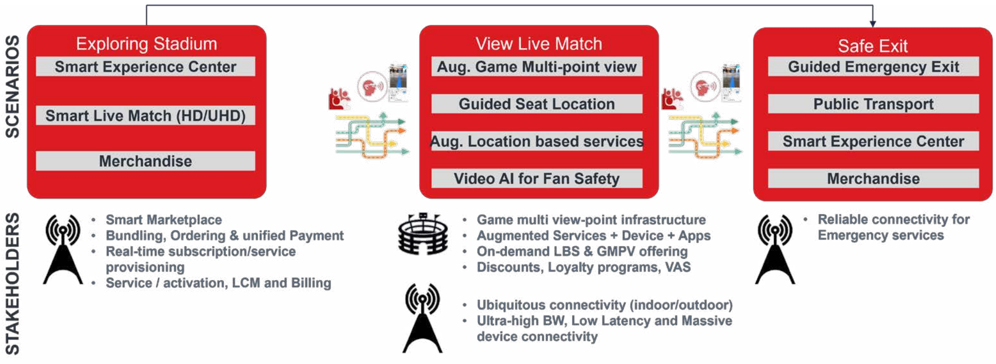


Figure 18: Smart stadium use case

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

The smart stadium scenarios described above aim to demonstrate autonomous behavior across all loops (explained further in the next section) with the 5G network as the connectivity backbone and video analytics capabilities at the edge. Autonomous self-service fulfillment is depicted in Figure 19 on the next page as an example of usage of AN capabilities. More details can be found in this Catalyst white paper.

Autonomous self-service fulfillment

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

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

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

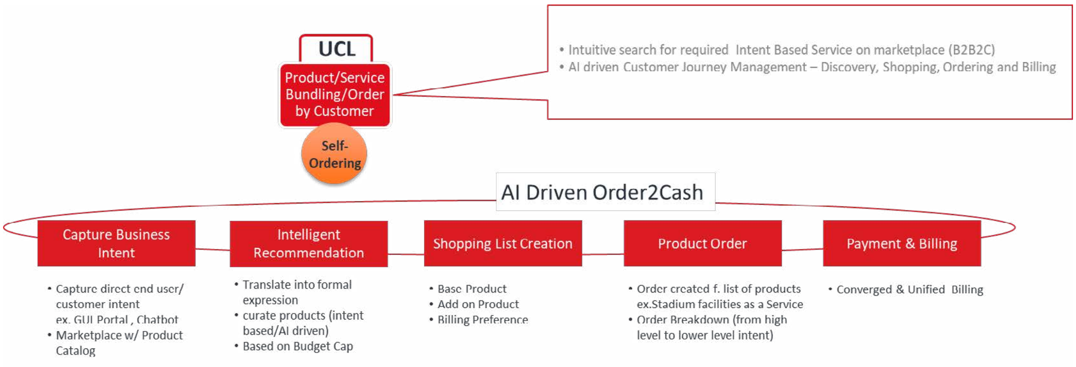


Figure 19: Self-ordering

3. Intent translation and decomposition study

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

Figure 20 shows the technologies for achieving intent-based operation. Intents are not always given as specific requirements by users. For example, ambiguous demands for functional requirements, such as "enjoying watching sports", or ambiguous demands with no index or value for the quality or performance of certain functions, such as "feeling of being there" can be assumed.

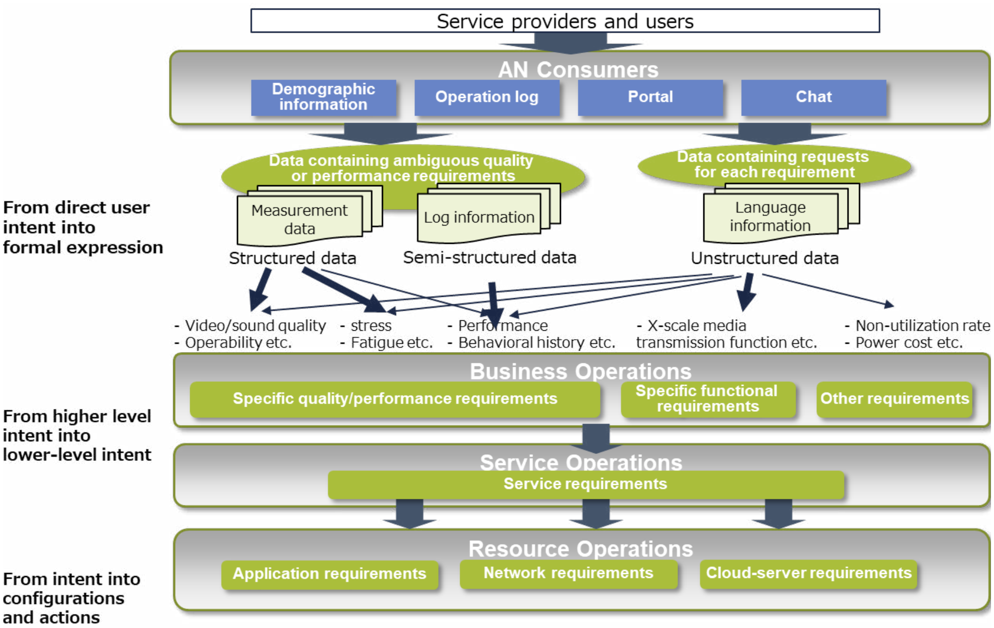


Figure 20: Fundamental technologies of intent-based operation

To apply these ambiguous intents in service operation, the team needs to break them down and define a set of requirements (intent definition) – see Figure 21. To express quantitative values of non-functional requirements related to quality or performance, the Catalyst is studying the definition of general indices for various intents and quantitative values for each index.

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

Figure 21: Intent definition

Intent-extraction technology

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

Resource-requirement-conversion technology

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

Implementation architecture of AN hyperloops

By combining Self-X capabilities with intent study, the Catalyst is exploring much new ground, and new component areas need to be introduced in reference to AN reference architecture. Intent extraction as part of knowledge and intelligence plays a major role in during the journey to usable intent-driven orchestration (see Figure 22).

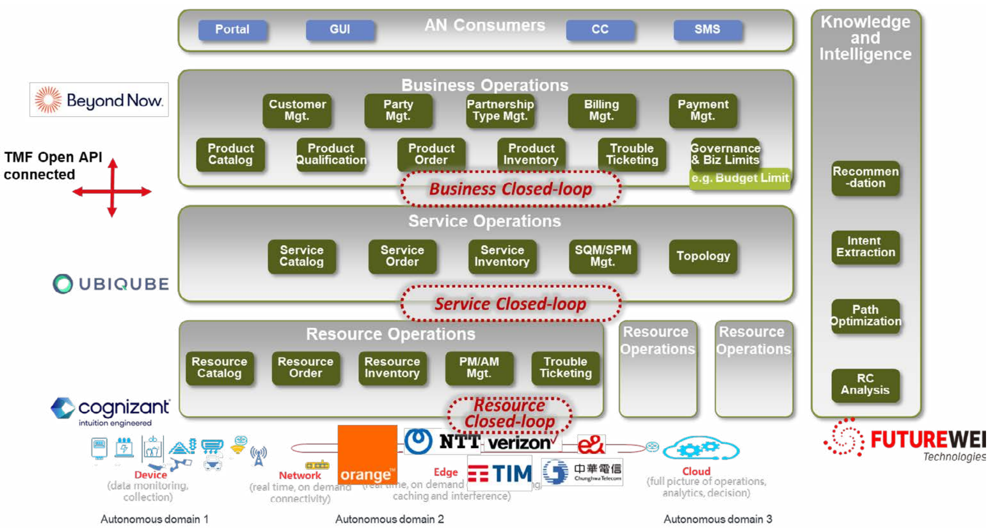


Figure 22: Implementation architecture

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

Using AI to make energy use more efficient

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

> "The Catalyst shows that the change in energy consumption over time brings time series data that can be used to understand patterns and predict future patterns."

On-demand self-service networks make eco easy

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

CHINA MOBILE: EASTERN DATA AND WESTERN COMPUTING FORCE

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

Solution

China Mobile gives full play to the resource advantages of the whole network, comprehensively promoting the capability improvement of the Autonomous Network. Through construction of its Jiutian AI platform, the company is building a nationwide, non-real-time computing power support base to achieve eastern data trained in western China. Figure 23 shows how it works.

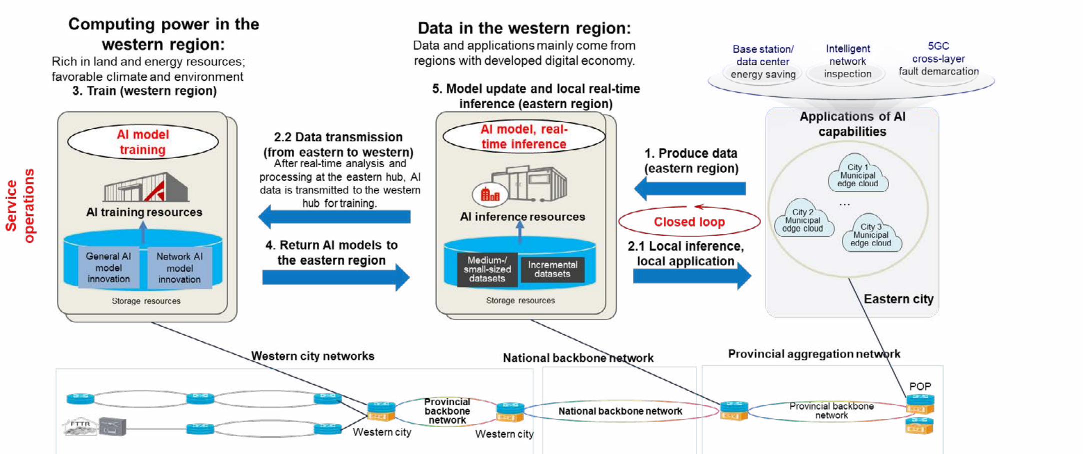


Figure 23: China Mobile's Jiutian AI platform supports energy optimization

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

"China Mobile's Jiutian AI platform is reducing carbon emissions by 30%, and overall efficiency is optimized."

Application and benefits

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

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

CHINA TELECOM: SMART MANUFACTURING – MULTI-CLOUD AND MULTI-BASE AUTONOMOUS AND FLEXIBLE INTERCONNECTION

Large manufacturers typically own multiple R&D bases, manufacturing campuses, test sites and offices. To leverage digital transformation in many areas of the business including R&D, manufacturing, office buildings and marketing departments, manufacturers require a network to suit the needs of manufacturing, research, quality inspection and marketing. Such a network featuring "multi-branch collaboration and one-point access to multiple clouds" is described in Figure 24.

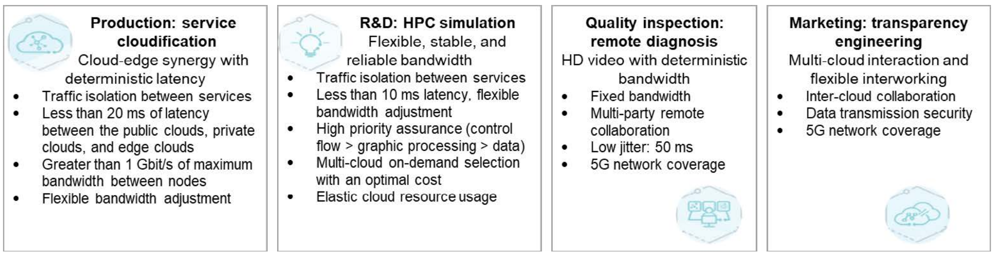


Figure 24: Manufacturers' network needs

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

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

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

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

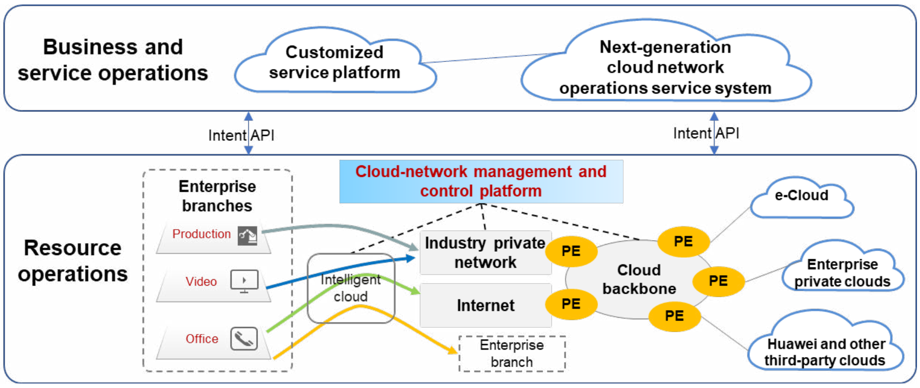


Figure 25: Overall architecture of the cloud private network solution

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

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

"China Telecom is reducing one-way latency to 3ms to provide high-quality enterprise network services."

CHINA UNICOM: AGILE SERVICE PROVISIONING – INTENT-BASED AUTOMATIC PROVISIONING OF ENTERPRISE PRIVATE LINES

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

China Unicom is committed to providing customers with zero-wait and self-provisioning agile service experience and proposes an intent-based automatic provisioning solution for private line services. The solution adopts the three-layer architecture of AN and uses intention-conversion technology to convert the customers' business intention into the specific service, sending the request to the orchestration module through the intent execution interface. Figure 26 on the next page shows how autonomous service provisioning works, and an explanation of what happens at each layer follows.

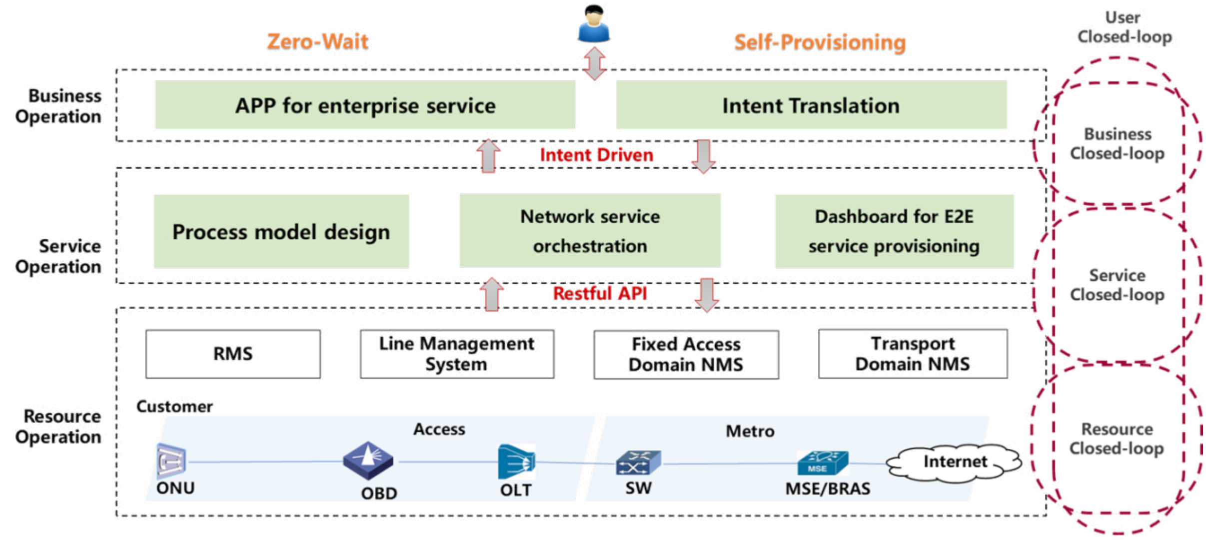


Figure 26: Autonomous service provisioning

- **Business operation-intent handler –** converts a customer's business intention into a service intention. The handler receives the customer's intention, determines the specific service through intent matching, and invokes the service through the intent execution interface. Take internet private line provisioning as an example. It is a business intention, and through intention matching decides to provision an internet private line service, such as PON.
- **Service operation-service orchestration –** this refers to the [Open Digital Architecture (ODA)] Product, Service, Resource (PSR) model. The network service is orchestrated into resource- and customer-facing services (RFS and CFS) through a graphical user interface based on the service provisioning action flow. The designed and compiled CFS model is deployed to the running state and uses an Open API to provide services. For example, the Internet private line can be orchestrated as PON access CFS, IP RAN access CFS, and fiber direct connection CFS.
- **Resource operation –** the provisioning platform is connected to the fixed access domain network management system (NMS), transport domain NMS, line management system, and public customer system, thus realizing end-to-end automatic provisioning of private lines.

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

5.2 CUSTOMER EXPERIENCE AND BUSINESS GROWTH

INTENT-DRIVEN AN (IDAN) USE CASES

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

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

Use case 1: Intent-driven Autonomous Networks for smart mobility
This use case is a cellular vehicle-to-everything (C-V2X) scenario that demonstrates how true intent implementations decouple layers and allow for better optimization of services and resources based on the business objectives defined by the CSP. CSPs want to apply autonomous network technologies and principles to the problem space of toll road operations/transportation. Figure 27 illustrates IDAN phase I.

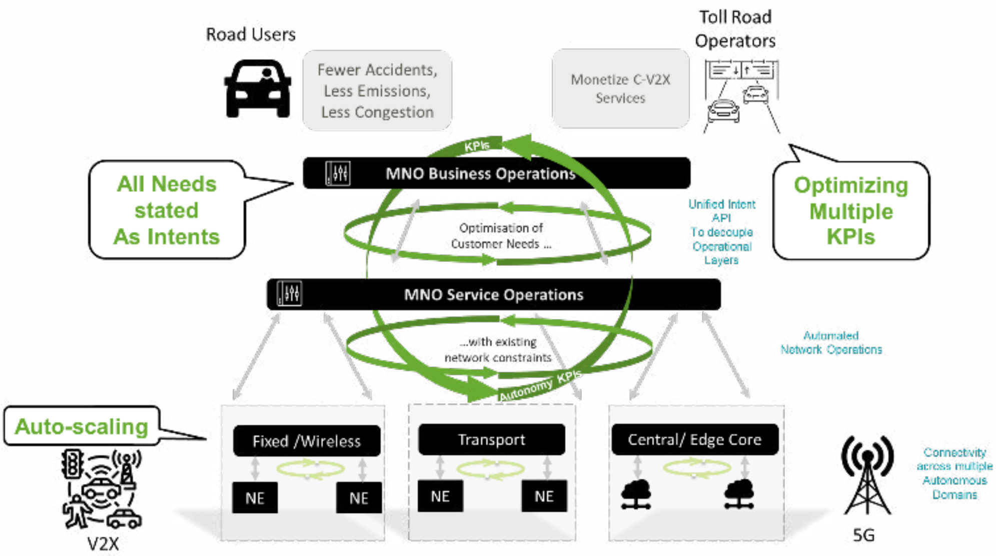


Figure 27: IDAN Phase 1 – Applying AN to smart mobility vertical industry

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

- Road users communicate their requirements at the application layer.
- The autonomous network automatically divides user requirements layer by layer (Intent API at business layer -> service layer -> resource layer), translates requirements into system instructions and executes them.
- The AN feeds back the instruction execution result to the user or upper-layer system layer by layer.

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

Use case 2: Intent-driven Autonomous Networks for dynamic pricing connectivity service
This use case demonstrates a dynamic pricing scenario that provides zero-touch customer experience, self-healing and self-optimization capabilities leveraging intent. The scenario applies to customers needing non-real-time connectivity, such as large research institutions or hospitals, which need to periodically synchronize a large amount of data with a data center or cloud. In this mode, customers can obtain higher-experience services with lower tariffs, and carriers can better utilize idle bandwidth resources to obtain more value without disrupting existing business. Figure 28 on the next page illustrates IDAN phase II.

"Customers can have a better experience if their needs are captured and translated into intent without revealing any implementation details."

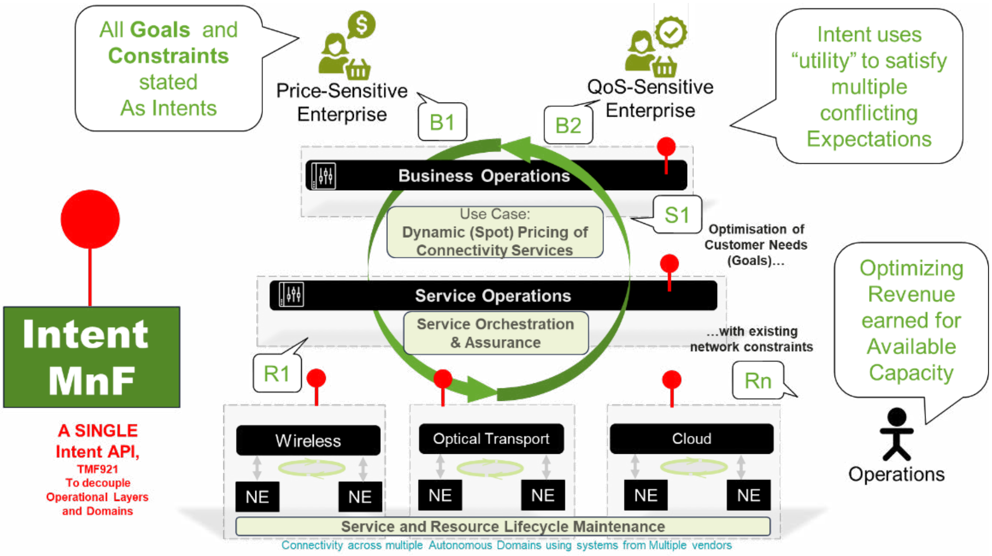


Figure 28: IDAN-Phase 2 – TMF921 Intent "red lollipop" for AN

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

The Catalyst developed a complete intent interface (from swagger to user guide to fully working reference implementation) as a formal contribution to TMF921 Intent management API and the associated intent ontology (Turtle) to make the intent approach more concrete and real. Figure 29 shows how the Catalyst uses multiple innovations to create a uniform yet flexible interface that allows the intent-driven approach to be applied to not only dynamic pricing but to any use case of scale across AN.

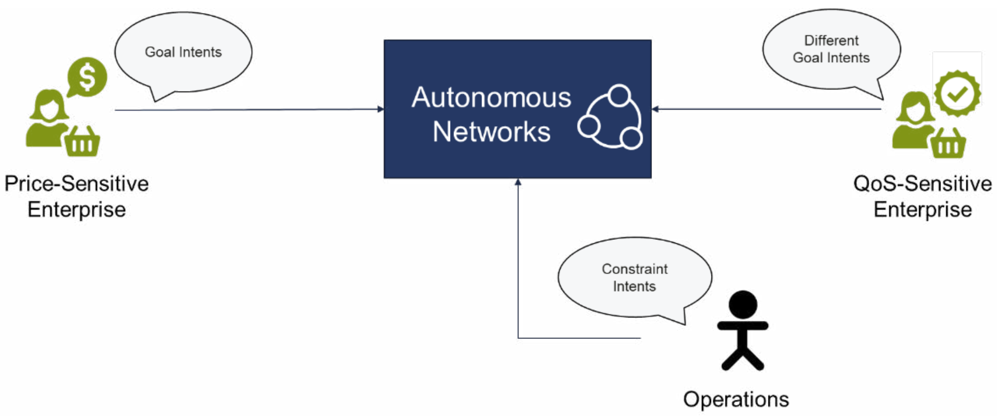


Figure 29: Intent can be applied to any AN use case

HKT: ZERO-X CUSTOMER EXPERIENCE ON HEALTH TECH APPS (DR. GO)

The Covid-19 pandemic created a market need for remote medical consultation. HKT (Hong Kong Telecom) launched a health tech platform called Dr. Go, the objective of which is to build an intelligent B2B2X platform to link up Health Care partners (hospitals, doctors, pharmaceutical companies, etc.) and patient and health products consumers. The DrGo apps (see Figure 30) connect patients and doctors through high-definition video calls. HKT, joining with Huawei technology, deploys the autonomous operation concept to enable Zero-X experience.

> "HKT's Dr. Go apps eliminate human support in booking appointments with doctors to achieve zero-touch."

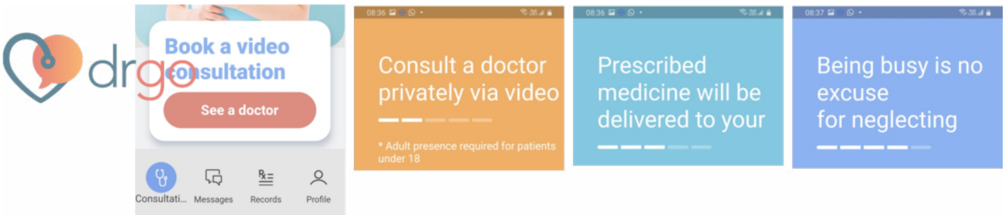


Figure 30: Dr. Go apps functions

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

To ensure quality video calls, Autonomous Operation with AI modelling and Customer Experience Index+ (CEI+) digital metrics are being used for service guarantee of all video calls. Figure 31 shows the autonomous framework concept used in the use case.

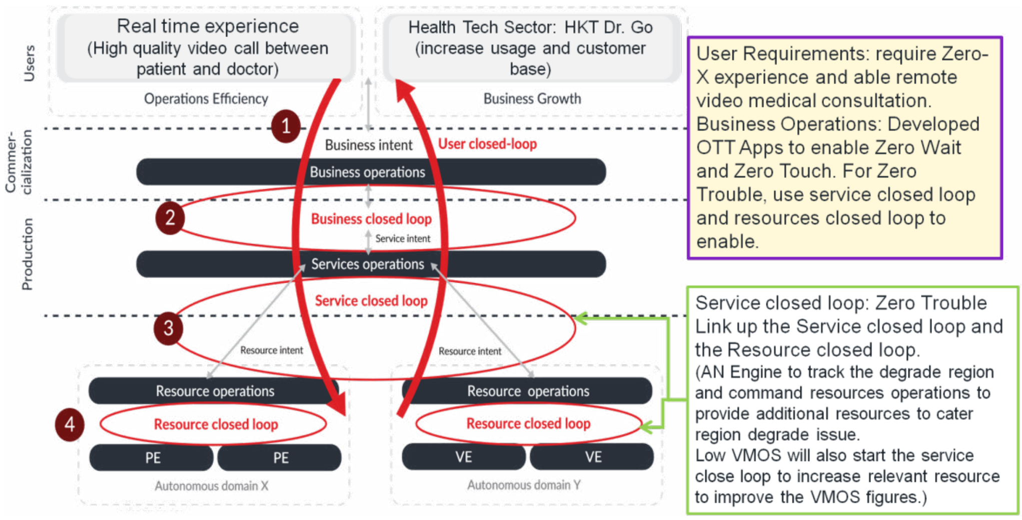


Figure 31: Dr. Go with superior CX to support Health Tech Platform

Figure 32 on the next page shows a high-level diagram on the AN approach using the Intelligent Engine. When the CEI is low, the Intelligent Engine will look at the quality of experience (QoE) and the KPI/KQI responsible for changing VMOS (Video Mean Opinion Score) figures. Identifying the problem set of figures, the Intelligent Engine will command the relevant resources cluster to provide additional resources to improve the VMOS figures.

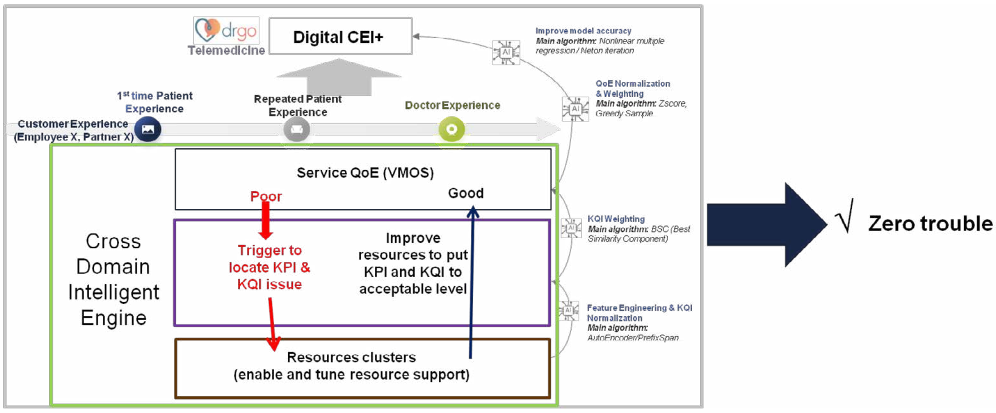


Figure 32: Intelligent Engine to support Zero-X

> "With good experience and word of mouth, the customer base using Dr. Go increased by 214% year over year."

Business benefits and outcomes

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

Next steps

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

MTN: BUILD A MOBILE BEARER NETWORK WITH THE BEST EXPERIENCE, ENABLING SELF-OPTIMIZATION AND SELF-CLOSED-LOOP MANAGEMENT

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

Solution

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

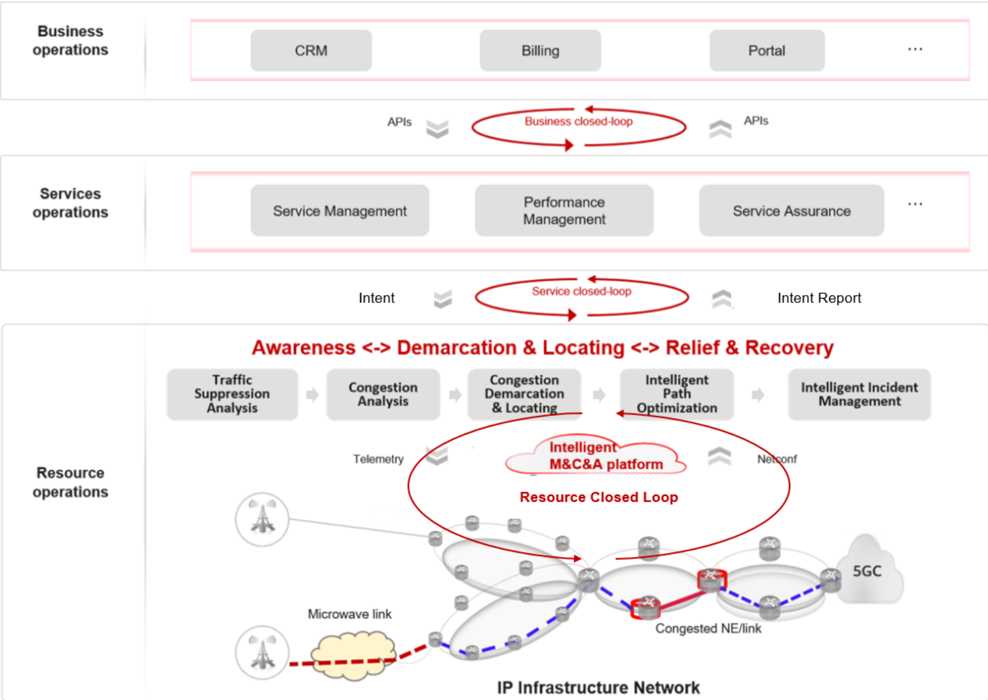


Figure 33: IP Autonomous Network with congestion-free mobile transport

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

Resource closed loop

Awareness

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

Analysis (demarcation and locating)

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

Decision and Execution (relief and recovery)

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

Intent Report

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

> "MTN Nigeria is using intelligent optimization to reduce fiber cut recovery to minutes and improve bandwidth utilization by 30%."

Service closed loop

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

Business closed loop

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

Benefits

MTN South Africa continues to use the traffic suppression model to analyze congestion on the live network and provide guidance for precise capacity expansion. The average daily traffic suppression data decreases by 28%.

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

XL AXIATA: MARKET EXPANSION THROUGH OUTCOME-BASED DECISION, INTENT-DRIVEN SYSTEM

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

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

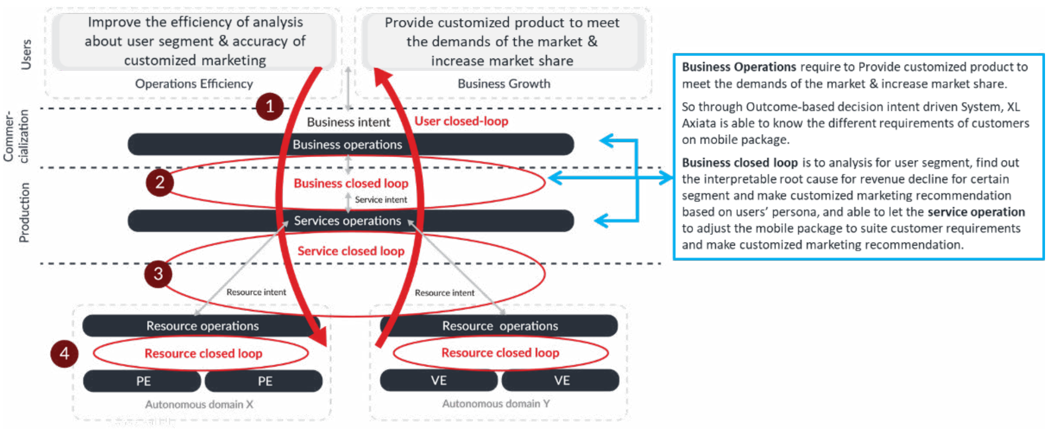


Figure 34: Outcome-based decision, intent-driven system

Figure 34 on the previous page shows that self-marketing is achieved through business closed loop with the introduction of the autonomous outcome-based decision intent-driven system:

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

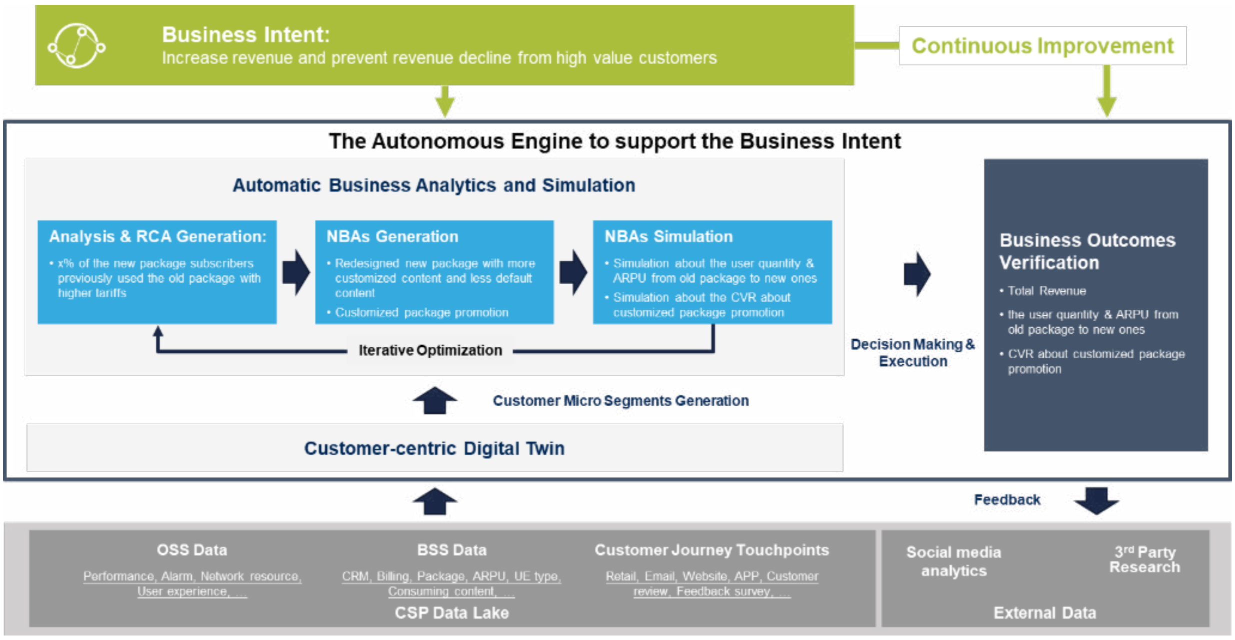


Figure 35: Technical architecture for outcome-based decision intent-driven system

Figure 35 above shows a technical architecture for the AN approach through the outcome-based decision intent-driven system. The autonomous system developed a special digital twin for decision intelligence, which includes a detailed description of the objects and their relationship in the telecom marketing scenario. After the execution of a decision generated by the system, business outcomes verification as well as the continuous improvement is done after the market feedback data is integrated into the digital twin.

Business impacts

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

TELKOMSEL INDONESIA: AI FOR CROWDSOURCED USER EXPERIENCE

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

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

Architecture and solution

This solution includes four major innovations: baseline self-study, user experience-network KPI correlation, intelligent root-cause-analysis (RCA) and AI-based network tuning. With its implementation, the level of network automation is enhanced further as shown in Figure 36.

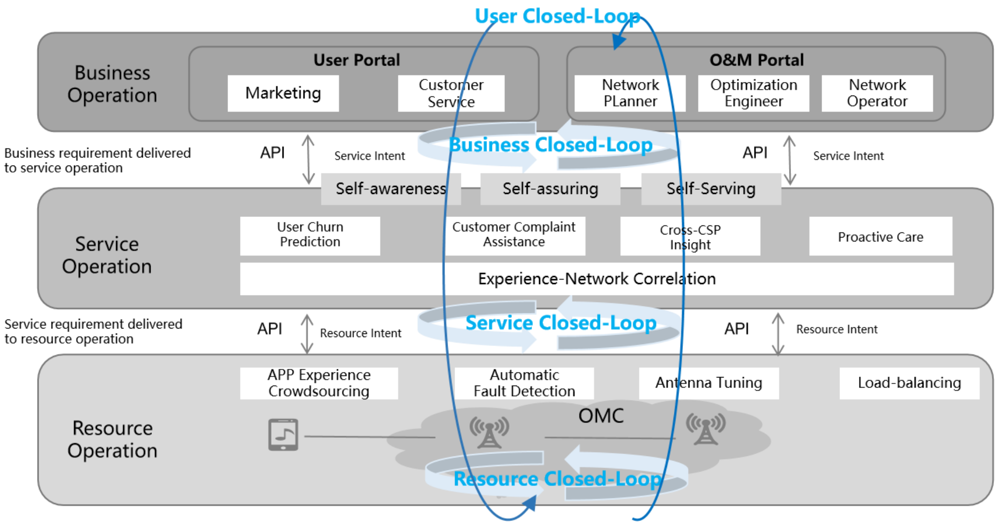


Figure 36: AI for crowdsourced user experience solution

Resource closed loop

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

Service closed loop

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

Business closed loop

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

Benefits

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

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

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

> **"After one month, Telkomsel's NPS increased from 51 to 59 and churn dropped from 6.2% to 5.5%.**

AIS: CUSTOMER COMPLAINT PREVENTION

To improve customer experience (CX), AIS will leverage a new solution called CCP (Customer Complaint Prevention), which captures real-time CX data, network events and process information based on an AI model to proactively identify poor experiences. Then, using resource operations intelligent analysis and a decision engine, AIS can identify customers' problems and through optimization automation solve them to deliver a "wow" experience. Figure 37 shows the CCP architecture.

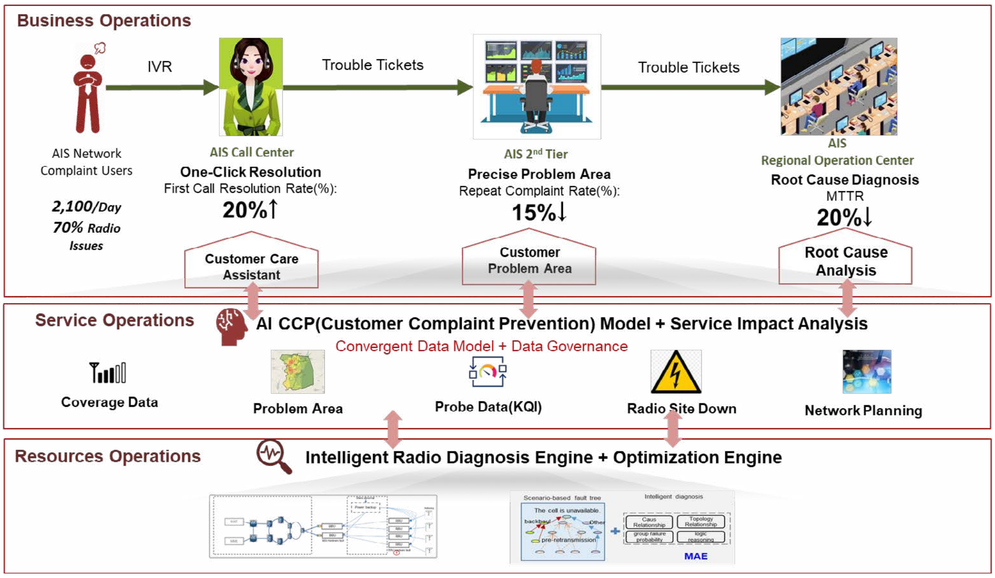


Figure 37: CCP architecture

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

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

"Using its AN framework, CCP, intelligent diagnosis and a network optimization decision engine, AIS can proactively identify customers with poor experience and determine the root cause."

Benefits

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

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

5.3 EFFICIENT O&M

INTELLIGENT LOCATING OF OPTICAL PATH INTERRUPTIONS WITHIN MILLISECONDS

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

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

Rectifying optical path faults involves three main challenges:

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

Solution

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

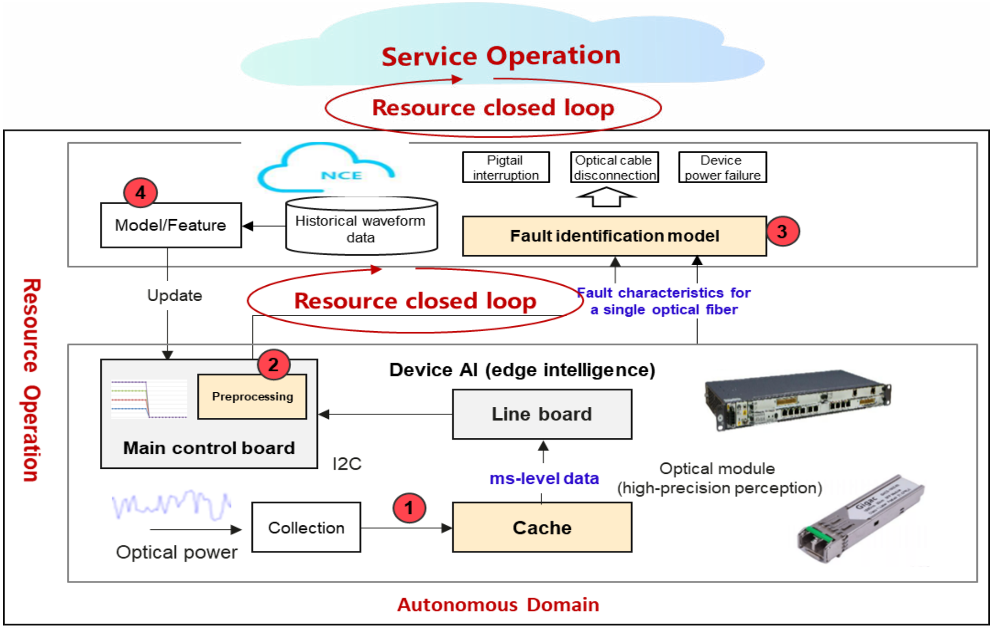


Figure 38: Millisecond-level intelligent optical path interruption locating solution

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

Benefits

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

HITLESS AUTOMATIC UPGRADE OF 5G CORE NETWORK NEs

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

> "One CSP in China has improved troubleshooting efficiency by 30% and decreased site visits."

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

Solution and benefits

To overcome these challenges, Huawei proposed an innovative hitless automatic upgrade solution for 5G core network NEs. This solution leverages automatic orchestration, automatic rolling upgrade, and other capabilities to simplify the long and complex traditional upgrade process, achieving single-domain autonomy and closed-loop resource operations on core networks. The approach is shown in Figure 39 followed by an explanation of how it works.

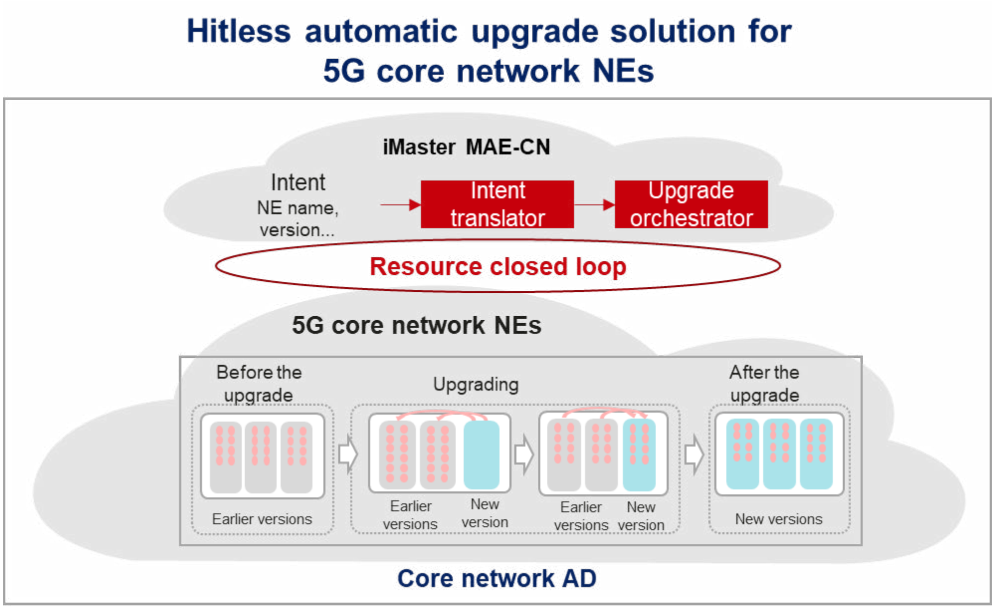


Figure 39: Hitless automatic upgrade solution for core network NEs

- **Automatic orchestration –** a workflow orchestration engine performs flexible scheduling to remove manual breakpoints and automate the entire core network NE upgrade process. The core network software package can be downloaded on a centralized GUI in one-click mode. Risks can be automatically checked, and the upgrade can be automatically performed, significantly reducing risks caused by manual misoperations.
- **Automatic rolling upgrade –** NEs are deployed based on the stateless design and microservice architecture to ensure compatibility with user data of multiple versions and allow instances of multiple versions to coexist. The internal network topology is shielded, and services on peripheral devices are not affected by the upgrade. 5G core NEs are divided into three modules from bottom to top: basic service platform, data and link service and business service. Each module is upgraded in rolling mode (migration > upgrade > migration), in batches.

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

- **Zero service interruption –** services are hitlessly upgraded in batches for all users on the live network. User data is automatically synchronized, and the data formats of the earlier and new versions are automatically regenerated to meet new service requirements.
- **Zero manual operations –** the entire upgrade process is automated to deliver a zero-touch experience.
- **Zero additional resources –** NEs are deployed based on the distributed microservice architecture, and no additional resources are required for the upgrade.

Application and promotion

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

> **"Pioneering operators are developing automatic troubleshooting capabilities and shifting their focus to intelligent troubleshooting."**

WIRELESS NETWORK – INTELLIGENT FAULT MANAGEMENT BASED ON PREDICTION

Intelligent wireless network fault management happens in three stages:

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

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

Predictive and proactive O&M

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

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

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

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

Intelligent AR inspection

In the "last mile" practice based on device-network collaboration, augmented reality (AR) technology is applied to site devices. Image recognition technology and device-network collaboration enable automatic AR inspection, dumb resource modelling and real-time fault point identification. An intelligent wizard-based engine for troubleshooting is developed on MAE to communicate with site devices in real time to help site personnel perform efficient and accurate operations, greatly improving onsite troubleshooting efficiency. Figure 40

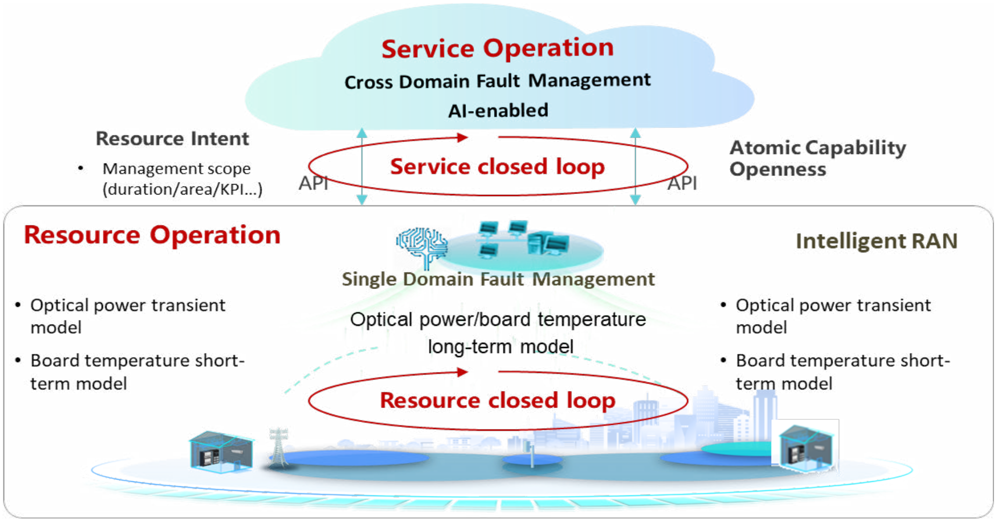


Figure 40: Equipment high temperature/optical power prediction solution

shows the solution, and a more detailed explanation follows.

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

Benefits

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

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

"The AR site inspection solution has been verified in many provinces and cities in China where it has reduced the time it takes to inspect a site from 70 minutes to 30 minutes."

verification in typical scenarios.

MTN: BUILDING AN ALL-OPTICAL AN TO ENABLE AGILE BUSINESS AND INTELLIGENT O&M

The digital economy and digital transformation of industries pose new requirements on CSPs' network capabilities and operations. An intelligent, native, efficient and reliable network with deterministic experience is now the development direction for future networks. MTN is actively carrying out network digital transformation in line with its Ambition 2025 strategy, MTN promotes the exploration, practice and application innovation of autonomous networks based on optical network automation scenarios.

Challenges

With the deployment of optical infrastructure networks and the rapid development of optical services, MTN is facing challenges in terms of time to market (TTM) and O&M efficiency. Table 11 describes the challenges.

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

Table 11: Optical network challenges

Solutions and benefits

With the intelligent management and control system as the core, the all-optical AN solution introduces AI to the NE, network and service layers to implement efficient O&M of all-optical networks and provide industry customers with zero-touch, zero-wait and zero-fault premium private line service experience. Figure 41 shows the approach, and a more detailed explanation follows.

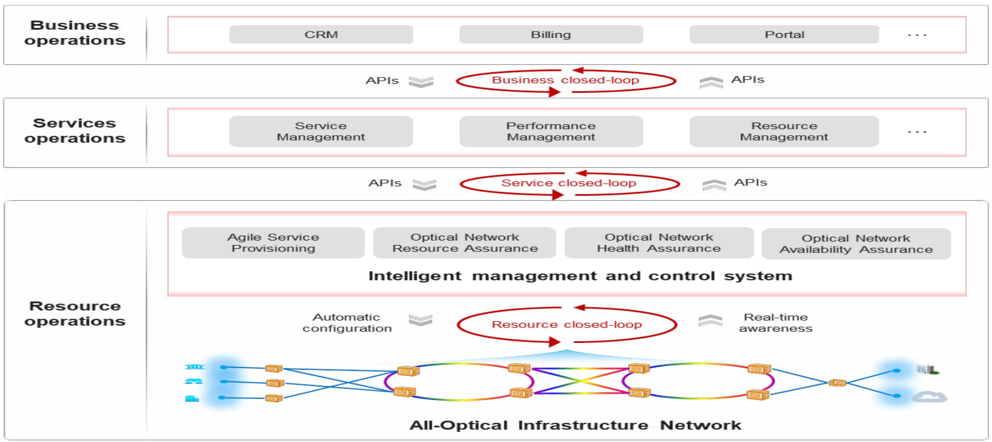


Figure 41: All-optical AN with intelligent management and control system

Resource closed loop

- **Agile service provisioning –** to shorten the service TTM, improve the service go-to-market pace and accelerate business monetization, automatic service provisioning is provided for MTN in South Africa. The simplified model of automatic service provisioning and multi-factor route calculation policies (the most comprehensive routing policies in the industry, meeting differentiated market requirements) greatly improve the one-time service provisioning success rate, shortening the TTM from weeks to minutes and providing the ultimate service experience with zero-wait time.

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

"MTN's solution is identifying more than 95% of fiber and optical channel deterioration faults in advance, reducing fault-locating duration by 83% and reducing fiber cuts by 30%."

Service closed loop

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

Business closed loop

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

Prospects

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

CHINA TELECOM: AGILE PROVISIONING OF 5G CUSTOMIZED NETWORK

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

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

Solution

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

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

> **"By the end of 2021, China Telecom had provisioned nearly 500 5G slice private lines, generating total revenue of 270 million Yuan ($39.6 million)."**

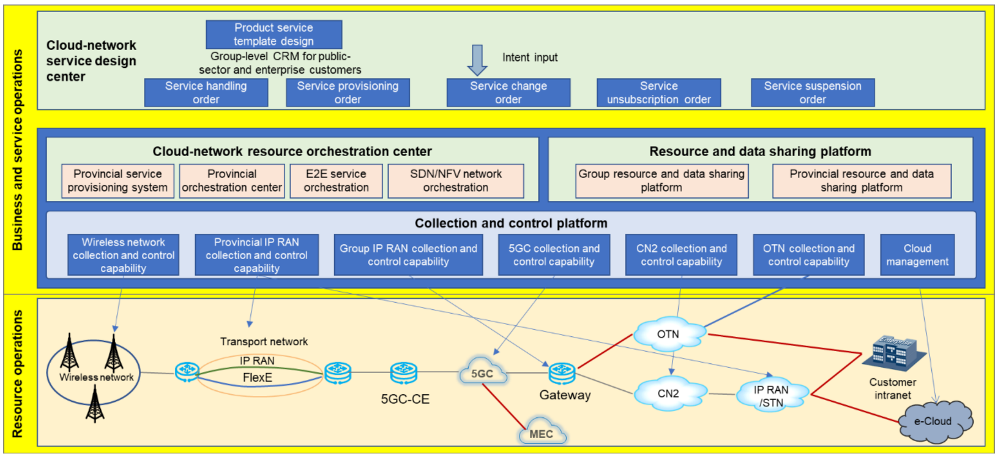


Figure 42: Agile provisioning of 5G customized network solution

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

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

Benefits

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

AI-INTELLECTUALIZED O&M MANAGEMENT

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

Architecture and solution

The architecture for the AI-intellectualized O&M management solution, shown in Figure 43, has several goals:

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

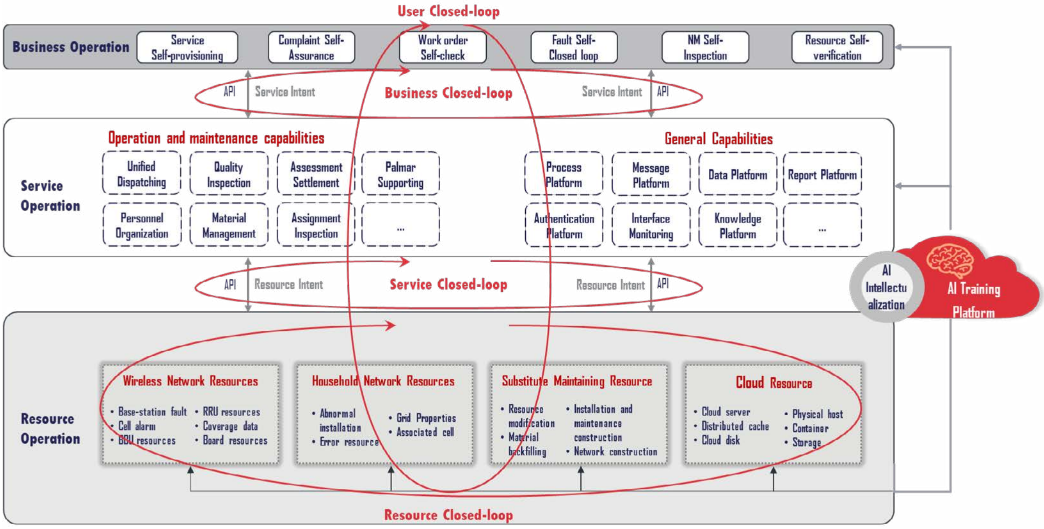


Figure 43: AI Intellectualized O&M management solution

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

- **Visualized fault closed loop –** when a fault event is triggered, the processing group/personnel and all task lists to be executed are automatically matched according to the scheduling process configuration. The task can be presented quickly to realize the visual closed loop of the work order and fault self-monitoring.
- **Intelligent work order quality inspection –** analyzes the assessment intention of the manager and completes mass work order quality inspection through intelligent methods with AI training instead of manual. It promotes the standardization of fault handling process and improves the efficiency of O&M management from the perspective of the authenticity of fault recovery and the normalization of work order response.
- **Automatic patrol inspection of network management –** analyzes the intention of patrol inspection objectives and scenarios, automatically selects the corresponding operation plan and completes the distribution to realize the unified management and scheduling of cross-domain and cross-integrated network management intelligent patrol inspection.
- **Resources patrol inspection with AI –** completes a series of operations such as “scanning, target identification, photo uploading and compliance detection” through AI capabilities including video scanning and identification, and helps O&M personnel conduct paperless and standardized patrol inspection during the work. The patrol inspection records can be uploaded to the server in real time for future reference, and the resource data can be automatically retrieved and verified according to the resource situation.

Application and outcome

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

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

> "China Unicom's work order quality inspection has reached AN Level 3."

5.4 GREEN ENERGY

CHINA MOBILE: GREEN AND INTELLIGENT OPTICAL CROSS-CONNECT (OXC) NETWORK

Development of services such as 5G, cloud and "eastern data and western computing" (**see page 41**), as well as customers' demands for green energy saving and zero-wait ANs, transmission network nodes face unparalleled challenges in capacity, energy saving, latency and autonomy. At the same time, the traditional optical switching solution occupies a large amount of cabinet resource, fiber patch cords between cabinets and much energy. Therefore, a new optical technology solution is badly needed. To meet the low-latency and intelligent O&M requirements of premium private lines, operators must greatly accelerate the deployment and expansion of optical paths to achieve single-day service provisioning and intelligent assurance.

Solution

OXC supports single-domain autonomy and enables resource closed loops. The company pioneered the adoption of multi-dimensional, all-optical OXC technology on intelligent transmission NEs to accelerate single-domain autonomy, save energy and enable intelligent O&M.

In addition, network capabilities are open to enable agile business. OXC replaces the traditional optical-to-electrical conversion, thereby achieving high integration, low-energy consumption, zero fiber connection and simplified O&M. In addition, the network architecture is optimized (Meshnet), leading to a significant decrease in latency and increase in transmission network quality (see Figure 44).

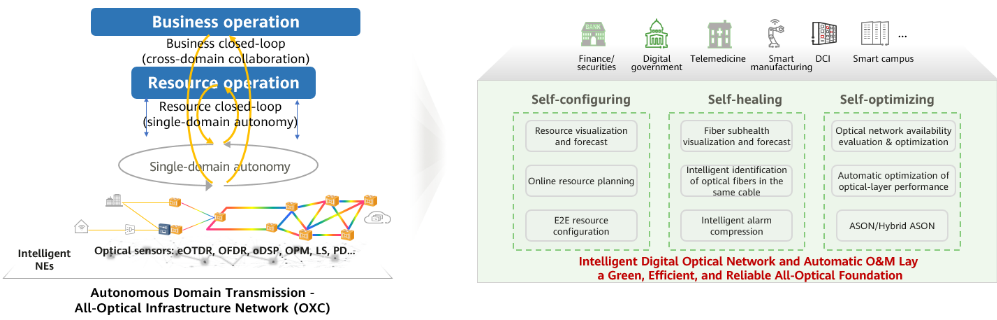


Figure 44: Architecture of a green and intelligent OXC network

Application and benefits

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

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

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

"China Mobile Jiangsu estimates its energy savings to be 1.3 million kilowatts a year, with a 45% reduction in energy consumption."

CHINA MOBILE: DYNAMIC ENERGY SAVING WITH SLICING PACKET NETWORK (SPN)

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

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

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

Solution

Working with Huawei and ZTE, China Mobile built an AI system to accurately forecast link traffic trends based on historical traffic data, network topology, and service routes. This system collects network data in real time, models traffic-burst patterns, intelligently analyzes service load changes, and automatically generates multi-layer (chip/module/board) multi-mode energy saving solutions (see Figure 45). This makes dynamic energy saving a reality.

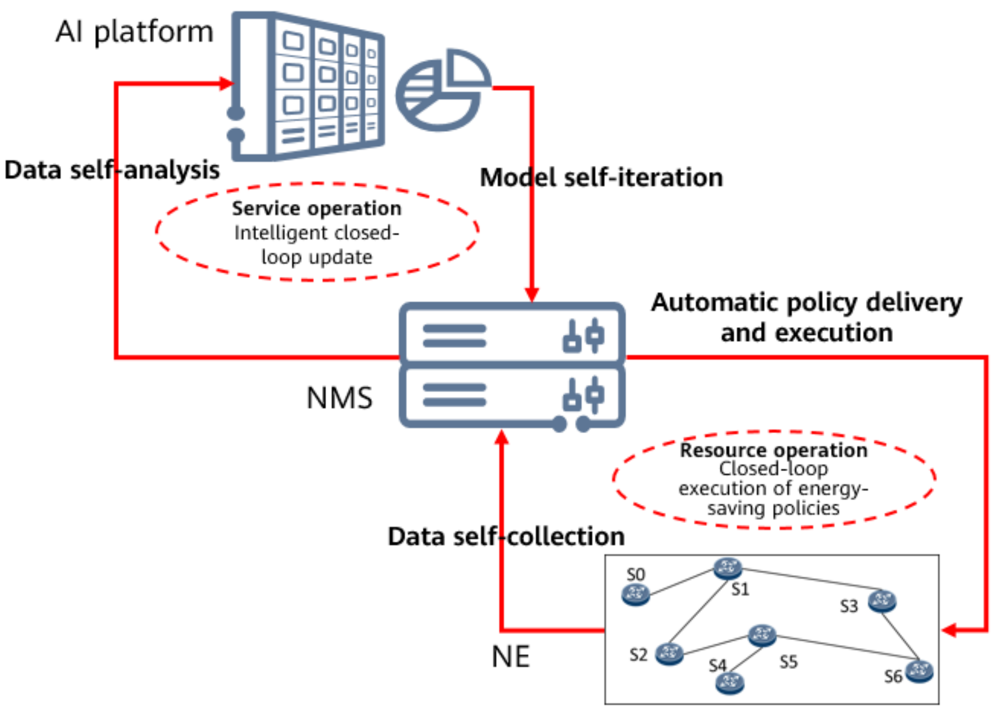


Figure 45: AI platform for dynamic energy saving

Application and benefits

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

"China Mobile Guangdong has reduced energy consumption by 15% to 18%."

CHINA MOBILE: FACILITATING LOW-CARBON OPERATIONS OF STATE GRID CORPORATION OF CHINA

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

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

Solution

Based on China Mobile's BAF atomic capability (the company's BAF business model is a multi-dimensional, 5G dedicated network business model based on "Basic network + Advanced value-added functions + Flexible personalized services"), China Mobile Anhui is building a 5G private network for the State Grid of China. The solution combines a dual-network integration mode for the 5G private network and the power grid communication network, applying the 2B Smartlink one-stop service solution from ZTE to provide precise network planning and 3D modelling and simulation of the 5G power distribution intelligent O&M service (see Figure 46).

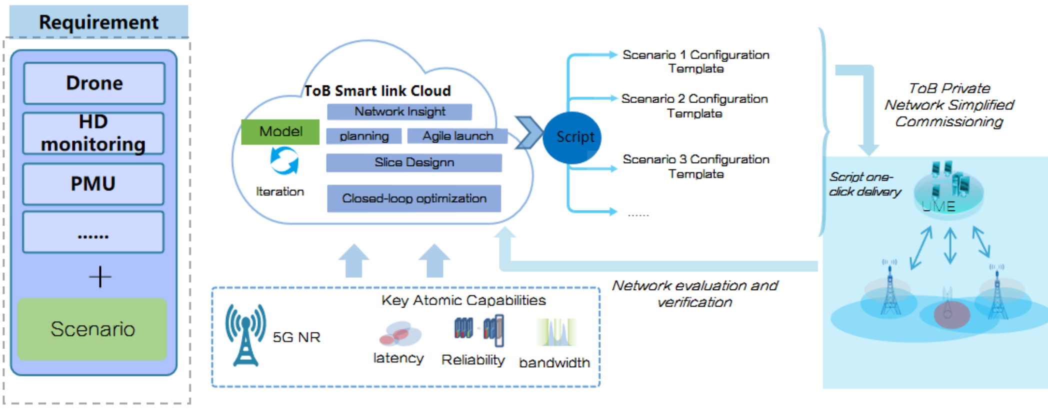


Figure 46: 2B Smartlink 5G closed-loop management in the full lifecycle

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

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

Benefits

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

"Compared with traditional private lines, wired access, and 4G networks, the cost and deployment speed are reduced by 50%, and the reliability is greatly improved."

AN industry prospects

6.

6.1 ANALYSTS' PERSPECTIVES

Analysts agree that we are in the midst of an AN revolution that is progressing from concept to implementation at a rapid pace. CSPs and their partners are participating in trials and pilots and beginning to use AN in production deployments. This is a critical phase for the industry as leading operators put their methodologies into practice, learn from their mistakes, and align with organizational processes.

The goal for CSPs is two-fold: deliver tangible progress of AN implementation, while minimizing disruption to existing services and business. Success in this phase will build the needed confidence and experience for deploying more advanced AN capabilities to more extensive network domains and at greater scale.

Today, most operators are using automation to reduce operational costs. In TM Forum's AN surveys, this continues to be the No. 1 driver, followed by improving customer experience and delivering new services (see Figure 47).

what are the most important drivers of your AN strategy?

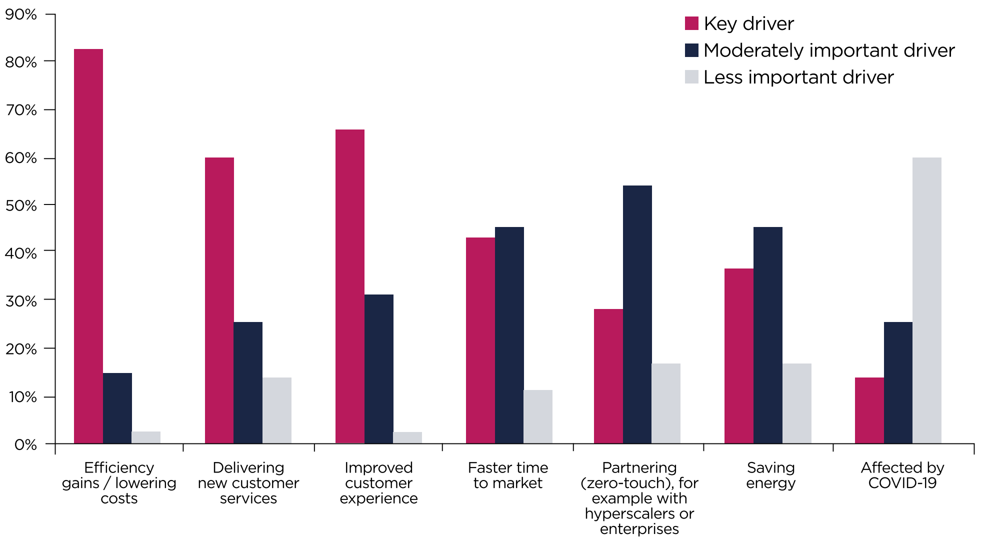


Figure 47: Key AN drivers

But as noted previously in the white paper, TM Forum's recent AN research report also shows that in addition to quick cost-cutting wins, CSPs have long-term strategies for ANs. More than half of CSP survey respondents "have a vision that involves the continual improvement and automation of operations with increased investment," and nearly 40% have an even more ambitious strategy with large-scale investments in AN planned. Very few respondents said they have no vision. This reinforces the first of the four key AN enablers we have discussed: creating a vision and target architecture (**see page 25**).

> **"More than half of CSP survey respondents 'have a vision that involves the continual improvement and automation of operations with increased investment,' and nearly 40% have an even more ambitious strategy."**

A strategy manager at a European mobile network operator who was interviewed for TM Forum's research report echoed a sentiment shared by CSPs around the globe when he said: "Fully automating network capabilities for certain lines of business is probably the single most important move we could make if we're ever to enter truly digital markets and diversify beyond classical telecom services. Our move to fully cloud-native in the network and the introduction of AI/machine learning in the management layer can be seen as stepping stones to that autonomous network goal. We're still quite a long way away from achieving that end goal, but you'll see many transformational steps we're taking today that are directly aimed at full automation through the network technology."

> **"Fully automating network capabilities for certain lines of business is probably the single most important move we could make if we're ever to enter truly digital markets and diversify beyond classical telecom services," says the strategy manager at a European mobile operator.**

5G, IoT and AI all rely on ANs designed to operate with minimum human intervention and deliver superior customer experience. These existing technologies combined with new ones will result in a wide range of applications, from improved internet access in rural areas to better healthcare delivery. But even though analysts agree that ANs are moving quickly and will have a transformative impact on many industries, they want to see more evidence of how ANs will create new services and improve customer experience.

As TM Forum Principal Analyst Dean Ramsay explains, "methodologies state that if a network can be 'self-x' – self-serving, self-fulfilling and self-assuring – then that should empower 'zero-x' in the user experience layer: zero-wait, zero-trouble and zero-touch." He adds: "We estimate that within the next five years the number of users will increase by 10,000 times thanks largely to massive IoT, and 5G will increase network capacity 10-fold. This will make zero-touch provisioning essential."

It is a long journey to build an autonomous network, one that requires resources, knowledge and experience in many areas — from standards, design, and operational issues to software and services, systems engineering and project management, data security and privacy. This year, CSPs are moving into the deep end of AN exploration and practice. In the next two to three years, we will witness leading CSPs practice L3 and even L4 in real networks, which is exciting.

6.2 TECHNOLOGY TREND OUTLOOK

Tremendous breakthroughs are expected in the following key technologies to facilitate AN evolution:

1. Network AI foundation models

Telecom networks have a huge amount of data that can be used to develop AI foundation models. These models are expected to greatly improve the way various service issues such as energy saving, traffic prediction, and demarcation and locating of unknown faults are resolved.

AI will be widely used in almost all network service scenarios. Foundation model technologies demonstrate great potential in tackling engineering issues, such as AI generalization and model fragmentation. For example, "pre-training+fine-tuning in downstream tasks" mode can be introduced to accelerate AI implementation and improve AI application results.

AI foundation models can deliver significant benefits in scenarios such as fault demarcation, traffic prediction and network coverage simulation. Take fault demarcation as an example. A machine language foundation model can be developed for the core network to improve the precision of the core network fault demarcation model and expand the model application scope to include more services.

From a model development perspective, secondary model development based on pre-training can reduce time to market and improve efficiency by 80%. From the application result perspective, inter-network element horizontal demarcation and intra-network element vertical demarcation take just a few minutes to demarcate faults at the minimum recoverable unit level. The accuracy of identifying known faults increases, and unknown faults can be automatically demarcated, achieving both qualitative and quantitative improvements.

2. Cognitive intelligence

This technology integrates the advantages of knowledge-based expert systems and data-based deep learning networks, leveraging the expertise in the telecom field. It is expected to become a key technology for developing the next-generation intelligent network operations system.

Evolution towards AN L5 means that people are less likely to be involved in the network lifecycle. Cognitive intelligence technology uses human-like decision-making methods to transform perceptual intelligence into cognitive intelligence, supporting the evolution towards L5.

In fault O&M scenarios, this technology increases the fault demarcation accuracy to more than 95% and makes demarcation results highly explainable. Recovery commands can be automatically generated based on knowledge to implement automatic network recovery. In CSPs' network O&M scenarios, cognitive intelligence technology can be used to automate fault O&M and implement self-learning of fault knowledge. Various applications, including the virtual alarm assistant and automatic fault demarcation and recovery, can be deployed to generalize fault scenarios, improve precision and explainability, and implement self-learning. This facilitates the evolution towards L5 autonomous and self-healing O&M.

"Intent APIs leverage intent-based AI to further simplify the implementation of the business closed loop, service closed loop and resource closed loop for AN, helping CSPs quickly evolve towards L4."

3. Digital twins

A digital twin is "a digital representation of a physical object, process or service that uses real-world data to create simulations to predict how a product or process will perform". CSPs can use this technology to deploy a digital twin network, verify network changes, provide an efficient verification platform for innovative technologies, and evaluate in real time the risks to running networks. It will become a key technology for network planning, running, management, and operations in the future.

Digital twins can be used to create virtual twins with consistent topologies, services, and data for physical network entities. They can also be used to develop a digital twin network that can interact and map with physical network entities in real time, and to provide a test bed for verifying network configurations and new technologies to reduce network risks. CSPs can deploy a digital twin network to accelerate service innovation and incubation.

The core elements of a digital twin network are:

- **Data perception –** researchs high-performance network measurement technology to achieve approximately error-free measurement
- **Model definition –** performs layered network abstraction to research and define layered, abstract models oriented to network twins (the models are defined based on data for various network applications)
- **Twin mirroring –** uses network twins to map physical network entities on a high-fidelity page in visualized mode to form a mirror for the twin and physical networks
- **Virtual-reality interaction –** uses technologies such as big data analysis, AI algorithms, and cognitive intelligence to implement full-lifecycle analysis, diagnosis, simulation, and control of physical networks, achieving closed-loop control of the twin network and physical network.

4. Intent APIs

Intent APIs leverage intent-based AI to further simplify the implementation of the business closed loop, service closed loop and resource closed loop for AN, helping CSPs quickly evolve towards L4. TM Forum is defining the AN OpenAPI Map standard to set up an AN OpenAPI evaluation system based on O&M processes and levels. This standard offers a framework and an action guide to describe the API capabilities that are required at each ANL for specific domains, evaluation objects, and business processes.

In the future, the key to implementing intent APIs will lie in streamlining the concept and definition of intent metamodels in the industry, unifying intent metamodels, mapping intent models in different domains, and ensuring that cross-domain intents can be implemented and are interoperable in an end-to-end manner. In addition, research on key intent technologies, such as intent conversion, retention, and negotiation, needs to be accelerated. To learn more about intent in autonomous networks, see this TM forum research report.

5. AN MLOps

Machine Learning Operations (MLOps) is a management practice for machine learning models, aiming to link up the development, deployment and operation of AI models. It also aims to connect algorithms and business and operation teams, improve the efficiency of lifecycle management of AI models, and promote their large-scale application.

MLOps can be viewed as an extension of DevOps methodology to deliver machine learning models instead of software. It includes three steps:

1. **Project design,** including requirements collection, scenario design, data usability check
2. **Model development,** including data engineering, model engineering, evaluation and verification
3. **Model operation,** including model deployment, continuous integration, delivery and testing (CI/CD/CT) workflow, monitoring and scheduling.

MLOps can be applied to enable the following autonomous network scenarios:

- Manage the R&D assets of AN applications, including data, models, algorithms, etc.
- Standardize the development process of AI models with extra focus on demand analysis and establish an effective application value evaluation system
- Realize large-scale automatic deployment of AN applications.
- Continuously monitor the effect of AN applications, avoid the risk of model degradation caused by data drift, and support iterative training and continuous optimization of the model
- Standardize the workflow of AN applications from model development to model delivery and operation, and improve the quality and efficiency of model delivery.

6. AN knowledge management

Knowledge is the concept, notion or skill acquired through study, practice or exploration. In an Autonomous Network, it refers specifically to the concepts, rules and experiences that are applied to management of the whole lifecycle of ANs (planning, deployment, maintenance, optimization and operation) to enable system automation and intelligence.

Knowledge can be embodied in pre-configured static rules, programmable dynamic policies, machine learning algorithms and AI models. Knowledge management is the lifecycle management of knowledge, including construction, processing, sharing, application and updating.

An advanced knowledge management system (as opposed to simple execution engines for rules/policies) is supposed to improve the quality of generated knowledge and promote efficient lifecycle operation of knowledge, so as to achieve timely update and accurate application of knowledge. At the same time, through cross-domain knowledge creation, integration and transmission, knowledge sharing and collaboration at different layers and levels can be realized.

Knowledge management can be introduced into AN level evolution. Benefits of AN knowledge management include:

- Streamlining of redundant processes
- Fulfillment of automated management processes
- Improved operations efficiency
- Lower management costs, especially when humans can't meet the huge demand for knowledge management.

"Knowledge refers specifically to the concepts, rules and experiences that are applied to management of the whole lifecycle of ANs to enable system automation and intelligence."

6.3 COLLABORATION TO ADVANCE THE AN INDUSTRY

AN development calls for collaboration and in-depth coordination among all industry partners, including standards bodies and collaborative organizations, CSPs, suppliers, research institutes and others. We jointly propose the following recommendations:

Focus on innovation, revenue growth, quality enhancement and efficiency improvement – and continuously develop innovative applications.
We recommended that all industry partners focus on these goals and continuously develop innovative applications for planning, construction, maintenance, optimization, and marketing in all network domains and for high-value scenarios such as 5G 2B, enterprise cloud access and home broadband, contributing numerous mature commercial solutions for AN.

Encourage CSPs to accelerate large-scale L3 deployment and promote a virtuous business cycle for industry prosperity.
As noted, nearly 40% of CSP respondents to TM Forum's latest AN survey believe that AN will reach L3 over the next three years and create significant business value. We recommended that carriers speed up the process of introducing and experimenting with new AN technologies, products and solutions, as well as the process of replication and promotion of mature technologies, products and services. We also suggest that they accelerate the process of using autonomous capabilities to deliver business value and operations benefits, seize new opportunities for digital transformation in the industry and promote a virtuous business cycle for industry development.

Deploy an industry collaboration platform to promote co-construction and mutual recognition of standards and efficient collaboration among industry, academia, research, and application providers.
TM Forum has played an active role in coordinating various standards organizations over the past year. We recommend that multiple SDOs further collaborate on a top-level design and efficient communications to achieve standards recognition between different network domains and establish a means for co-constructing and mutually recognizing standards. SDOs should also accelerate the transformation from industry standards to business and technical implementation solutions, achieve efficient collaboration among all involved parties and promote joint innovation with upstream and downstream industry partners.

Jointly define L4 target profiles, launch basic theoretical research and make technological breakthroughs as early as possible.
The evolution from AN L3 to L4 creates numerous benefits, but it is also a daunting challenge. We recommend that all parties in the industry focus on business and service requirements, target architecture, key technologies and core capabilities (including APIs), evolution paths, and product and solution innovation to jointly define L4 target profiles. The goal should be to remove the barriers to precise real-time awareness in complex scenarios, real-time simulation based on digital twins and a user-service-resource correlation autonomous operations model.

"SDOs should collaborate on a top-level design and efficient communications to achieve standards recognition between different network domains and establish a means for co-constructing and mutually recognizing standards."

To achieve these recommendations, we propose focusing on three cooperative initiatives:

1. **Reach consensus on target architecture –** to achieve the high-level goal of ANs, it is necessary to coordinate evolution of networks and network management systems towards 5.5G, an enhanced version of 5G, under the guidance of a unified architecture and on the basis of active practice and verification. Coordinated planning is required. At the same time, network management should cooperate with the evolution to provide support for the 5.5G network. A sound management system needs to be established for digital knowledge assets such as business rules, expert experience, AI models, etc. All parties in the industry should work together to establish a cross-organization cooperation a platform for cross-organization cooperation to build the network automation capability system, promoting common advancement of network equipment and network management systems. All SDOs should strengthen communication and cooperation in terms of the target framework, unified evaluation model and technical path of Autonomous Networks, promote mutual recognition of achievements, enhance complementarity, jointly draw a common blueprint, and build a common set of standards.

2. **Enhance business drivers –** the ultimate goal of AN construction is to support the growth of operators' businesses. During this process, we must always strengthen the evolution of network and network management automation capabilities based on business drivers, and advance in an orderly manner around the markets. In practice, TM Forum can take a leadership role by cooperating closely with CSPs, network equipment suppliers and network management systems integrators to empower industry development.

3. **Pool ecological strengths –** continuously improving the level of network autonomy involves the gradual transfer of network O&M responsibilities from people to network equipment and O&M systems, and expansion of the basis for system decision-making from interpretable experience to AI algorithm models. As the pioneer of developing ANs, TM Forum will join with industrial organizations, research institutes and other innovative R&D forces to explore theoretical innovation and engineering realization of advanced technologies, resulting in a win-win for all parties. The large-scale deployment of AN depends on close collaboration across the industry. We hope that industry partners can work together to promote the healthy and prosperous development of AN.

To learn more about the work the TM Forum is doing in Autonomous Networks, visit the website and join one of our collaboration projects, or contact Aaron Boasman-Patel.
TM Forum members can download more AN resources here

"A sound management system needs to be established for digital knowledge assets such as business rules, expert experience and AI models."