< Back to Contents

AN JOURNEY GUIDE

# Autonomous Networks

Level 4 industry blueprint – high-value scenarios

NOVEMBER 2024

**Objective:** to highlight a blueprint for progression toward Level 4 autonomous networks, with a particular focus on high-value scenarios.

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# contents

# Introduction

Autonomous networks (ANs) represent a transformative shift for communications service providers (CSPs), enabling them to operate more efficiently, deliver better customer experience and innovate rapidly. TM Forum is at the forefront of industry-wide collaboration to drive the deployment and evolution of AN technology, processes and business models.

During the past year, CSPs have taken significant steps forward in laying the foundation for autonomous networks by upgrading ICT infrastructure including wireless and fiber-optic networks. Some mobile operators are beginning to roll out 3GPP's 5G-Advanced standards, while optical backbone networks are entering the 400-Gbps era, enabling ubiquitous, high-quality 10-Gbps access for end users.

At the same time, AI technology is evolving rapidly, with CSPs beginning to use GenAI and launch projects to develop telecom-specific language models. Telco operations are evolving, too, as operators adopt platform business models such as network-as-a-service (NaaS) to abstract the complexity of the underlying network using APIs such as the TM Forum Open APIs.

Ultimately, CSPs need to be able to scale orchestration of zero-touch, zero-wait and zero-trouble services end to end across network domains (for example, radio access, fixed access, core, IP, optical transport and data center/cloud networks). This requires automation of the entire service lifecycle, from ordering to fulfillment, activation, orchestration, management, assurance, optimization and billing.

Telcos have been working on this kind of automation for years and have made progress. In fact, TM Forum's Open API program resulted from these efforts. But end-to-end automation has remained elusive because of interoperability issues, architectural fragmentation and heavy customization. TM Forum's Autonomous Networks Project aims to change this.

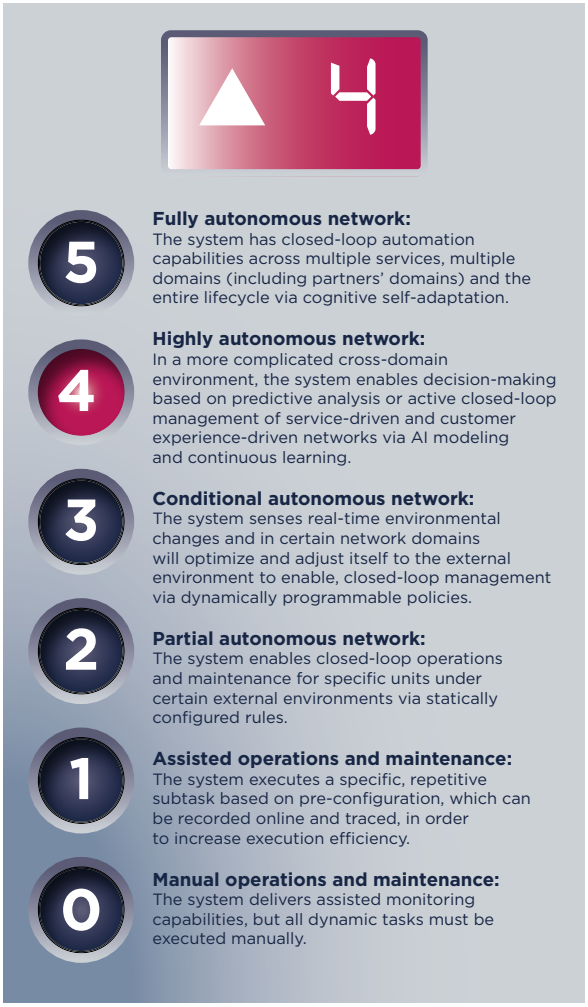
The project was formed in 2019 to define what it means for networks to be "autonomous" and to explain how to get there. Unlike automation, which relies on predefined rules, autonomy involves intelligent systems making independent decisions. Transitioning from automation to autonomy is a significant business and technology challenge, requiring straightforward implementation and integration patterns.

To help CSPs manage the transition from automation to highly autonomous networks, we published our first AN white paper in 2019, and since then the publication has evolved into an AN journey guide – this edition marks the sixth annual. Our goal is to build consensus around how to evaluate, design, implement and manage autonomous networks.

## GETTING TO LEVEL 4

A key element of TM Forum's AN work that is gaining traction across the industry is a six-level taxonomy CSPs can use to measure their progress implementing autonomous networks. Each AN level has a set of characteristics describing the evolutionary stage of the CSP's journey from manual to fully autonomous operations (see graphic).

## Autonomous network levels




TM Forum, 2024

According to TM Forum's definition, Level 4 autonomous networks represent a major shift from traditional human-defined automation processes to true autonomous decision-making. This is a significant leap from Level 3, where machines assist humans in decision-making but still rely on human oversight. At Level 4, the network can self-manage, self-optimize and handle complex tasks. To achieve this level of autonomy, CSPs need to translate their customers' business goals, or "intents", into network requirements that can be fulfilled without the customers needing to understand the underlying infrastructure. This requires a formal ontology to express these intents in a way that enables seamless machine-to-machine communication. Generative AI can be used to interpret natural language inputs from customers and generate intent expressions that the network can act upon.

To date, more than 60 companies have signed the Autonomous Networks Manifesto pledging to work rapidly toward Level 4 autonomy. Even more have participated in AN Catalyst proofs of concept. Across the telecoms industry, more than 120 AN standards and research projects have been initiated, with multiple standards-development organizations (SDOs) and open-source groups working to define and deploy ANs. Within TM Forum's AN Project, many CSPs have outlined their AN visions and strategies, and 24 have carried out Autonomous Network level (ANL) assessments to promote AN principles and practices. We look at the anonymized results of these assessments in Section 3 of the guide.

## IDENTIFYING LEVEL 4 HIGH-VALUE SCENARIOS

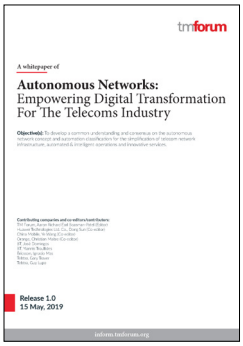
A main focus of the guide this time is on creating a blueprint for Level 4 high-value scenarios. Scenarios are use cases that combine an operation flow and a network domain (for example, fault management on the RAN). Level 4 scenarios are those that are likely to have maximum impact on the operations and/or business of a CSP. We explore how telcos and their technology partners are developing these scenarios, with a goal of evolving the necessary standards and sharing knowledge to make it easier to reach Level 4 autonomy.

In September 2024, TM Forum launched a special type of Catalyst proof of concept called the Autonomous Network Innovation Pioneer Project to study AN Level 4 high-value scenarios. That team's first implementations are being demonstrated at Innovate24 Asia. The goal for each scenario is first to identify gaps between the current level of automation in CSPs' networks and Level 4 autonomy. Then, the teams design solutions, implement and test them, and finally verify the achievement of AN Level 4.

Teams participating in the ongoing project are leveraging TM Forum's Autonomous Network Framework, which supports intent-based management and intelligent orchestration to simplify network management, automate service delivery, and enable self-optimizing and self-healing capabilities. We discuss this framework throughout the guide.

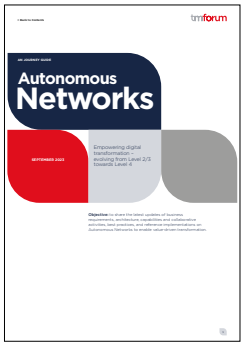
To create the guide, TM Forum solicited contributions from companies and individuals working both inside and outside TM Forum's AN Project. The guide provides an overview and summary of selected contributions. In the appendix you will find links to all contributions received, which have been published in their entirety on the AN Project's webpage.

You can read the first five AN guides by clicking on the images below. To learn more about how to get involved in TM Forum's industry-leading work on autonomous networks, please contact Alan Pope.









# How does TM Forum define autonomous networks?

Section 1

CSPs operating mobile and/or fixed networks have adopted a common vision for their businesses to deliver connectivity and other services via autonomous networks that use predictive analytics and AI, including generative AI (GenAI), to determine which network resources are used to fulfill a customer's business goals, with all complexity hidden from network operations teams and customers. As this guide shows, the vision is becoming reality.

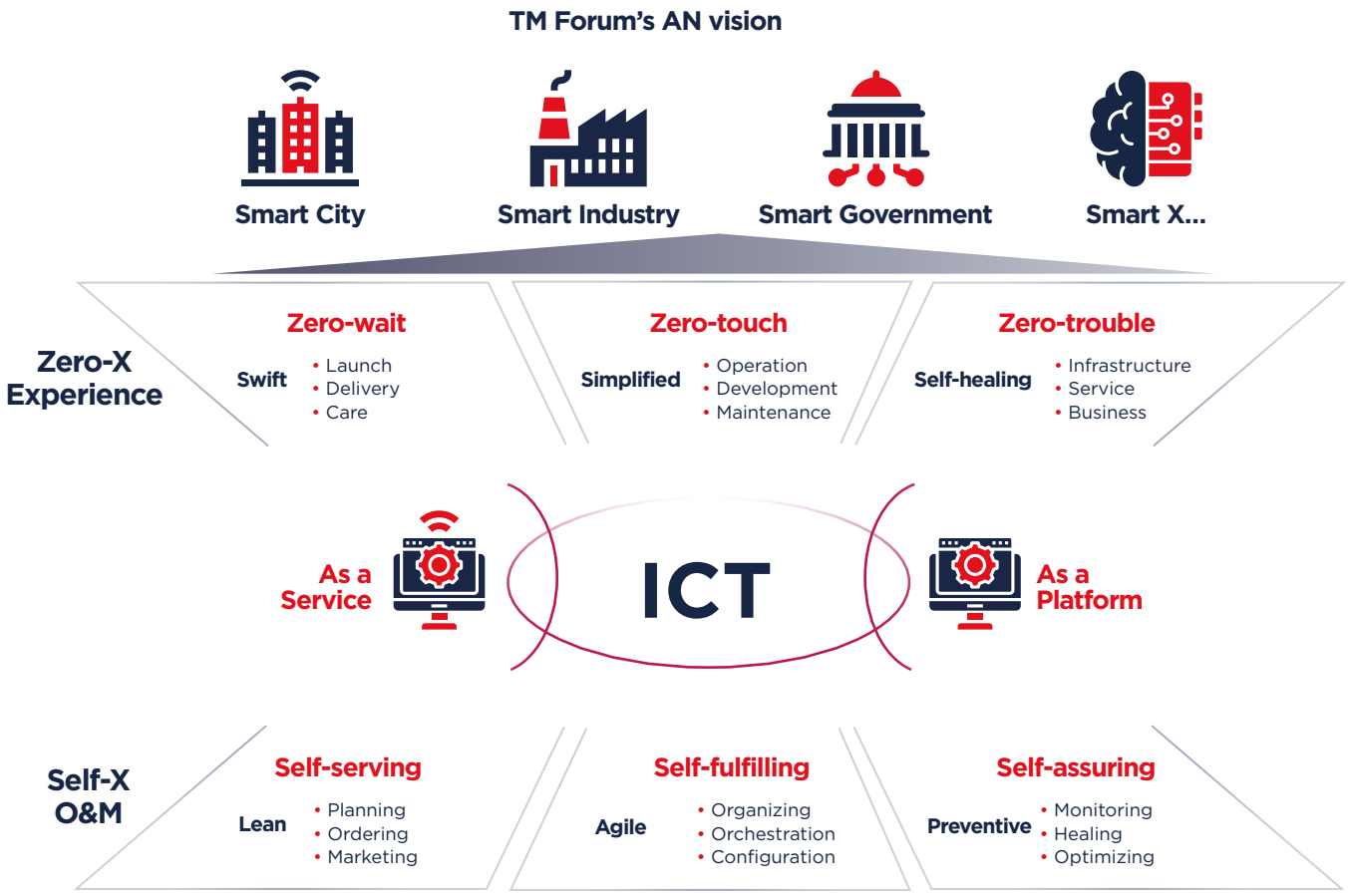
TM Forum is one of several SDOs and open-source groups that are defining and evolving autonomous networks concepts, standards, implementation methods, and use cases to build consensus across the telecoms industry. Achievements include:

- Agreement on concepts such as the vision for Zero-X experiences, Self-X capabilities, AN levels (ANL), and key effectiveness indicators (KEIs) to measure the business value and operations effectiveness of AN scenarios
- Development of a target architecture supporting single-domain autonomy, cross-domain collaboration and intent-driven, full-stack AI
- Collaboration among SDOs such as 3GPP, CCSA, ETSI, GSMA, IEEE, IETF, ITU, NGMN and TM Forum to unify AN standards (known as MDSO)
- Pledges from more than a dozen CSPs to aim for Level 4 autonomy in multiple domains between 2025 to 2027.

TM Forum members have developed an AN target architecture, which includes guiding architectural principles, a business architecture, and technical and formal reference architectures. CSPs already leveraging TM Forum's Open Digital Architecture (ODA) can now integrate autonomous capabilities into their existing frameworks, transforming ODA into composable, self-managing systems organized as autonomous domains.

All these assets are comprehensively defined in TM Forum's standards, and most of the concepts have been outlined thoroughly in previous AN guides. We recap the most important concepts and work here.

***CSPs have a common vision to deliver connectivity and other services via autonomous networks that use predictive analytics and AI to determine which network resources are used to fulfill a customer's business goals.***



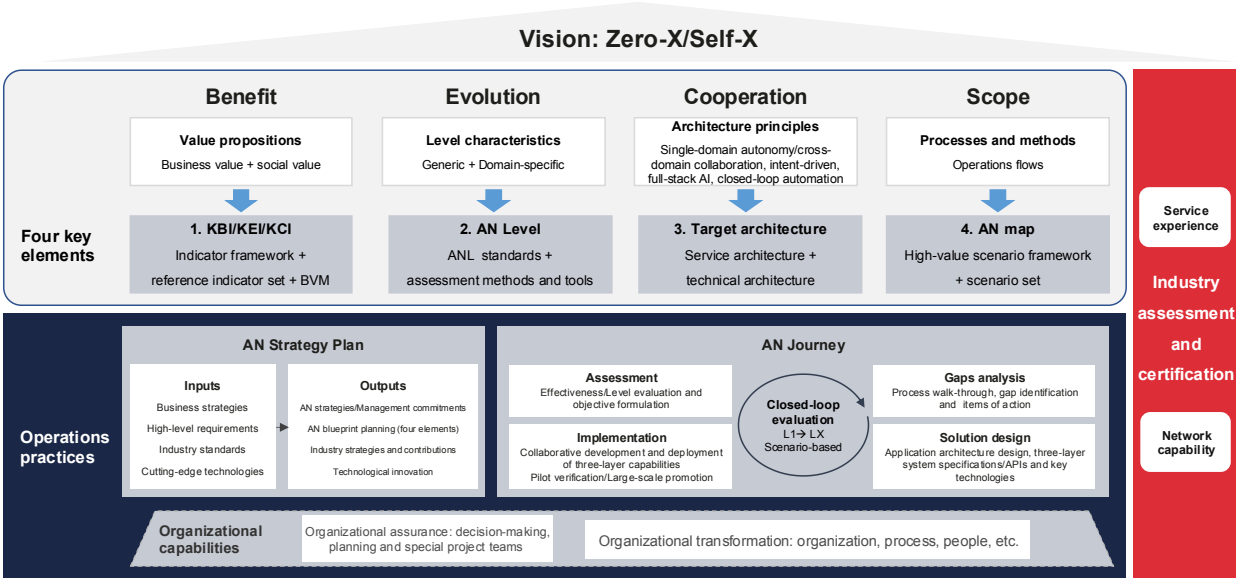

TM Forum, 2024

## AN VISION

The vision for autonomous networks is to provide zero-wait, zero-touch and zero-trouble customer experiences for consumers and businesses through intelligent infrastructure and agile operations (see graphic above). This makes the end user experience better, by providing higher availability of network services, quicker fulfilment of orders and easier description of orders as "intents" rather than detailed specifications. At the same time, ANs need to support self-service, self-fulfillment and self-assurance of telecom network infrastructures for internal users across various departments including planning, marketing, and operations and maintenance (O&M).

***The vision for autonomous networks is to provide zero-wait, zero-touch and zero-trouble customer experiences for consumers and businesses through intelligent infrastructure and agile operations.***

## TM Forum Autonomous Network Framework

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### AN FRAMEWORK

TM Forum's AN Framework (ANF) is an out-of-the-box implementation methodology to help CSPs plan and implement AN in an efficient and systematic manner (see graphic above). It consists of four key elements:

- KEIs to measure the benefits of implementing AN use cases
- AN level evaluations to measure progress
- Reference and technical architectures to guide implementation
- An AN Map to plan capability deployment.

The framework also includes operations best practices along with a methodology and tools for assessing AN levels. We discuss level evaluation in section 4, while section 5 focuses on best practices.

*The AN framework is an out-of-the-box implementation methodology to help CSPs plan and implement AN in an efficient and systematic manner.*

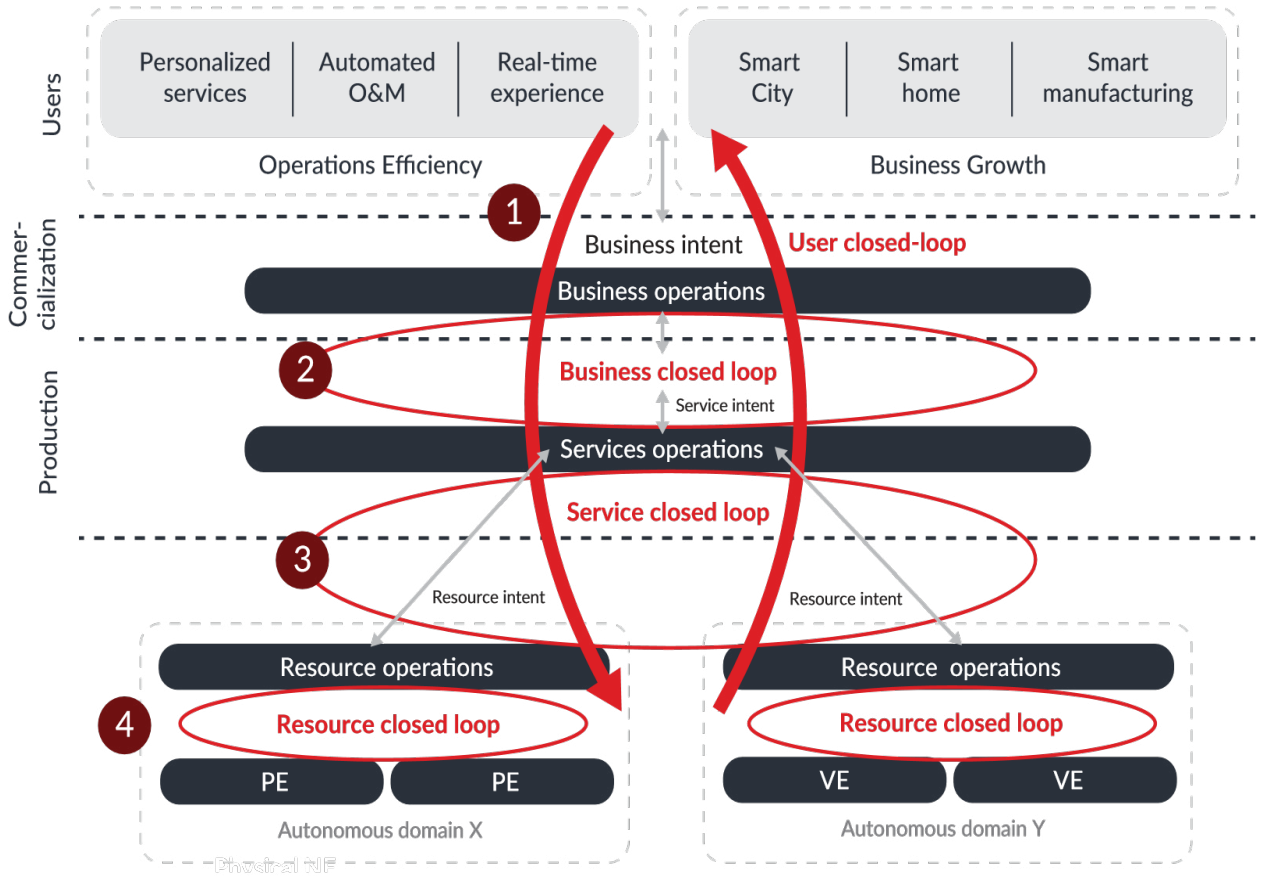
### INTENT AND AUTONOMOUS DOMAINS

To provide Zero-X experiences and Self-X O&M, the AN target architecture uses intent-based, closed-loop management as illustrated in the graphic on the next page. Intent is a way to express users' requirements, goals and constraints, and then interact with them in various domains in a way that allows a system to adapt its operation accordingly.

Importantly, intents are abstracted from the technical inner workings of the network. Put more simply, intents are the "what" not the "how" – meaning, you tell the system what goal or outcome is required without having to tell it how to achieve the goal. This decoupling increases agility, allowing autonomous systems to fulfill the intent using data, machine learning and AI, while enabling supplier innovation that can be easily integrated and adopted. Intent can be expressed at various operational layers (business intent, service intent and resource intent, for example). In the AN Reference Architecture (IG1251), intents guide the closed loop control process, which is a continuous process of monitoring, analyzing and adjusting performance to improve the quality of experience for end users and automate the full lifecycle of services.

Autonomous domains can be defined based on factors such as service types, network technologies or deployment locations. From an infrastructure perspective, examples include closed-loop systems within an operator's access, metro backbone, core, edge and customer networks. At the service operations layer, autonomous domains may also be organized around specific services such as SD-WAN, Voice over LTE (VoLTE) or content delivery networks (CDNs), with collaboration between domains to manage and optimize service delivery.

**Intent-based, closed-loop management**




TM Forum, 2024

Each autonomous domain operates independently, guided by the operator's business objectives, while hiding implementation details from customers through an API abstraction layer. When multiple autonomous domains are defined and deployed, the upper layer service operations leverage intent-driven interactions between domains to manage and fulfill the entire service lifecycle.

TM Forum members have collaborated in several Catalyst proofs of concept to develop the Intent Management API (TMF921), which communicates between autonomous domains to manage closed-loop operations across business, service and resource layers. High-level descriptions of intent are defined in TM Forum's Autonomous Networks Business Requirements and Framework (IG1218), and the technical work is published in Intent in Autonomous Networks (IG1253).

***Intents are the "what" not the "how" – meaning, you tell the system what goal or outcome is required without having to tell it how to achieve the goal. This decoupling increases agility.***

**KBIS, KEIS AND KCIS**

Key effectiveness indicators, or KEIs, measure the business value and operations effectiveness of autonomous networks. The AN KEI system included in the AN Framework is based on: the balanced scorecard theory (a widely used KEI creation tool); CSPs' practical experience with KEIs; and TM Forum's indicator framework as described in TM Forum Metrics Framework (GB935), TM Forum Metric Definitions (GB988) and other standards documents. This value-driven system focuses on both effectiveness and efficiency. TM Forum members have also created the AN KEI Framework (explained in Autonomous Networks Effectiveness Indicators – IG1256), which allows CSPs to add, delete or modify indicators to develop their own KEI system. We discuss key indicators more in the next section.

### TM Forum AN level taxonomy

| 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)

TM Forum, 2024

## AUTONOMOUS NETWORK LEVELS

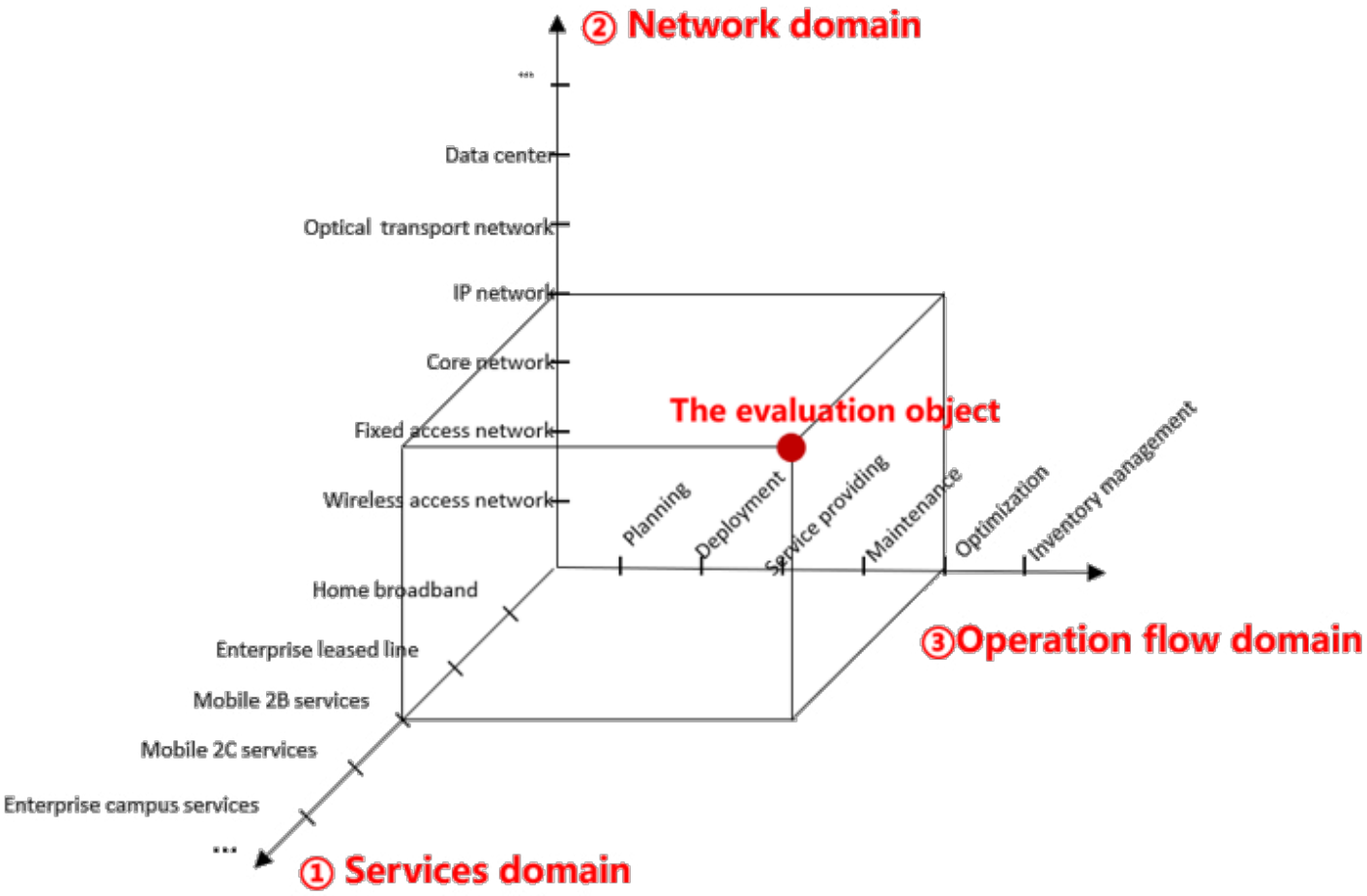
As explained in the introduction, TM Forum has established a six-level taxonomy to categorize the progression of autonomy in networks, ranging from Level 0 (no automation) to Level 5 (full autonomy). This model is gaining acceptance industry wide, with other SDOs such as the China Communications Standards Association (CCSA) using the AN levels to define autonomous networks and measure CSPs' progress in adopting them.

The ANL evaluation methodology is published in Autonomous Network Levels Evaluation Methodology (IG1252), which describes the evaluation approach and operation flows, task-evaluation criteria, scoring method, etc. An evaluation tool (GB1059) enables CSPs to measure their operations' current level of autonomy.

The first step is identifying "evaluation objects", which are determined by selecting an operational use case based on services domain, network technology domain and operational flows (see graphic on the next page).

*TM Forum's AN level taxonomy is gaining acceptance industry wide, with other SDOs using it to define autonomous networks and measure progress.*

**AN evaluation objects**



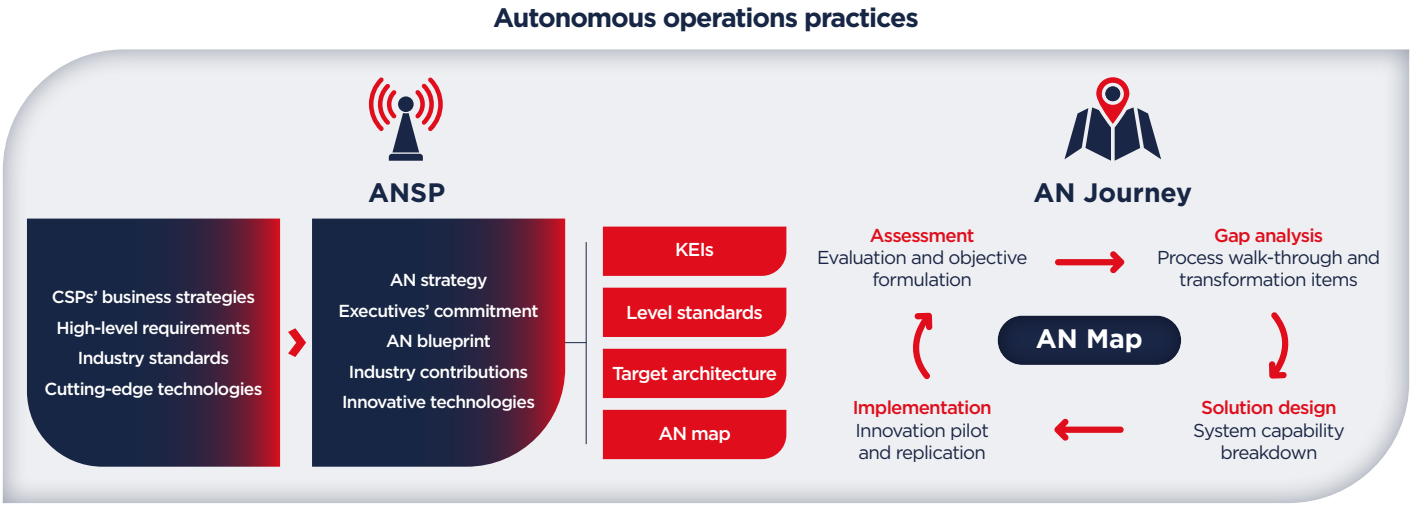

TM Forum, 2024

Then, CSPs can evaluate AN levels for these scenarios based on an assessment questionnaire that evaluates cognitive activities in the network like intent handling, awareness, analysis, decision and execution (IAADE), each of which contains a set of tasks to be measured. At Level 3 and below, users' intents can be achieved using policy-driven operations and existing interfaces. At Level 4, AI generates rules so that the network can optimize itself. We'll discuss AN level assessment more in Section 3.

***The first step in AN level evaluation is identifying 'evaluation objects', which are determined by selecting an operational use case.***

## REFERENCE ARCHITECTURES

In addition to standards for ANL assessment and KEIs, members of the AN Project are working on reference, business and technical architectures as part of the AN Framework. While TM Forum is focusing on creating domain-agnostic AN standards, other SDOs such as 3GPP and IETF are defining technology-specific autonomous domain architecture. TM Forum is working with these groups to align standards. We discuss standards more in Section 6.

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## AN MAP, STRATEGY PLAN AND JOURNEY

Finally, as part of the AN Framework TM Forum members have developed a set of best practices for planning and deploying AN. These include the AN Map, AN Strategic Planning (ANSP) and AN Journey (see graphic above).

The AN Map identifies the scope and priority of AN planning and deployment, serving as a "sandbox" for evaluating and promoting AN work. Creating the map began with defining AN implementation scenarios. The team initially identified the 11 high-value scenarios below. We discuss these scenarios and others in the next section, where we look at the AN Level 4 Industry Blueprint.

1. Service marketing
2. Service delivery
3. Service assurance
4. Complaint handling
5. Network planning
6. Network deployment
7. Network change
8. Fault management
9. Quality optimization
10. Energy-efficiency optimization
11. Resource management

***The AN Map identifies the scope and priority of AN planning and deployment, serving as a 'sandbox' for evaluating and promoting AN work.***

ANSP outlines corporate level AN strategies and executives' commitments while also providing guidance on implementing the four key elements of the AN Framework. It also specifies strategies for contributing AN strategies to the wider telecoms industry.

The AN Journey (sometimes called AN practice) refers to the overall transformation process, guiding CSPs from their current state to the desired future state of higher network autonomy. It is an iterative, four-step process based on high-value scenarios for telcos to plan and execute their AN strategies:

**1. Assessment** – for each high-value scenario, CSPs evaluate the live network based on ANL and KEIs to establish baselines and set improvement goals based on service requirements and the investment plan.

**2. Gap analysis** – CSPs analyze the gaps between the baselines and goal to identify the root causes of breakpoints and weaknesses.

**3. Solution design** – based on their target architectures, CSPs convert capability requirements into functional requirements for their solution providers to follow and then test new developments in pilot solutions.

**4. Implementation** – based on the results of the pilots, CSPs launch the solutions within a designated operating company and then replicate in other companies to improve the group's overall ANL and KEIs.

Next, we look at the development of TM Forum's new AN Level 4 Industry Blueprint and the role that AI plays in autonomous networks.

***The AN Journey (sometimes called AN practice) refers to the overall transformation process, guiding CSPs from their current state to the desired future state of higher network autonomy.***

# What is the AN Level 4 Industry Blueprint?

Section 2

Level 4 autonomous networks require AI. Indeed, at this level networks are transformed to become based on knowledge and inference so that they can behave with human-like intelligence and achieve an autonomous closed loop that encompasses context awareness, action planning, problem solving and decision-making.

TM Forum sees Level 4 autonomous capabilities as critical to helping CSPs reach their business goals, or "value outcomes". These include:

**Monetization of the network** – achieving time to market of one week or less for new services, plus realization of network-as-a-service (NaaS) and deterministic service level agreements (SLAs)

**Operational efficiency** – creation of digital employees to increase the number of devices maintained per person and reduce the onsite maintenance workload by thousands of person-years, while ensuring secure network operations

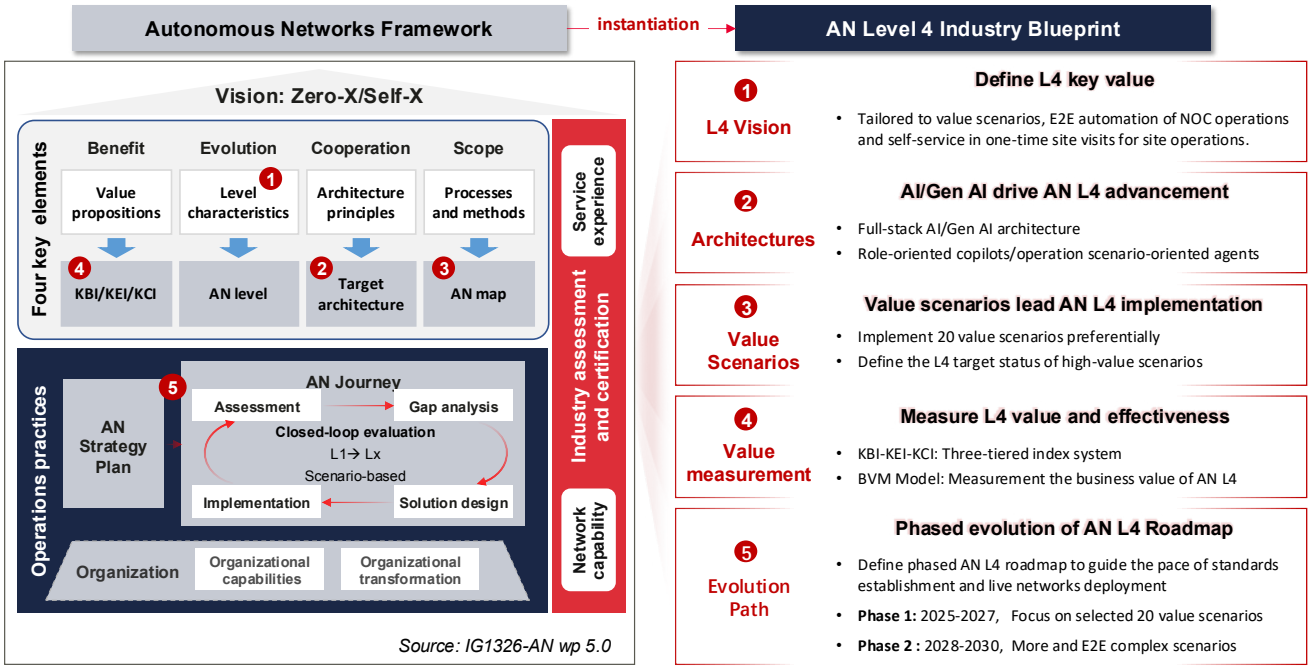
**Resource efficiency** – reducing energy consumption and carbon-dioxide (CO2) emissions, and increasing return on network investment

**Experience excellence** – reducing the rate of faults and complaints, providing minute-level service delivery and fault rectification, and improving SLA compliance.

To guide Level 4 AN deployment, TM Forum's AN Project, in collaboration with other standards bodies, is developing the AN Level 4 Industry Blueprint. Based on the Autonomous Network Framework, the blueprint serves as a foundation for industry-wide collaboration on, and improvement of, AN capabilities.

*The AN Level 4 Industry Blueprint explains that Level 4 requires end-to-end automation of NOC (network operations center) operations in high-value scenarios and a reduction in the number of site visits by engineers or technicians to just one.*

## TM Forum AN Level 4 Industry Blueprint



The blueprint includes:

- An expanded definition of Level 4 AN
- A reference architecture that includes enabling technologies such as AI
- Summaries of high-value scenarios
- A measurement system including KBIs, KEIs and KCIs (key business, effectiveness and capability indicators) to assess scenarios
- A phased evolution roadmap

*The TM Forum AN Reference Architecture introduces the concept of full-stack AI in autonomous networks, operating across layers of the AN Framework.*

## DEFINING LEVEL 4 AN

TM Forum's AN level evaluation methodology defines Level 4 AN like this: "In a complex, cross-domain environment, the system enables decision-making based on a predictive analysis or active closed-loop management of service-driven and customer experience-driven networks via AI modeling and continuous learning."

The AN blueprint goes further, explaining that Level 4 requires end-to-end automation of NOC (network operations center) operations in high-value scenarios and a reduction in the number of site visits by engineers or technicians to just one.

NOC operations encompass all production tasks except those requiring onsite visits during network planning, construction, maintenance, optimization and operations (though in principle AI-driven robots would handle site visits at Level 5). This includes analysis, prediction, solution development, decision-making, command and dispatch, and remote operations. The idea is to facilitate predictive and proactive O&M driven by enhancement of services and customer experience. This is achieved through predictive analysis based on real-time analysis of vast amounts of data, automated decision-making and automated use of tools.

Site operations include activities that require onsite visits (for example, network device installation, service provisioning, hardware fault rectification and board replacement). The goal is to achieve independent onsite operations performed by installation and maintenance engineers with the assistance of copilots so that they do not need additional human guidance. This approach enables all production tasks to be completed in one go, significantly reducing labor and O&M costs.

## AN L4 REFERENCE ARCHITECTURE INCLUDES AI

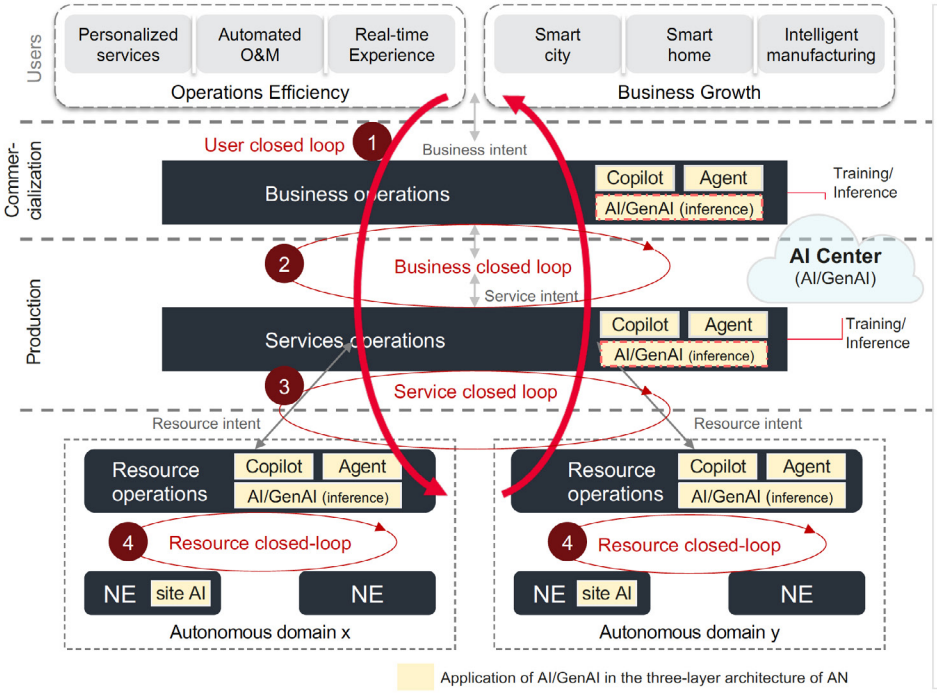
The TM Forum AN Reference Architecture introduces the concept of full-stack AI in autonomous networks, operating across layers of the AN Framework (see graphic on the next page). Here's what happens at each layer:

- **Business operations layer –** AI focuses on implementing intelligent applications for business processes such as precision marketing, translation of customers' intents, customer experience, and flexible combinations of products and offerings.
- **Service operations layer –** AI focuses on implementing intelligent applications for service processes such as service intent translation, end-to-end resource orchestration and scheduling, SLA policy creation, and end-to-end fault and performance management.
- **Resource operations layer –** AI focuses on local, lightweight development, model retraining and AI asset management to optimize local intelligence and support intelligent perception, analysis, decision-making and execution on local networks. In network elements, AI can comprehensively detect network status in real time and perform inference.

Effective cross-layer AI collaboration makes it possible to complete increasingly complex tasks. The goal is to support AI-based, automated closed-loop network operations and implement intelligent automation in different service scenarios to reach higher levels of AN.

GenAI will play an important role, working together with traditional AI/ML. ML can be used to identify patterns in data, predict results based on historical information and make decisions. GenAI is particularly well suited to tasks that require high creativity and innovation, such as intelligent Q&A for routine O&M tasks and complex network configuration. Combined, traditional AI and GenAI will be able to identify constantly changing network requirements and generate optimal network configurations.

## Full-stack AI/GenAI in the AN architecture




**Full-stack AI/GenAI in AN**

At AN Level 4, AI/GenAI will be widely used in the three-layer architecture of AN. Two types of agent applications, including **copilots** oriented to operations roles and **agents** oriented to operations scenarios, are used to enhance the autonomous capabilities of each layer.

- **Business/service operations:** agents are developed for users, businesses and service operations to achieve an end-to-end autonomous closed loop. AI/GenAI on which the agents depend can be implemented in either of the following modes:
  - ✓ Model inference integrated to the agents
  - ✓ Model training/inference centrally provided by the cloud AI center
- **Resource operations:** agents integrating AI/GenAI model inference collaborate with intelligent network elements (NEs) to implement a closed loop of single-domain network autonomy.
- **NE:** built-in AI models offer local inference, high-precision awareness and control capabilities.

TM Forum, 2024

GenAI can be used at any operational layer in the AN reference architecture and can work in tandem with other types of AI to develop two primary kinds of agent applications: role-oriented copilots and scenario-based agents capable of acting on behalf of users or systems. This integration significantly enhances autonomous capabilities across all operational layers (business, service, and resource operations) as depicted in the graphic above. The AN reference architecture inherently distributes intelligence and knowledge across all three operational layers, with each autonomous domain containing intelligence specific to its functions. As AI continues to evolve, the formal reference architecture remains robust and adaptable, accommodating advancements without the need for structural change. We discuss AI agents more at the end of this section.

In December 2023, TM Forum set up the GenAI for AN Standards working group in the AN Project and launched a discussion about a recently published document called Embracing Generative AI in Telecom: Amplifying Autonomous Network Evolution (IG1345). The group plans to expand on this work.

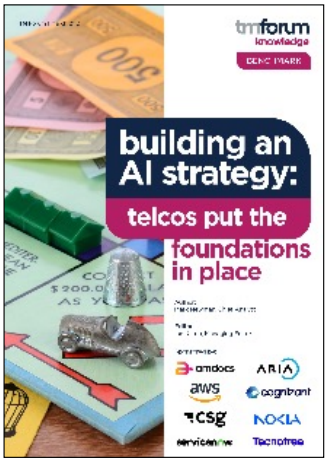
### IDENTIFYING L4 HIGH-VALUE SCENARIOS

Selecting high-value scenarios helps CSPs specify the practice scope of autonomous networks. It also helps them improve their return on investment and achieve potential business or operational improvements.

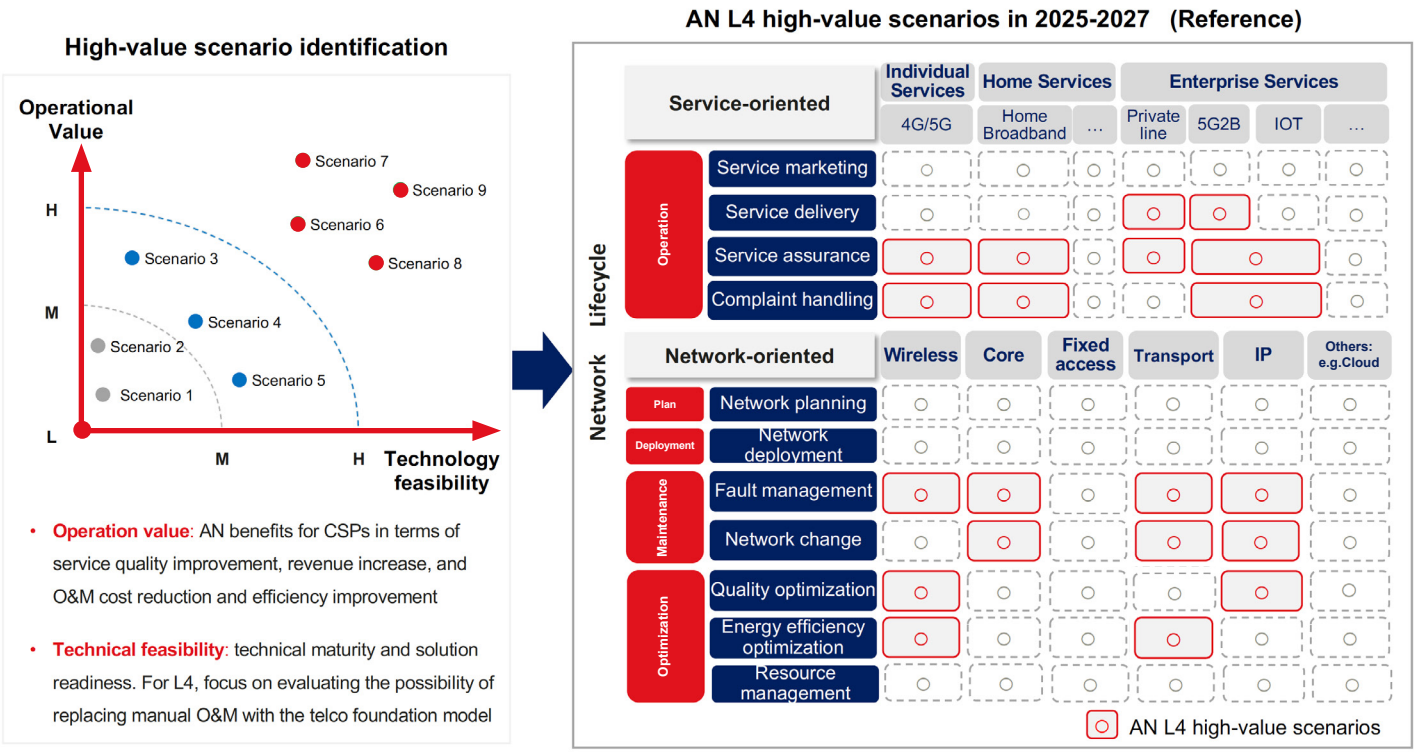
The AN Level 4 Industry Blueprint contains methods and references for identifying high-value scenarios, on which the entire telecoms industry is now collaborating to refine. The identification method is as follows:

1. CSPs clarify the scope of key services and networks and match them with the 11 end-to-end network operation processes to form a complete set of operation scenarios.
2. Then, they comprehensively analyze the cost and human resources needed, the impact on cybersecurity operations, and the technical feasibility of each scenario to select the scenarios they want to promote – that is, Level 4 high-value scenarios.

**Read this research report to learn more about how CSPs are using AI:**



## Identification of AN Level 4 high-value scenarios

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### TARGET-STATE DESIGN FOR LEVEL 4 HIGH-VALUE SCENARIOS

Accurately designing the Level 4 AN target state for high-value scenarios enables CSPs and suppliers to achieve technical breakthroughs, drive application innovation and accelerate the adoption of Level 4 practices. Here, we look at three examples: fault management (in multiple domains), wireless network quality optimization and complaint handling in home broadband services. In each case, the operator follows four steps:

1. **Set business and operations effectiveness objectives** – establish L4 objectives for high-value scenarios by referring to AN KEIs
2. **Define AN capability objectives** – identify critical AN capabilities needed to achieve Level 4, focusing on the intent-awareness-analysis-decision-execution closed loop
3. **Break down AN capability requirements** – use the three-layer AN architecture (the business, service and resource operations layers) to sort key technologies and guide technical breakthroughs and solution design
4. **Define the Level 4 target process** – streamline the end-to-end business process, identify workload distribution and AN capability weaknesses, and combine this with the AN capability breakdown to clarify development directions for key processes.

## Level 4 target state: fault management

| | |
|---|---|
| **Level 4 characteristics** | For single-domain/cross-domain faults and risks, all other phases are fully automated, except for necessary site visits (such as onsite hardware operations and high-risk command review). |
| **Scenario** | End-to-end process from fault/risk identification to fault/risk rectification in single network domains (such as wireless, core, transport and IP networks) and cross-network domain scenarios (such as wireless+transport and IP+transport) |

### 1. KBI/KEI objectives

**KBI objectives**

- Reduced annual opex: $XXX,000
- Number of employees who have transitioned ≥ XX
- Number of major faults per year: 0

**KEI objectives**

- MTTR ≤ XX minutes
- Number of major risks per month: 0

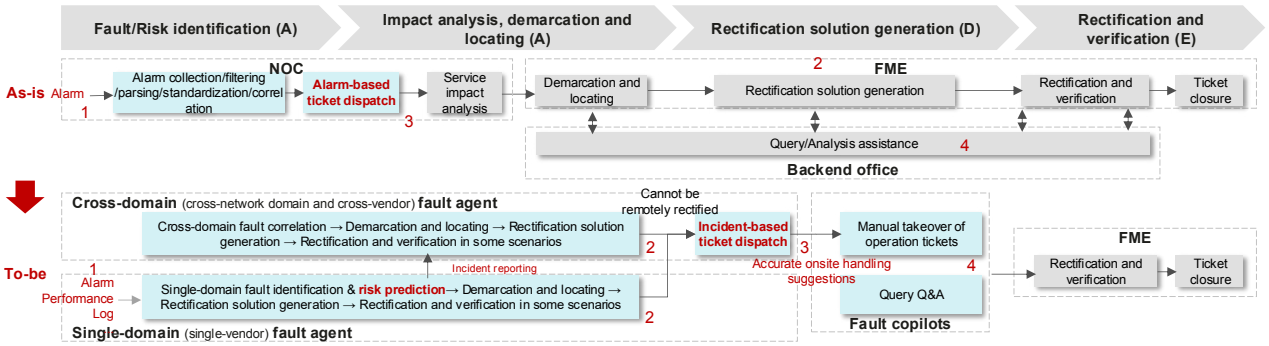
### 2. Autonomous capability requirements

- Faults and risks that can be **remotely rectified**: automatic rectification (manual review is required for certain ones)
- Faults and risks that require **onsite operations**: automatic and accurate diagnosis and automatic recovery solution recommendation
- **Automation rate**: proportion of the number of sub-scenarios that have been automatically processed to the total number of sub-scenarios ≥ 90%

### 3. AN capability requirement breakdown

| | |
|---|---|
| **Service operations layer** | **Cross-domain fault agents**: Fault aggregation analysis **across vendors and network domains** as well as cross-domain fault diagnosis and rectification are automatically completed.<br>**Cross-domain fault copilots**: Single-domain copilots are integrated as the unified entry for role-oriented copilots. Faults and risks are manually rectified based on the rectification guide provided by the copilots. |
| **Resource operations layer** (EMS + NE) | **Single-domain fault agents**: Faults and risks **in a single domain (single vendor)** can be automatically identified, diagnosed and rectified. Additionally, the copilots are used to notify O&M personnel for manual takeover (if necessary).<br>**Single-domain fault copilots**: Single-domain copilot APIs can be integrated with and invoked by cross-domain fault copilots. |

### 4. AN L4 major transformation item




**Highlights**

1. **Network quality improvement:** Analysis based on a single data source (alarm) → Analysis based on multiple data sources (alarms/performance/logs), quickly identifying and handling potential faults and risks, achieve proactive maintenance.
2. **New handling mode**: Manual handling for all faults → Automatic handling for certain faults by fault agents

## Level 4 target state: wireless network quality optimization

| | |
|---|---|
| **Level 4 characteristics** | 24/7 proactive optimization is provided, and 100% automation is achieved for routine wireless network optimization. More than 60% optimization tickets require no site visit. Self-service site visits are enabled to resolve issues at one time. |
| **Scenario Description** | **Mainly including three sub-scenarios: 1) Performance optimization** involves coverage, rate, interference, high load, and low traffic. **2) User experience** optimization involves top **data services** such as web browsing, video, gaming, payment, and instant messaging, and **voice-related experience optimization** for call connection, call drop, and voice quality. **3) Typical scenes** involve tidal traffic, burst traffic, and compensation for cell outage. **The E2E quality optimization process** includes poor network quality/experience deterioration identification, root cause locating, optimization solution generation and decision-making, automatic optimization implementation, and optimization effect evaluation. |

### 1. KBI/KEI objectives

- The E2E automatic closure rate of routine optimization is over 60%.
- The total network optimization time is reduced by 15%.
- The network optimization issue handling duration is reduced by 25%.

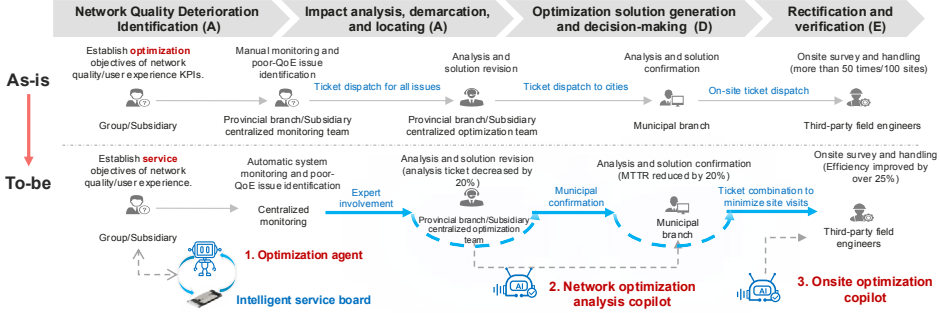
### 2. AN capability requirements

- High-precision real-time awareness of poor network quality and user-/service-level experience deterioration
- 100% automation of software commissioning optimization
- 100% coverage of three types of optimization sub-scenarios
- Interactive assistance and automatic optimization advice generation for optimization analysis and onsite optimization

### 3. AN capability requirement breakdown

| | |
|---|---|
| **Network optimization platform** | Formulates routine optimization appraisal objectives and ticket dispatch rules |
| **OMC** | Automatically analyzes performance and experience issues, Automatic single-domain optimization or outputs optimization advice. |
| **Base station** | 1) Accurately identify application- and user-level poor-QoE<br>2) remote and automatic adjustment of digital antennas. |

### 4. AN L4 major transformation item




**Highlights**

- Network native intelligence will be introduced to implement precise awareness of poor network quality and user-/service-level experience deterioration.
- Automatic system monitoring will replace manual monitoring to identify poor network/service quality and automatically generate tickets.
- More than 60% tickets can be automatically closed based on the agent.
- The optimization copilot will provide accurate adjustment and DT operation guides for live network optimization.

## Level 4 target state: HBB service complaint handling

| | |
|---|---|
| **Level 4 characteristics** | Self-service and remote handling of home broadband (HBB) complaints, no site visits for non-hardware faults, fault interception ahead of time, no NOC intervention, and precise guidance for installation and maintenance engineers |
| **Scenario Description** | End-to-end process includes complaint prediction, complaint handling, complaint preprocessing (including complaint demarcation, self-troubleshooting by users and remote system self-healing), ticket dispatch, onsite ticket handling, acceptance test and ticket closure. The process focuses on customer complaints caused by network faults (user devices, Wi-Fi networking mode and access network lines/devices) or poor service quality (of service platforms and content sources). |

### 1. KBI/KEI objectives

- Onsite HBB complaint handling rate: < 45%
- Average duration of onsite complaint handling: < 15 minutes

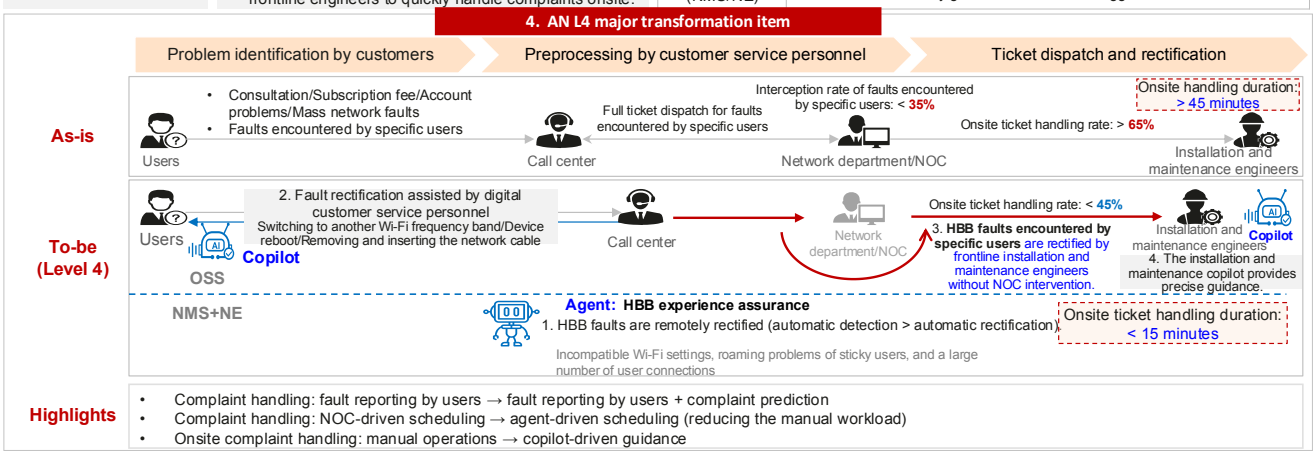
### 2. AN capability requirements

- **Self-service**: Users interact with the system through natural language to rectify common faults.
- **Remote rectification**: 55% of common faults (such as software and configuration faults) can be remotely rectified. For other types of faults, root causes are automatically identified, and handling suggestions are provided.
- **Remote guidance**: Operation guide is provided for frontline engineers to quickly handle complaints onsite.

### 3. AN capability requirement breakdown

| | |
|---|---|
| Business operations layer | The user copilot invokes agent capabilities to guide users to rectify common faults. |
| Service operations layer | The installation and maintenance copilot enables installation and maintenance engineers to handle faults through natural language. The OMC copilot is pre-integrated, which invokes agent capabilities. |
| Resource operations layer (NMS/NE) | The experience assurance agent identifies app-level poor-QoE problems, supports fault inference based on the fault tree and COT, accurately locates faults, and automatically generates rectification suggestions. |

### 4. AN L4 major transformation item




**Highlights**

- Complaint handling: fault reporting by users → fault reporting by users + complaint prediction
- Complaint handling: NOC-driven scheduling → agent-driven scheduling (reducing the manual workload)
- Onsite complaint handling: manual operations → copilot-driven guidance

## Level 4 target state: MBB customer complaint handling

| | |
|---|---|
| **Scenario Description** | **Scenario**<br>The mobile broadband (MBB) customer complaint handling process is important for routine management. It consists of tasks such as complaint prediction, analysis and decisioning, network issue execution, and complaint issue verification until closure of the complaint ticket. Call center, NOC and radio optimization teams use various tools to complete those processes. The main objective is to quickly analyze root cause and output precise resolution and suggestion to improve customer satisfaction. |

### 1、KBI/KEI objectives

1) First call resolution ↑
2) Auto complaint handling rate ↑
3) Repeated complaint rate ↓

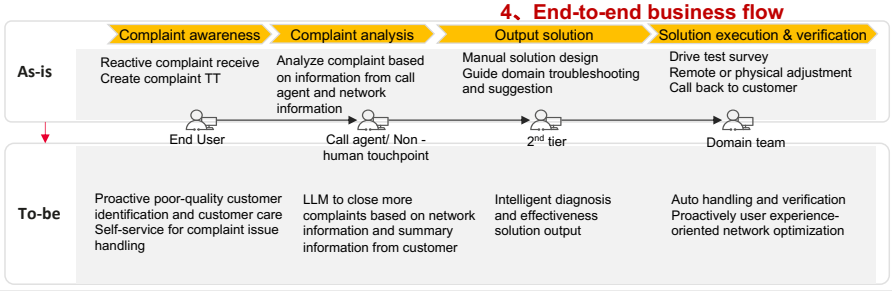
### 2、Capability objectives

1) Network complaint prediction and prevention ↑
2) Auto complaint issue demarcation ↑
3) Auto network issue diagnosis ↑
4) Auto execution and verification ↑

### 3、Break down AN capability requirements

| | |
|---|---|
| **End user** | Identify user receiving poor quality with network root cause to support proactive customer care and self-service checking |
| **Call agent** | Use LLM to interact with affected user to provide more information online and close more complaints without network teams |
| **2nd tier/domain team** | Intelligent complaint issue diagnosis and solution output to support auto-execution and verification<br>Proactive user experience-oriented network optimization |

### 4、End-to-end business flow




### Key transformation point

From reactive complaint handling to proactive and predictive

From report complaint issue by end user to self-service checking and verify suggestion

From manual complaint issue analysis and decision to intelligent output

From manual complaint issue resolution to auto-execution and verification

## Level 4 target state: RAN energy efficiency optimization

**Scenario Description**

**Scenario**

Using intelligent technology to achieve accurate service prediction of the base station, generate personalized energy saving schemes and automate execution can effectively improve the energysaving effect and reduce operating expenses. This includes collection of network data, analysis of service characteristics, generation of energy-saving schemes, dispatch of energy-saving instructions and provide feedback optimization of execution results.

### 1. KBI/KEI objectives

- Base station energy-saving gain increases by 10% annually

### 2. Capability objectives

- **Data acquisition:** one point access to the national base station data, resources, instructions, AI computing power, etc.
- **Accurate prediction :** Realize the intelligent prediction of the tide law of the base station business and determine the energy-saving time
- **Solution generation:** Automatically generates a complete energy-saving solution, including energy-saving period and energy-saving method.

### 3. Break down AN capability requirements

| | |
|---|---|
| **Business operation** | Business intent translated into energy-saving policy requirements |
| **Service operation** | It should support the automatic analysis capability of base station characteristics; the ability to generate energy-saving schemes that maximize the reduction of base station energy consumption and minimize network impact; the automatic generation and delivery of instructions; and the optimization and adjustment of energy saving strategies |
| **Resource operation (OMC+NE)** | Realize the automatic collection of base station data, resources, instructions, AI computing power, etc.; can automatically execute instructions and feedback optimization results |

### 4. End-to-end business flow

| | Historical data analysis | Energy saving plan generation | Configure strategy delivery | feedback and optimization periodicity |
|---|---|---|---|---|
| **As-is** | Collect and analyze the historical traffic data to determine the traffic low period | Based on the analysis results and experience,expert make specific energy-saving plans | Deliver the configuration strategy in the network management system or base station device | Regularly evaluate the energy-saving effect, adjust and optimize according to the actual situation |

| | Network data acquisition | Intelligent prediction | Automatic energy saving strategies generation | Automatic instruction scheduling | Result feedback optimization |
|---|---|---|---|---|---|
| **To-be** | base station data, resources, instructions, AI computing power, etc | the tide law of the base station business | Realize the coordination of soft and hard close of base station energy saving | The remote control of the base station is realized through the command online arrangement and command automatic scheduling module | Using reinforcement learning techniques, parameter thresholds in policy configuration are optimized |

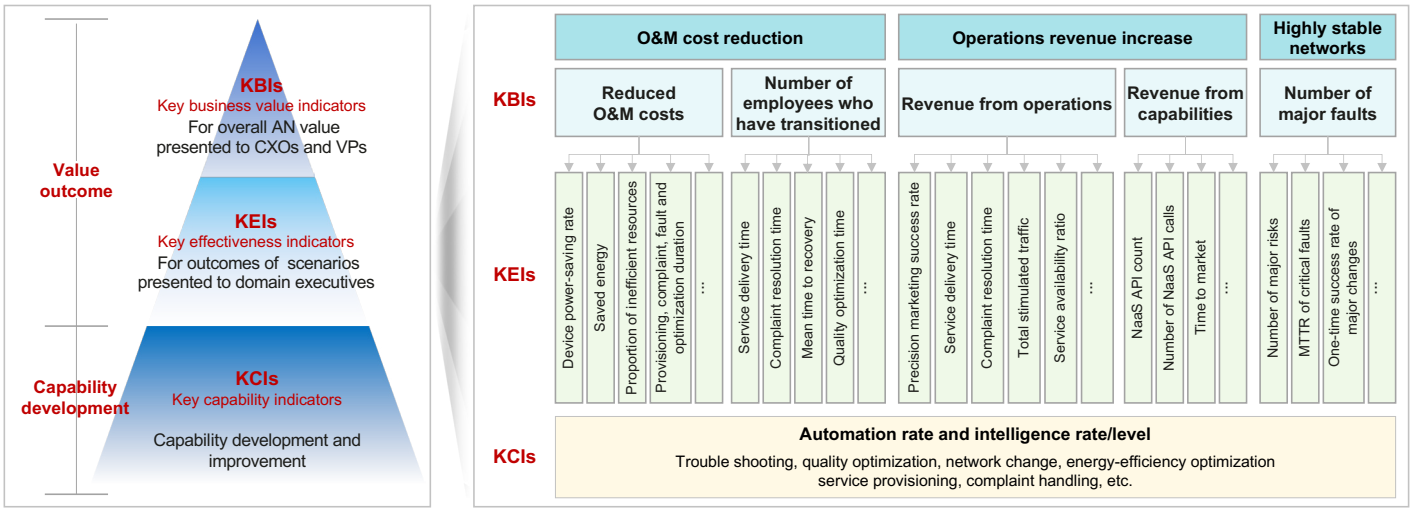
### Key transformation point

- **Data analysis:** Transition from historical data analysis to automatic collection and intelligent prediction
- **Energy-saving solution generation:** Transition from expert experience to automatic generation
- **Strategy configure:** Transition from manual configuration to automatic scheduling and remote configuration
- **Feedback adjustment:** Transition from periodic manual adjustment to automatic parameter optimization through machine learning

## MEASURING VALUE WITH KEIs, KBIs AND KCIs

In the Level 4 blueprint, TM Forum has expanded the KEIs outlined in the AN Framework to include a three-layer AN Indicator Framework that also uses KBIs and KCIs to measure the value of use cases. We explained KEIs in Section 1 (see page 11). KBIs measure the business value of AN scenarios and can be used to demonstrate this value to executives. KCIs are used to set capability development objectives and guide all departments and operating companies in developing them. The graphic below shows the AN Value Indicator Framework.

### AN Value Indicator Framework

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TM Forum has also developed a Business Value Measurement (BVM) model to analyze the correlation between KEIs and KBIs and measure how changes in KEI affect KBI improvements. For example, a CSP can look at the correlation between customer satisfaction (a KEI) and the customer churn rate (a KBI) to determine how to increase revenue. The table below shows KEIs and KBIs for select Level 4 scenarios, which we look at in more detail in Section 4, which focuses on best practices for implementing these scenarios.

## AN Business Value Measurement model

| High-value scenarios & KEIs # mapping | |
|---|---|
| Service marketing | 7 |
| Service delivery | 2/3 |
| Service assurance | 2/4/5/6 |
| Complaint handling | 2/4 |
| Network planning | ... |
| Network deployment | ... |
| Fault management | 2/4/9/10 |
| Network change | 11 |
| Quality optimization | 2/5/6 |
| Energy efficiency optimization | 1 |
| Resource management | ... |

| KEI | KBI | | Average Factor | | Scale Factor (Optional) | | Financial Factor |
|---|---|---|---|---|---|---|---|
| 1. Saved energy | **Reduced O&M costs**<br>- Less electricity fees | = | Annual power consumption of a single device x Power saving rate of a single device | x | Device scale | x | Electricity price |
| 2. Average duration per ticket | - Lower outsourcing costs | = | Δ Average maintenance duration per ticket | x | Total number of tickets | x | Outsourcing labor cost per unit time |
| | **Number of employees who have transitioned**<br>- Shift of employees towards higher-value work | = | Δ Average person-hour per ticket | x | Total number of tickets | ÷ | Annual labor hours per person |
| 3. Service Delivery Time | **Revenues from operations**<br>- Increased revenue from early provisioning and early sales | = | Number of provisioning days reduced for each user | x | Annual average service provisioning volume | x | ARPU (Revenue per user/month) |
| 4. Service availability Ratio | - Increased revenue from shorter interruption duration and less revenue loss | = | Reduced interruption duration per user | x | Number of users | x | ARPU |
| 5. Total stimulated traffic | - Increased revenue from experience improvement and stimulated traffic | = | Average stimulated traffic per area | x | Number of stimulated areas | x | Δ Traffic revenue per unit |
| 6. Service availability Ratio | - Increased revenue from quality improvement and SLA monetization | = | Δ Availability x Annual duration | x | Number of users | x | ARPU |
| 7. Precision marketing success rate | - Increased revenue from precision marketing/Sales | = | Δ Precision marketing success rate | x | Total number of marketing users | x | ARPU |
| 8. Number of NaaS API calls | **Revenues from capabilities**<br>- Increased revenue from capability openness | = | Number of new APIs | x | Average number of API calls | x | API unit price/call |
| 9. Number of major risks | **Number of major faults**<br>- Major faults caused by major risks | ≈ | | | Number of major risks | | |
| 10. MTTR of major faults | - Major faults that are not handled within the specified duration | = | | | Number of times that major faults are not handled within the specified duration | | |
| 11. One-time success rate of major changes | - Major faults caused by major network changes | = | (1 – One-time success rate of major changes) | x | Number of major changes | | |
| ... | ... | | | | | | |

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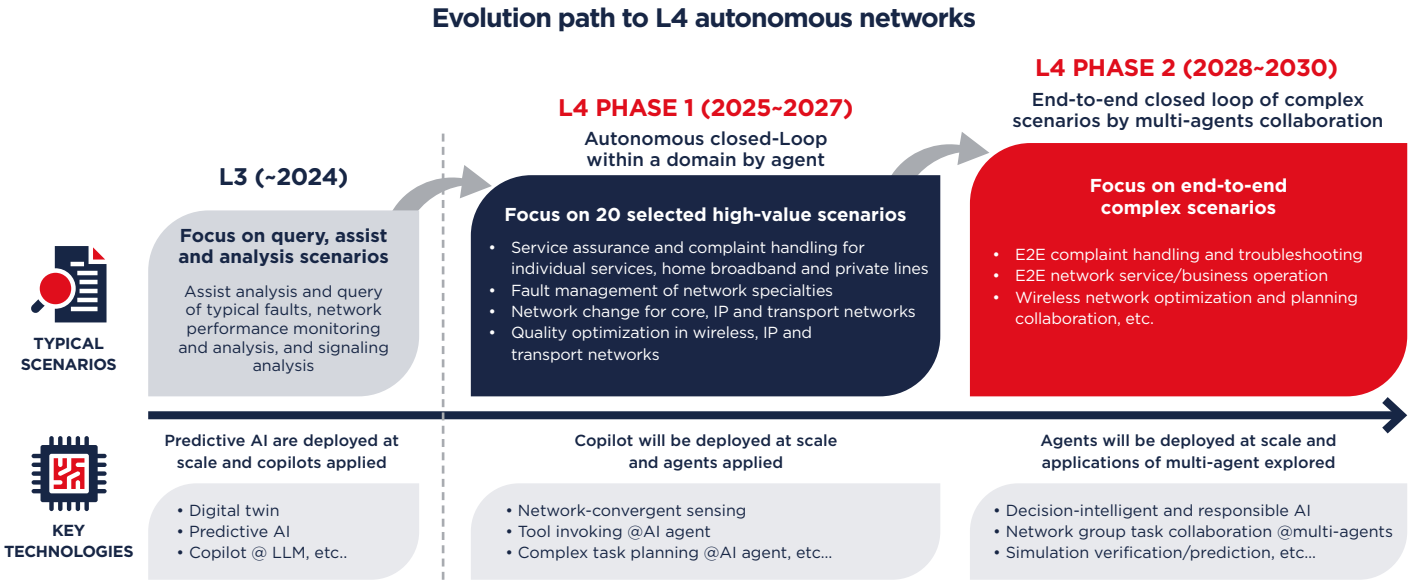
## EVOLVING TO LEVEL 4

TM Forum recommends that the journey to Level 4 autonomous networks be divided into two phases as shown in the graphic below. The objectives, typical scenarios and key technologies of each phase have been defined in this preliminary model as a starting point for discussion and improvement by the entire telecoms industry.

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Getting to Level 4 AN essentially means that CSPs' operations move from an environment where systems assist humans to one where humans assist machines. Many large operator groups are currently operating at or near Level 3 in at least some domains (see Section 3). This means they are deploying predictive AI and digital twin technology and are experimenting with GenAI.

*Getting to Level 4 AN essentially means that CSPs' operations move from an environment where systems assist humans to one where humans assist machines.*

In the first phase of Level 4 deployment, operators will apply agents to ensure that the network makes decisions based on awareness information and instructs corresponding modules to take further action without manual intervention. Agents can be leveraged to solve complex problems, including network self-optimization and self-healing, without a high degree of human intervention.

In phase 2, multiple cross-layer and cross-domain agents will collaborate to complete tasks like optimization of user experience and networks. Multi-agents can be different functional entities, such as network elements, autonomous domain management and control systems, and application programs. By collaborating, they facilitate distributed decision-making and a high degree of flexibility and scalability.

Until Level 5 AN is reached, human-machine collaboration will be required to support smooth network operations and ensure network security. The main objective of such collaboration is to smoothly switch between network control modes and minimize the impact of the sudden changes caused by the switching.

AN Level 4 cannot cover all scenarios. For example, the system may not know how to resolve or mitigate conflicts between multiple automatic closed-loop objectives. At Level 5 when no humans are involved machines will generate their own intents and could decide to prioritize customer experience versus carbon footprint. But some operators may stop short of implementing Level 5 in their production networks because they may not be willing to exclude humans completely from service delivery and assurance processes.

Next, we look at where CSPs are on their AN journeys.

# Where are we on the AN journey?

Section 3

Many CSPs are making progress implementing autonomous networks. Several operators have stated publicly their ambition to achieve Level 4 AN in at least some domains and use cases over the next two years.

The table on pages 28-30 provides a snapshot of AN implementation based on contributions received from CSPs involved in the AN Project. Attained levels noted in the table are self-reported by the CSP and typically reflect a value for the operator's network overall. But this doesn't offer a true comparison of operators' progress.

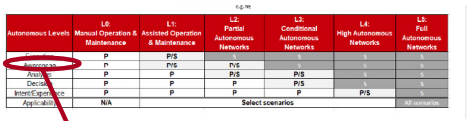
To enable comparison, the way AN levels are assessed needs further standardization. TM Forum's Autonomous Network Levels Evaluation Methodology (IG1252) helps CSPs self-assess their progress, but detailed scoring for specific domains and scenarios hasn't been fully standardized. The AN Project has been working to change this by enabling normalized comparison of operators' AN levels.

In the first half of 2024, TM Forum – together with CSPs including AIS, Orange and Telefónica and suppliers such as Detecon, Ericsson and Huawei – held a series of workshops to further define AN level evaluation methodology and develop a self-service assessment tool to gauge AN deployment. The group began with fault management in the RAN and core network, which CSPs have identified as key scenarios.

As noted in Section 1, AN level scoring is based on an assessment questionnaire that evaluates cognitive activities in the network like intent handling, awareness, analysis, decision and execution (IAADE), each of which contains a set of tasks to be measured. The questionnaire is based on the professional grading standards of SDOs such as 3GPP and ETSI with added weighting and detailed scoring criteria. The graphic below shows an example, with questions based on 3GPP's published standards in the RAN and core.

*The way AN levels are assessed needs further standardization, so TM Forum's AN Project has been working on an evaluation tool to enable normalized comparison of operators' AN levels.*

## AN level evaluation sample question




| High-Value Scenario | Cognitive Activity (IAADE) | Service Capability | Weight | Question | Option A | Option B | Option C | Option D | Answer |
|---|---|---|---|---|---|---|---|---|---|
| RAN Fault Management | Awareness | Data collection | 5% | Does the wireless network fault management system support automatic data collection in various fault scenarios? Fault scenarios include NE disconnection or out-of-service, cell faults, and fronthaul network faults. | Yes. The system can automatically collect data(alarm, configuration, and performance data etc.) | Partially. Data collection rules or templates are manually defined. The system can automatically collect data(alarm, configuration, and performance data etc.) | Partially. Manually select data collection items. The system can automatically collect data(alarm, configuration, and performance data etc.) | No. People use the system to collect data | B |
| | | Alarm filtering | 5% | Does the wireless network fault management system support automatic alarm filtering in various fault scenarios? Fault scenarios include NE disconnection or out-of-service, cell faults, and fronthaul network faults. | Yes. The system can automatically filter out invalid or redundant alarms. | Partially. Manually define alarm filtering rules. The system automatically filters out invalid or redundant alarms. | Partially. People use the system filter out invalid or redundant alarms. | No. People filter out invalid or redundant alarms. | A |

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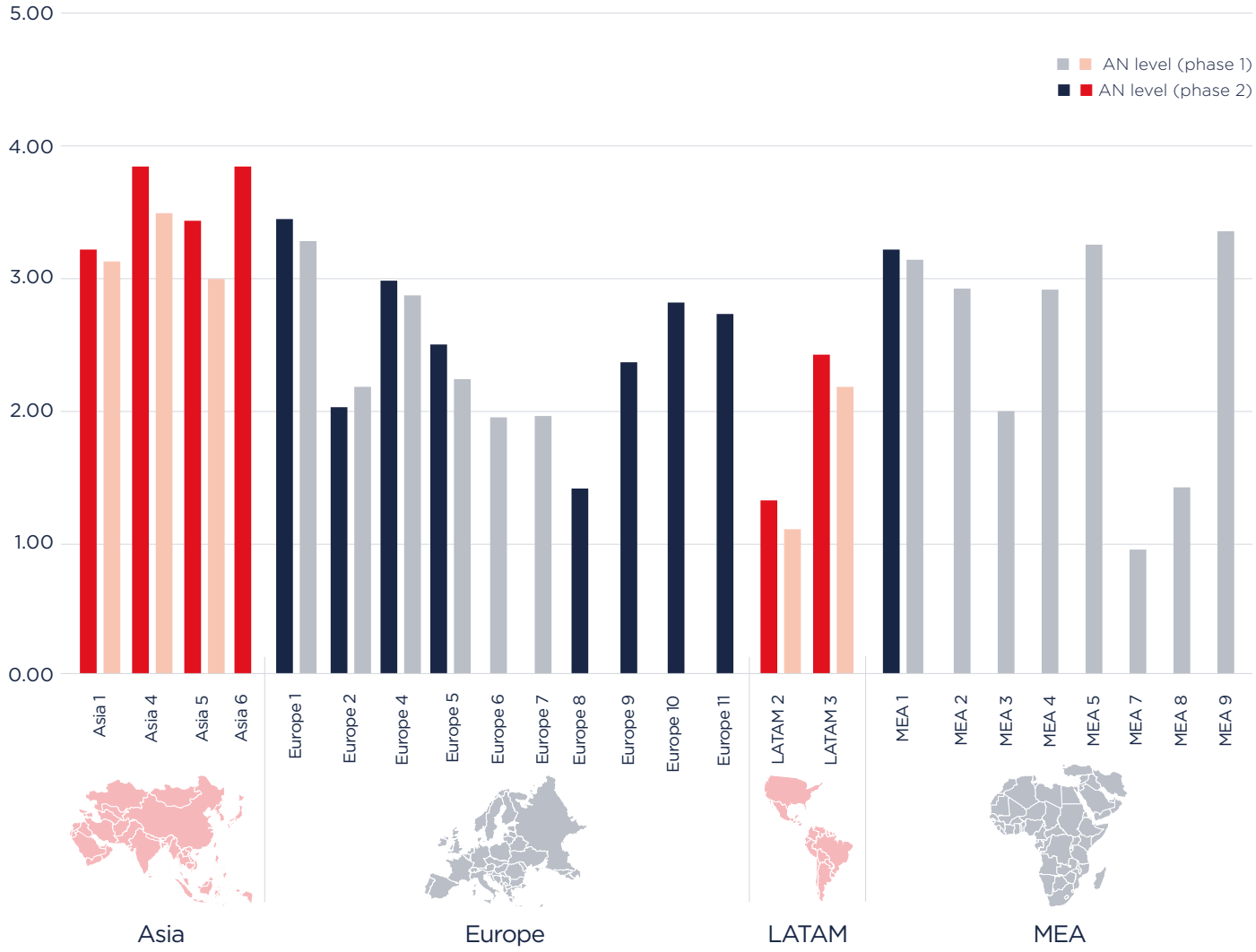
## PILOT ASSESSMENT RESULTS

During 2024, two dozen CSPs used the tool to assess their AN implementations of fault management in the RAN and core network, with plans to expand scenarios to include fault management and quality optimization in IP networks and network change in RAN and core networks. Some of the companies participating in the evaluations included AIS, Antel Uruguay, China Telecom, Elisa, Globe Telecom, IOH Indonesia, MTN Group, Orange, stc, Telecom Argentina, Telefónica, Telkomsel, among others that wish to remain anonymous. MTN, Orange and Telefónica evaluated the scenarios in multiple countries.

**Two dozen CSPs have used TM Forum's pilot assessment tool to evaluate their AN implementations.**

Preliminary AN level evaluation results were presented in June 2024 at DTW-Ignite after the first phase of the project. At this stage it was clear that the questionnaires used to carry out the evaluations needed refinement to enable normalized scoring. Changes were made during phase 2 of the project, resulting in the publication of two standardized AN Level Evaluation Tool (ANLET) questionnaires for fault management on the RAN and core networks, respectively. Most of the phase 1 participants and some new CSPs repeated evaluations using the new questionnaires. Anonymized results from both phases are presented below and on the next page.

**AN level evaluations for fault management in the RAN**

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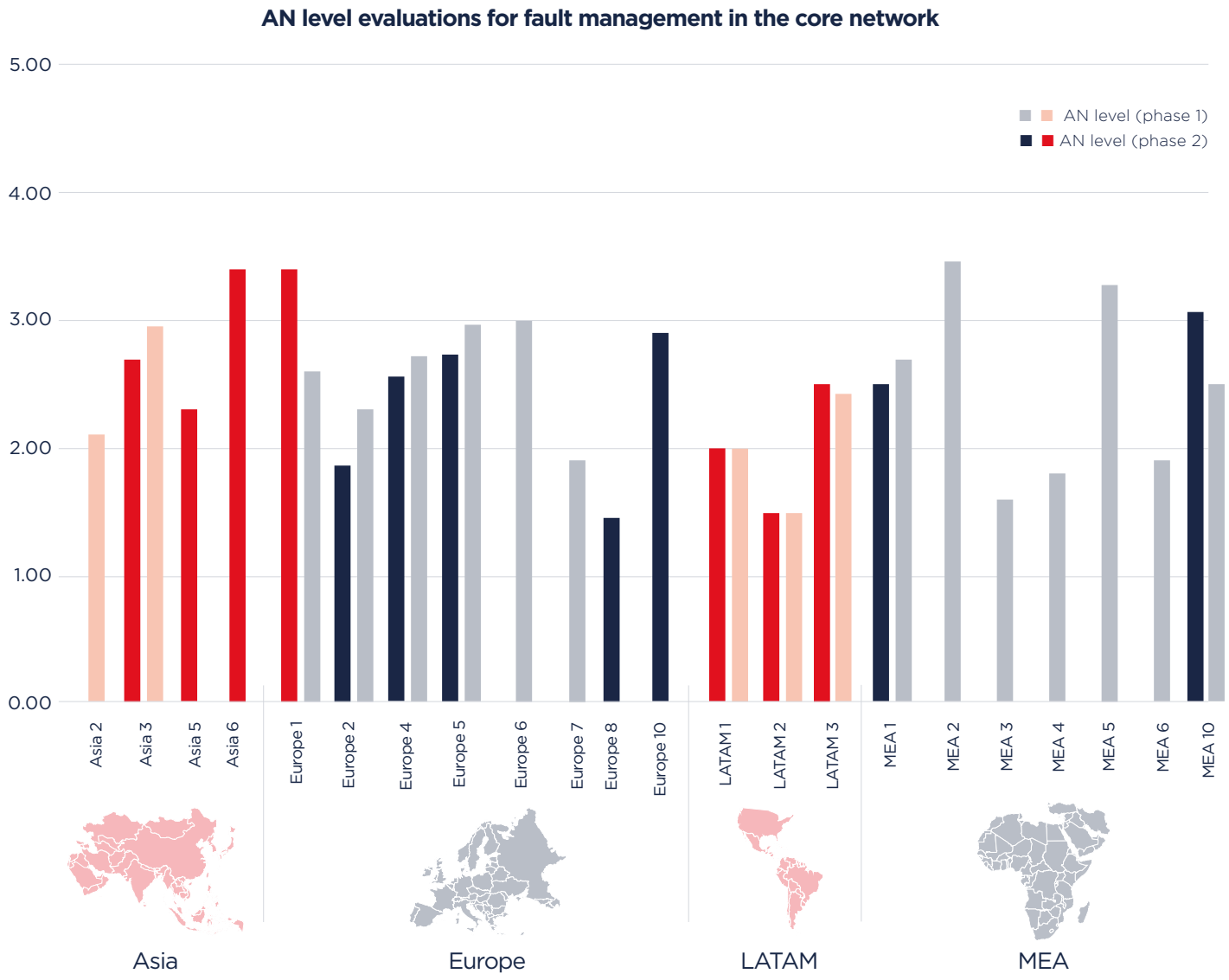


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The average ANL score for fault management in phase 2 was 2.5 in the core network and 2.8 in the RAN. Core network stability was also assessed, with a higher average ANL of 3.5. Overall, AN levels achieved remain relatively low considering the commitment of some of these operators to reach Level 4 by 2025, with most scores clustered between Level 2 and Level 3. Leading operators have outlined clear business objectives, capability goals and the evolution path toward Level 4 for high-value scenarios (see Section 7). Other operators can reference these examples to accelerate their development of Level 4 capabilities.

## CSPs' AN strategies and progress

| CSP | AN strategy | Level 4 high-value focus | Progress and plans |
|---|---|---|---|
| AIS | TM Forum's ODA, AN framework and AN level taxonomy are the foundation of AIS's 'Cognitive Techco' strategy | • Core network fault management<br>• Wireless network optimization: customer experience driven<br>• Optical and transport service assurance | Is participating in TM Forum's AN level assessment pilot; achieved L3 in the two targeted processes (RAN and core fault management); results include:<br><br>• CX optimized by 10%<br>• Traffic loss reduced by 90% in extreme scenarios<br>• Network efficiency improved by +20%<br><br>Is extending AN practices to network optimization, configuration, planning, change and other processes. |
| 中国移动 China Mobile | China Mobile was the first CSP to set a goal to reach L4 on a large scale in its production network; technology function is centralized, and the company is using end-to-end service operation layer across domains to drive overall development of technical AN capabilities | • Service delivery<br>• Network change<br>• Energy-efficiency optimization<br>• Service-quality optimization<br>• Troubleshooting<br>• Complaint handling | Achieved overall AN L3.2 in 2023; results include:<br><br>• Significant improvement in customer satisfaction<br>• 80% reduction in the number of major network faults<br>• 20% increase in average number of sites maintained per person<br>• Savings of 3,200 person-years of human labor and 4 billion Kwh of electricity<br>• Contribution to 70 AN technical standards and 15 whitepapers<br>• Has launched a telecoms LLM with 13.9 billion parameters, trialing applications like data self-service and AI chatbots. |
| 中国电信 CHINA TELECOM | China Telecom is guided by '3-ultra Vision', considers autonomous cloud-network operations as an important stepping stone for the transformation toward 'network + cloud' | • 5G core network: complaint handling<br>• IP network: network changes (intelligent online simulation)<br>• Innovative practice of network LLM in network maintenance scenario | Is participating in AN level assessment pilot. Achieved overall AN L3+ in 2023; results include:<br><br>• Return on equity up from 6.41% in 2022 to 6.93% in 2023<br>• Savings of 1 billion kilowatt-hours of electricity annually<br><br>In 2024 aims to achieve L4 in 40% of high-value scenarios and will promote large-scale application of its LLM in the network, creating thousands of digital employees. |
| China unicom 中国联通 | China Unicom aims to implement autonomous systems across all stages of planning, development, maintenance, optimization and operations to enable digital operations, intelligent scenarios and agile services. | • Optical private lines – service assurance<br>• Intelligent planning and construction<br>• Intelligent energy savings in base stations<br>• Closed-loop control of optical cable risks | Is performing ANL evaluations for 5 networks across 8 provinces focusing on high-value scenarios using GenAI; results include:<br><br>• 1.5 million customer complaint diagnoses per month with an 80% one-time problem resolution rate<br>• Intelligent energy-saving systems cover 98% of base stations, saving over 40 million kilowatt-hours monthly<br>• Open platform aggregates 2,800 capabilities, utilized over 38 billion times per month<br><br>Will focus on additional high-value L4 AN scenarios in the next two years. |

## CSPs' AN strategies and progress

| CSP | AN strategy | Level 4 high-value focus | Progress and plans |
|---|---|---|---|
| 中華電信 Chunghwa Telecom | Chunghwa Telecom has been working on closed-loop automation for specific network scenarios since 2019. | • Fault management in RAN and IP transport domains<br>• Energy-efficiency optimization in the RAN | Since 2023, the company has expanded AN operations management to enhance customer experience and reduce operational costs; results include:<br><br>• Conducted ANL assessments for fixed and mobile broadband services, achieving L3 autonomy<br>• Developed an automated fixed broadband service rate upgrade mechanism, benefiting 1.16 million users<br><br>Plans to apply AN to mobile broadband and IP transport networks, aiming to achieve L4 by 2025. |
| HKT | HKT aims to bring the right digital solutions to society to accelerate growth and create a sustainable future for all. | • Wireless network optimization focusing on energy usage according to data traffic using AI technology<br>• Optical and transport service to minimize energy consumption and improve energy efficiency through AI technology | Is participating in TM Forum's AN level assessment pilot.<br><br>Focus in 2023 was on reducing 20% of HKT's total energy consumption (compared with 2018 baseline), and HKT plans to further cut energy consumption this year and in the future using innovative methods over its AN. |
| MTN | MTN is implementing AN as part of its Ambition 2025 Strategy, which includes a technology framework called PACE (Platform, Agile, Connectivity and Experience).<br><br>All MTN operating companies aligned with the company's AN strategy and target architecture, which is based on TM Forum's AN framework. | • Cross-domain network – fault management<br>• IP and optical network – autonomous O&M | Participated in the AN level assessment pilot and will continue to align to the assessment for RAN, core, IP and change management.<br><br>In 2023, MTN released its AN Blueprint 2.0, establishing ANL standards and developing a comprehensive use case library. In 2024, the company plans to design Version 3 of the blueprint, identifying high-value scenarios to finalize assessment criteria, effectiveness targets, processes and architecture for AN L4. |
| Singtel | Singtel initiated its AN program in 2023, fostering group-level collaboration to benchmark, share best practices and apply them across the group. | • Fault management and customer-complaint management<br>• RAN energy saving and network optimization | Designated Singtel Group operator AIS as an AN coach to standardize the four key elements of the AN Framework and support operating companies in L3 and L3+ use-case deployment.<br><br>In 2024, will create its AN L4 Blueprint to transition from automation to autonomy. |

## CSPs' AN strategies and progress

| CSP | AN strategy | Level 4 high-value focus | Progress and plans |
|---|---|---|---|
| stc | stc has a goal to achieve ANL 4 in 2025 in some scenarios | Core network: fault management, network changes, design and deployment | Is participating in TM Forum's AN level assessment pilot.<br><br>2024 focus was on automatic network change and AIOps capabilities including:<br>• Digital twin-based cloud-network visualization<br>• Intelligent signaling storm simulation and emergency assistance<br>• Pipeline-based network change and deployment automation<br><br>Results included:<br>• Fault management - CNF and cloud health status unified visualization, moving from 5+ portals to 1 and cutting fault-demarcation time from 2 hours to 15 minutes<br>• Network changes and deployment: ultra-security (automatic execution by unified pipeline reducing 80% of manual breakpoints); high-efficiency (deploying 200+ test cases in minutes); and full scenarios for both telco-cloud and core network<br><br>In 2025, stc plans to introduce foundational models for alarm analysis, an intelligent copilot and a complaint handling expert. |
| telecom | Telecom Argentina drives its strategy of developing ANs and contributing to TM Forum's best practices through its Autonomous Network Transformation Office (ANTO). | • Wi-Fi optimization<br>• Core network: network optimization | Is participating in AN level assessment pilot.<br><br>Has committed to achieving its goals through a two-stage approach, with the first focusing primarily on developing technical use cases and the second aiming for more balance between technical and business domains. |
| Telefónica | Telefónica launched a program called Autonomous Network Journey (ANJ) in 2021 to increase autonomy and transform its architecture, management of data, and organizational structure to support AN; ANJ is being applied in all operating companies in Europe and Latin America, but deployment progress varies among OpCos. | Is focusing on getting to AN Level 4 for multiple processes (O&M, optimization/configuration, testing, deployment and planning) in multiple domains (radio access, transport, IP, core, IT cloud, and fixed access networks). The company is placing high emphasis on O&M in all domains and on RAN optimization, IP deployment and transport planning. | Is participating in the AN level assessment pilot.<br><br>Anticipates several key improvements in achieving AN Level 4 including :<br><br>• AI-powered operations assurance, where closed-loop automation will prevent service disruptions.<br>• Real-time optimization and decision-making, where automated systems will manage network configurations, including dynamic features like network slicing and NaaS capabilities.<br>• Efficient planning and deployment, where real-time inventory management, scenario-based planning (e.g., 'what-if' analysis) and AI-driven optimization will streamline deployment processes. |
| Telkomsel | Telkomsel adopted AN as part of its digital innovations, aiming to reach L4 by 2025.<br><br>Ensuring high service quality during peak events. | • Transport network (fronthaul optical link): fault predictive maintenance<br>• Wireless network: fault management (cross-domain)<br>Wireless network: optimization | Is participating in AN Level assessment pilot.<br><br>In 2023, Telkomsel's cross-domain experts, guided by the Networks Quality Digitalization Department, made significant progress towards L3. Notably, the self-assurance use case for massive events was recognized at TM Forum DTW2023-Ignite and deployed across 37 sites in Indonesia. |

# Best practices for implementing AN high-value scenarios

Section 4

In 2022 as CSPs began to gain some experience implementing autonomous networks, we added a section to the journey guide to highlight their best practices. Early on, these focused primarily on developing an AN vision and target architecture and then progressed to include development of KEIs and methods for evaluating AN levels.

Many of the best practices have been incorporated into TM Forum's AN standards. Indeed, the previous section outlines some best practices for designing the target-state for Level 4 scenarios, which have been added to the AN Level 4 Industry Blueprint.

This year we received best practice contributions from AIS, China Telecom, China Unicom, Singtel Group and its operating companies, stc, Telecom Argentina, and Telkomsel. All are available to read in their entirety on the AN Project website.

Here, we highlight some in the following areas, which are important to implementing AN:

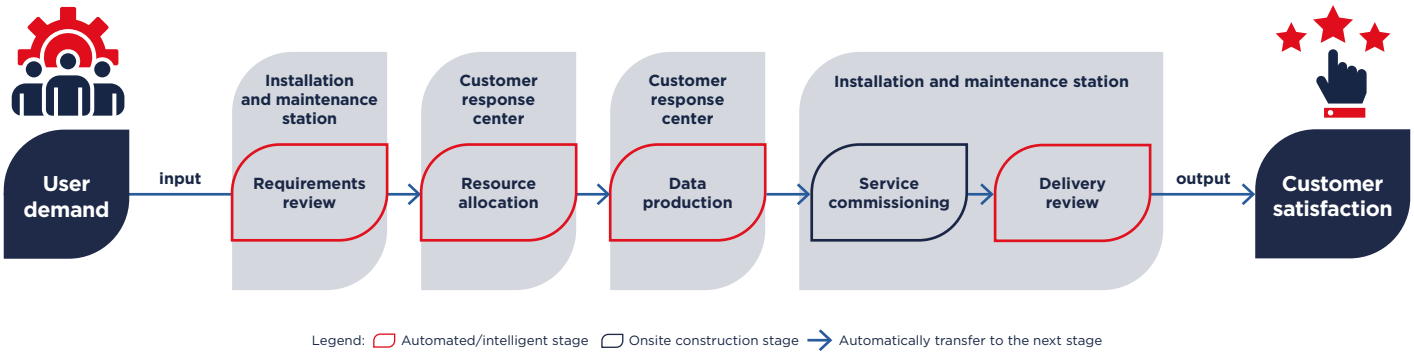
- **Business value measurement –** CSPs' main goal in adopting AN is to increase business value and operational efficiency. To do that figuring out how to evaluate and quantify the results of implementing AN is key.
- **Reference architecture development –** some CSPs are using TM Forum's AN standards to define their own target network architectures aiming for AN Level 4.
- **Collaboration between a telco group and its operating companies –** telco operating companies need to be able to quickly implement AN strategy communicated by the group, and this requires efficient collaboration.
- **Use case selection –** selecting AN Level 4 use cases and scenarios is an iterative process.

### CHINA MOBILE'S LEVEL 4 AN PRACTICE AIMS FOR 'LIGHTS-OUT FACTORY'

China Mobile's networks and operations are vast, with 31 local operators serving 1 billion mobile customers and 309 million wireline broadband customers as of June 2024. An autonomous networks pioneer, China Mobile has set a new Level 4 goal focusing on high-value scenarios, with an aim to create an end-to-end, fully automated "lights-out factory" pipeline for digital and intelligent O&M.

The core concept of the lights-out factory is to drive end-to-end full automation in every high-value scenario identified by China Mobile. Traditional O&M processes typically involve multiple steps, where each is partially automated through individual modules. These modules are then combined to complete the entire task. In the lights-out approach (shown below) each step is automatically completed, and data flows seamlessly between steps, enabling efficient collaboration without any human intervention. This enhances overall operational efficiency, reduces human-induced errors, improves service quality and lowers operational costs.

## China Mobile's approach to end-to-end, fully automated O&M




TM Forum, 2024

Through automation of O&M processes, China Mobile aims to enhance safety and quality, strengthen customer experiences, and improve efficiency and effectiveness:

- Enhancing safety and quality requires continuously improving customer satisfaction and reducing the number of faults.
- Strengthening customer responsiveness involves continuously improving the timeliness of service activation, enhancing the timeliness of complaint handling and continuously optimizing the workforce structure to transition more staff towards customer service support roles.
- Improving efficiency and effectiveness, while ensuring the stable operation of the network, involves gradually replacing human labor with machines, reducing the volume of frontline dispatch tickets, maximizing the reduction of equipment energy consumption, and lowering outsourcing costs.

The graphic below shows expected improvements for each of these goals.

## China Mobile's expected O&M improvements

**Network-wide application effectiveness goals**

**Safety and quality**

| Customer satisfaction | Number of important failures |
|---|---|
| Continuously improve | Continuously reduce |

**Customer responsiveness**

| Timeliness of service activation | Timeliness of complaint handling | O&M workforce structure |
|---|---|---|
| >99% | >95% | Continuously optimizing |

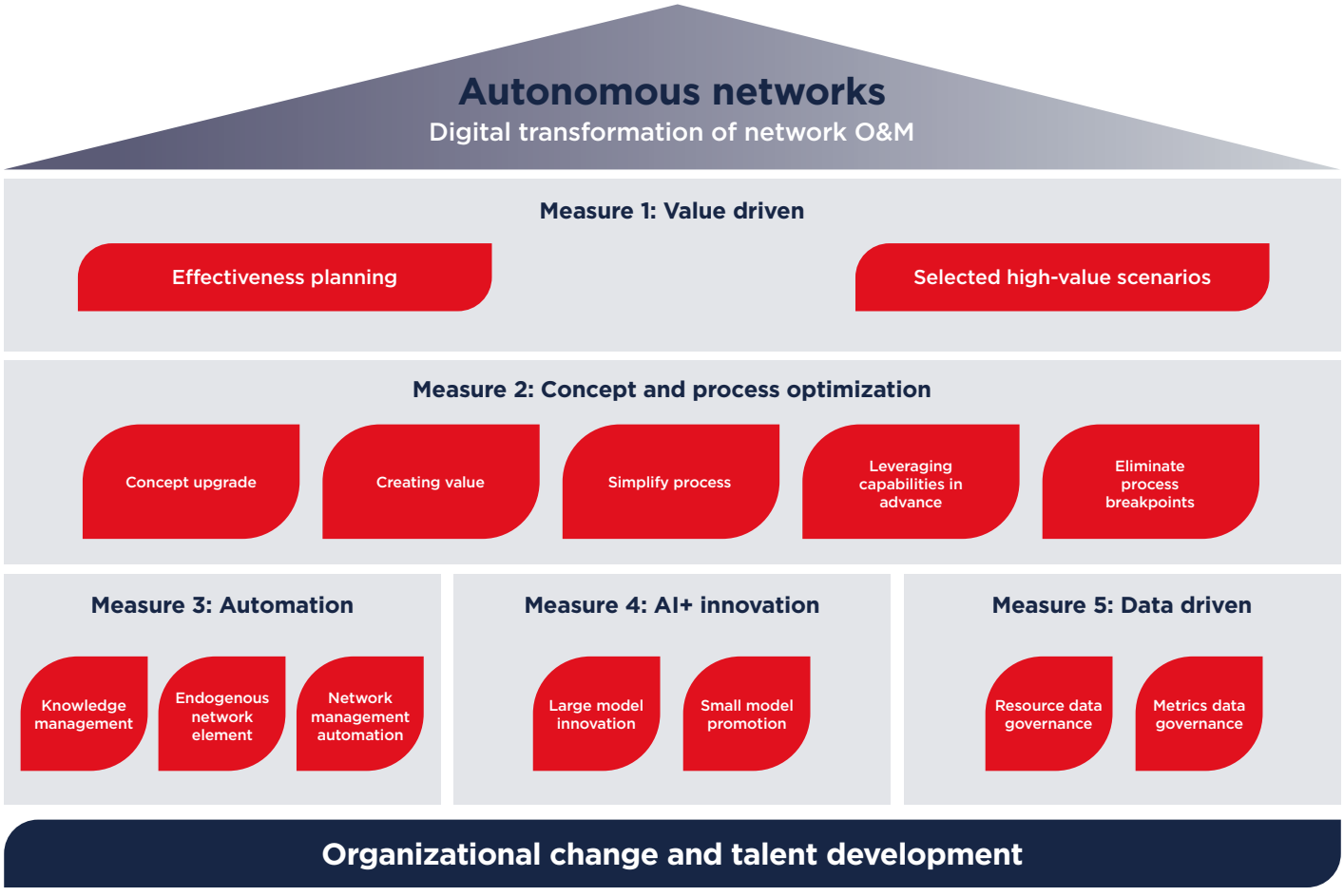
**Efficiency and effectiveness**

| Replacing human labor with machines | Reducing volume of frontline dispatch tickets | Reduction of equipment energy consumption | Reducing network maintenance costs |
|---|---|---|---|
| 5,000 person-years | 5%-10% | 5 billion kWh | Continuously reduce |

TM Forum, 2024

The sheer size of China Mobile's network means its O&M scenarios are diverse. This makes reaching Level 4 AN a huge and complex undertaking requiring a systematic approach that can be measured. The graphic below shows the step-by-step approach China Mobile is taking, and a description follows.

**China Mobile's step-by-step approach to the 'lights-out factory'**




TM Forum, 2024

1. **Driven by value –** with dozens of business types and five major network domains, China Mobile's first step was to comprehensively re-mapped the full panorama of O&M scenarios, which includes more than 100 end-to-end scenarios. Next, it established a three-tier value evaluation system and selected high-value scenarios based on their value ranking. A "pilot-first-then-promote" approach was adopted, ultimately leading to comprehensive implementation across all scenarios.

2. **Concept and process optimization –** China Mobile aims to shift its O&M philosophy from being device and management centric to become customer and business centric. The key is to use end-to-end processes as the breakthrough point, integrating new concepts and delivering new value. Through continuous process optimization, China Mobile plans to further simplify ineffective steps, reduce resource waste and time consumption, and eliminate process breakpoints and bottlenecks. This ensures that data and tasks flow automatically, fully leveraging capabilities in advance to avoid resource idleness and waste and optimizing resource allocation.

3. **Automation –** to build an end-to-end, fully automated O&M production pipeline, it is necessary to continuously improve the O&M knowledge system and expert rules for automation. It is also essential to continuously enhance the inherent capabilities of network elements and network management systems. This involves constructing a cross-domain, cross-vendor and cross-system production line that is fully automated end to end. This improves the efficiency and service quality of high-value scenarios.

4. **AI+ innovation –** with AI technology as the innovation engine, China Mobile aims to transform O&M from an auxiliary tool used enhance quality and efficiency into an indispensable core capability. The company is working to strengthen the collaborative and integrated innovation of both large and small AI models, which involves vigorously promoting benchmark applications of small AI models to fully realize their value at scale, as well as innovatively developing O&M AI agents. These agents will unify the scheduling of large and small models and various network management system capabilities, reshaping key production processes in network operations and maintenance, and enhance the intelligence level in high-value scenarios.

5. **Data driven –** to meet the requirements for data accuracy, completeness and consistency in network O&M scenarios, it is essential to focus on strengthening network data governance across the entire network, embedding high-quality data into production processes to support operational analysis and decision-making. This will allow China Mobile to shift O&M from being experience driven to become data driven.

*When implementing autonomous network scenarios, CSPs must consider what business value they can deliver and whether they can lead to a return on equity.*

## CHINA TELECOM'S AN BUSINESS VALUE ASSESSMENT

When implementing autonomous network scenarios, CSPs must consider what business value they can deliver and whether they can lead to a return on equity (ROE). China Telecom has been considering this in its cloud-network operations.

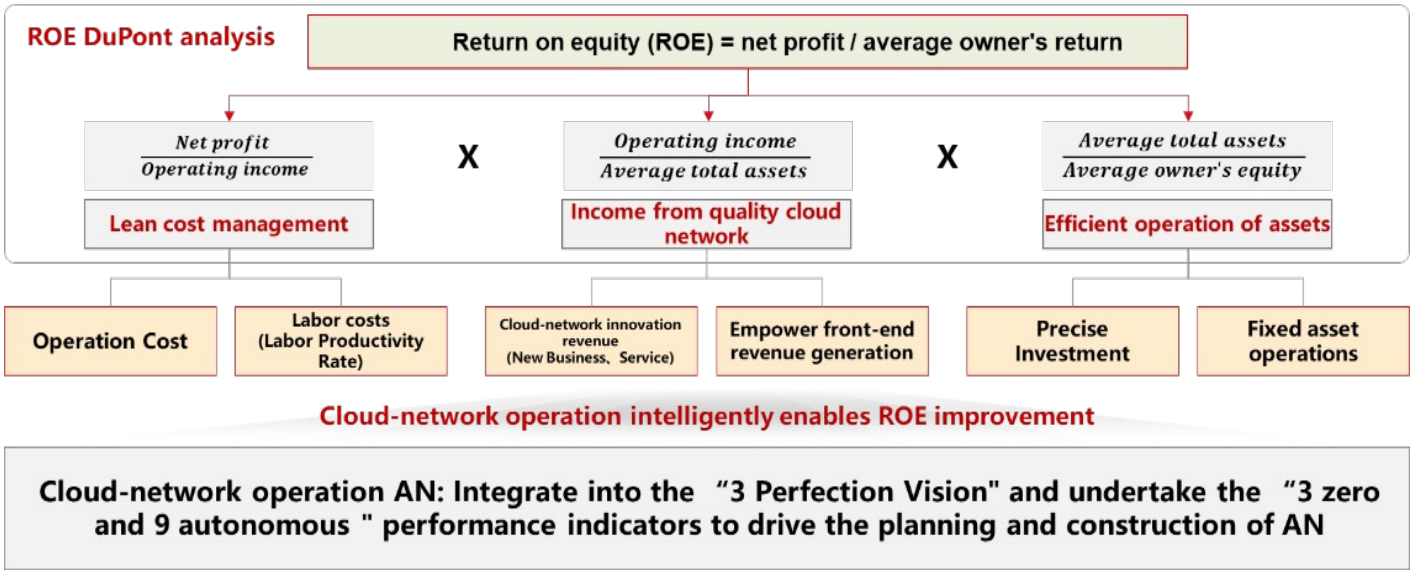
ROE reflects the ability of an enterprise to use its net asset value to generate profits. The idea is to focus on the quality of capital return and the business value of improved operating performance, and to pay more attention to input-output efficiency.

China Telecom used the DuPont analysis method, which is a framework for analyzing a company's performance originally developed at the DuPont Corporation. China Telecom started by decomposing the key factors that affect ROE. Then, the company clarified three business value directions:

- Lean cost management
- Cloud-network quality improvement and revenue generation
- Efficient asset operation.

The value directions were then decomposed into six specific requirements as shown in the graphic on the next page, and 16 indicators were added. Some examples of the indicators include  smart electricity meter collection coverage, automatic fault identification rate, identification rate of potential pitfalls, service-provisioning time, automation rate of service inspection, automatic customer complaint-handling rate.

### China Telecom's ROE process for cloud-network operation




TM Forum, 2024

**Promising results**

China Telecom's results are promising. The company reports boosting ROE from 6.41% in 2022 to 6.93% in 2023. This improvement supported significant revenue generation from B2B 5G services, home broadband and private lines, while saving over 1 billion kilowatt-hours of electricity annually.

Now, China Telecom is beginning to evaluate potential ROE improvement from the introduction of its network large language model (LLM), which will create thousands of digital employees in various roles. The company believes it will bring major changes in O&M, operations processes, systems integration and cloud-network capabilities by transforming NOC personnel, reducing the workload of external on-site installation and maintenance, and reducing labor costs.

Overall, China Telecom is aiming to achieve L4 AN in 40% of high-value scenarios in 2024, such as on-site O&M, cross-domain troubleshooting, hazard prediction and end-to-end service assurance.

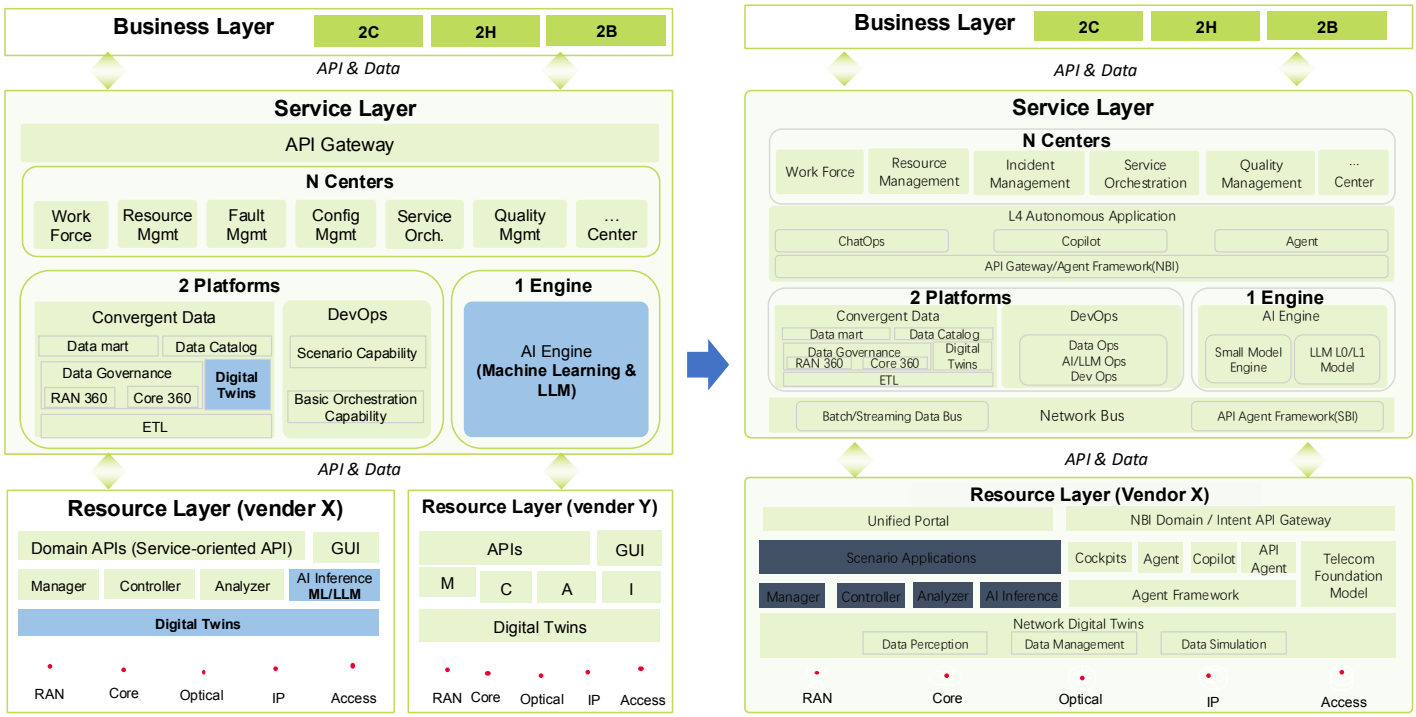
## AIS'S AN LEVEL 4 ARCHITECTURE EVOLUTION

Thailand's AIS is embracing a "Cognitive Techco" strategy to enhance network intelligence and automation in alignment with TM Forum standards. The company is developing an AN Level 4 target architecture that focuses on two processes – customer complaint management and network fault management – to improve customer satisfaction and operational efficiency. AIS has participated in TM Forum's AN level assessment pilot, achieving L3 in both processes.

AIS's AN L4 architecture shown on the next page embodies:

- A service layer with a "1+2+N" model that enhances cross-domain digital twin and LLM capabilities and facilitates cross-domain collaboration
- A resource layer that includes MCAID (manager, controller, analyzer, AI inference/LLM and digital twin) for single-domain autonomy
- Multi-vendor compatibility, convergent data integration, DevOps methodology, openness, near real-time analysis, simulation and intelligence
- Effective single-domain autonomy and cross-domain collaboration

## AIS's Level 4 target architecture evolution




TM Forum, 2024

Features of AIS's Level 4 target architecture include:

- Service layer addresses challenges posed by siloed systems, provides converged data subsystems and supports multiple centers. The convergent data platform enables data access through APIs, fostering business layer applications.
- Service layer interfaces with vendor-specific element and network management systems (EMS/NMS), centralizing data and enabling cross-domain collaboration based on digital-twin and LLM.
- Resource layer enhances data analysis with AI/LLM capabilities, achieving closed-loop processes based on the digital twin within a single domain and simplifying integration with the service layer.
- Digital twin and LLM make networks visible, perceivable and controllable, reshaping network O&M and enabling AIS to evolve from automation (+AI) to autonomy (AI+).

**Promising results**

AIS has reported encouraging results overall from its evolving AN practices including a 10% optimization of customer experience, a 90% reduction in traffic loss in extreme scenarios and a +20% network efficiency improvement. For example, for RAN burst traffic caused by crowd gathering such as at sporting events or in vehicle traffic jams, the system quickly detects traffic bursts in minutes and balances traffic between burst cells and neighboring cells through adjust antenna parameters, improving the edge user experience by 10%.

Antenna parameter adjustments in neighboring cells also make it possible to provide minute-level cell outage detection and compensation, which has helped AIS reduce traffic loss by 90%.

Finally, AIS is leveraging AI to improve the accuracy and efficiency of fault identification and root-cause diagnosis, and to improve customer-complaint prediction, resulting in efficiency improvement of more than 20%.

## TELECOM ARGENTINA'S TARGET ARCHITECTURE DEVELOPMENT

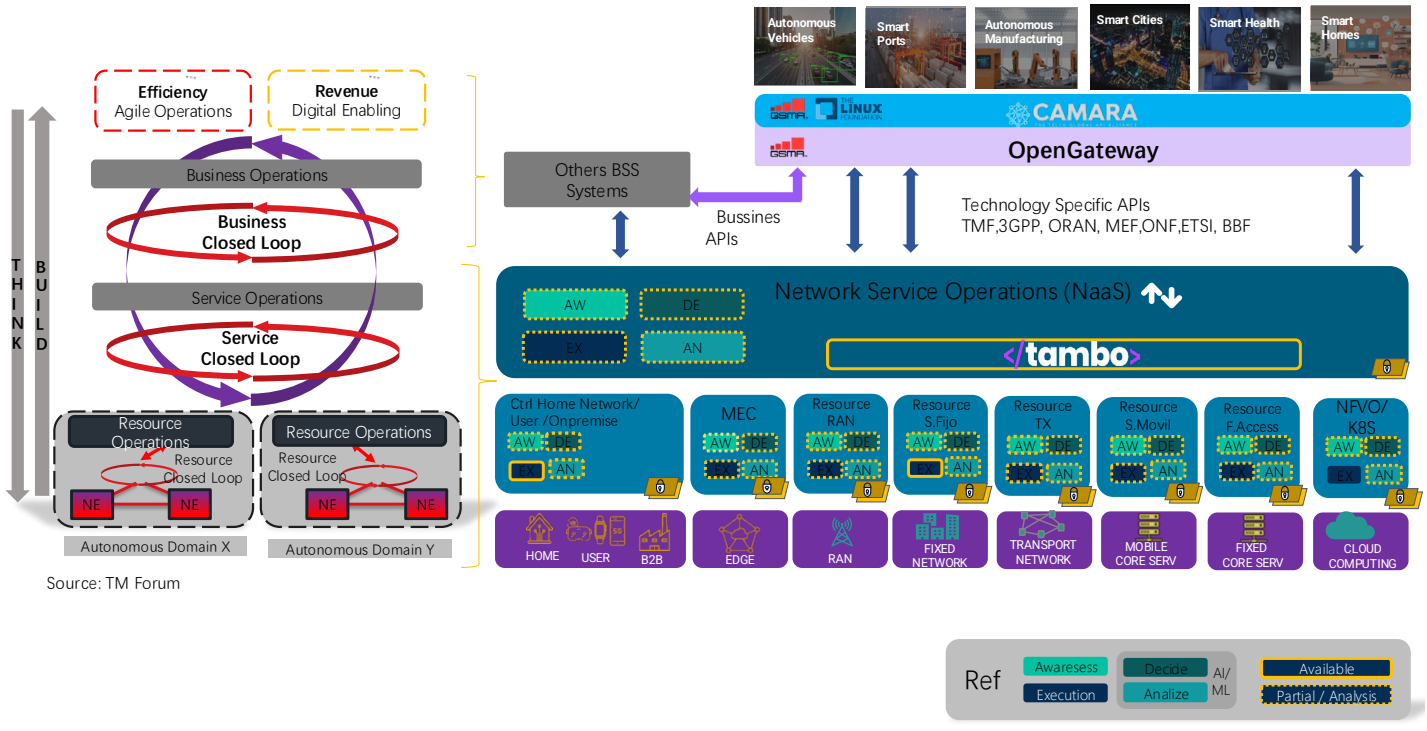
Telecom Argentina has established a AN Transformation Office (ANTO) to ensure success of its AN evolution. This team is evolving the company's AN framework, roadmap and target architecture.

ANTO has committed to achieving its goals through a two-stage approach. The first stage focuses primarily on developing use cases from a technical perspective, while the second stage aims for greater balance between the technical and business domains, plus other domains within the company where comprehensive use cases are being addressed.
See page 40 for more on the company's best practices for selecting use cases.

Telecom Argentina's AN target architecture (shown below) seeks to streamline operations and offer a completely autonomous network ecosystem. It includes three layers:

- The business layer focuses on providing an optimized user experience for telecom services through network exposure.
- The service layer focuses on service orchestration and automation, enabling multi-domain network interoperability.
- In the resource layer, an autonomous domain exposes a range of business services based on the capabilities of the objects it governs; it is self-managed, self-scaling and manages its own lifecycle.

### Telecom Argentina's reference architecture




Source: TM Forum

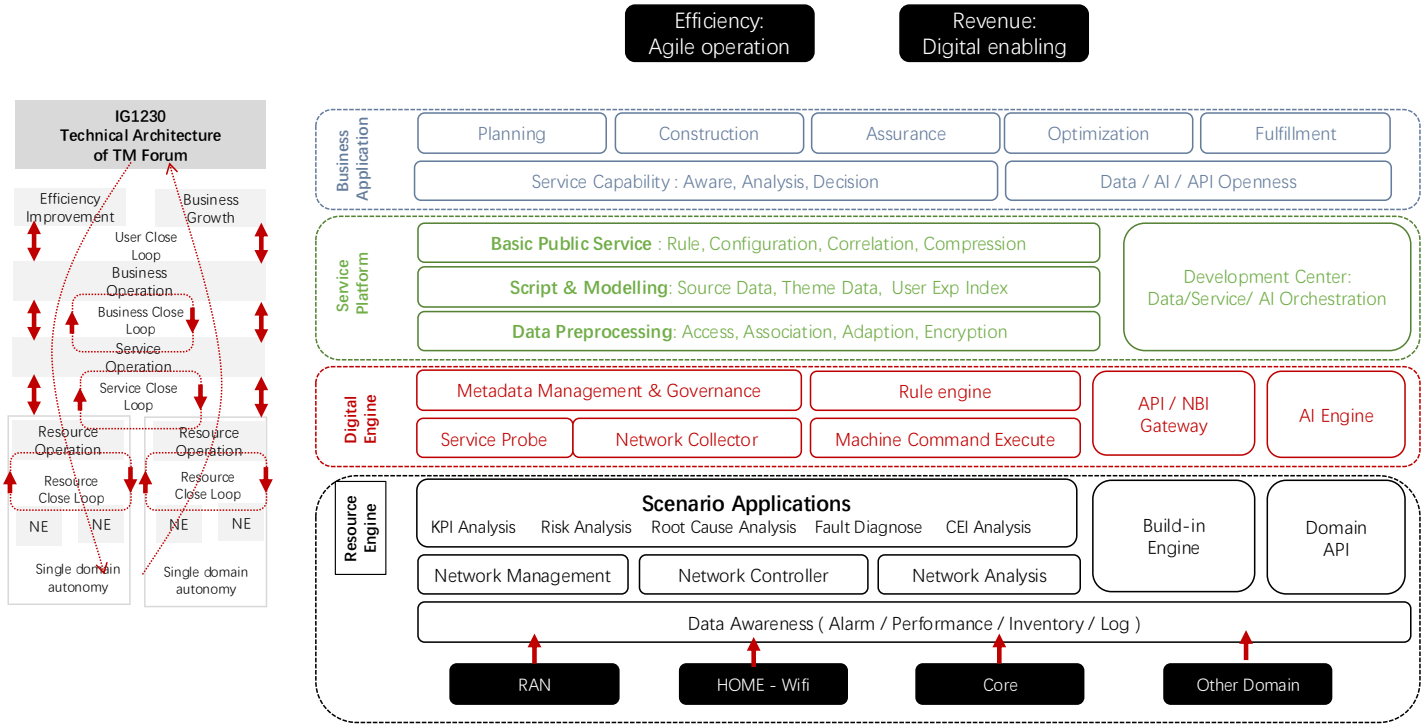
TM Forum, 2024

## TELKOMSEL'S AN LEVEL 3.5 ARCHITECTURE DESIGN

Telkomsel is using TM Forum's AN Framework and best practices to accelerate the development of autonomous networks in Indonesia. The company, which has a goal of achieving AN Level 4 by 2025, outlined its AN Level 3.0 architecture last year, focusing on fault management.

Now, Telkomsel is highlighting its AN Level 3.5 architecture design, which introduces a Resource Engine to attain autonomy within a single domain and enhance collaboration across domains at the service level. The graphic below shows the architecture with the Resource Engine at the bottom bolstering the Digital Engine's closed-loop capabilities. An explanation of some of the key elements of the Resource Engine follows.

### Telkomsel's AN Level 3.5 architecture




TM Forum, 2024

**Scenario applications –** the objective in each scenario is to increase and improve intelligence and automation. For example, intelligent analysis performed on alarm data has the ability to discern underlying alarms and offer intelligent recommendations for resolving them.

**Network management, controller and analysis –** utilizing a built-in AI Engine (see below), control components execute automated operations and conduct intelligent governance and analysis on data gathered across various scenarios

**Data awareness –** network elements provide the element management system (EMS) with a variety of data, including performance and alarm information, via standard southbound interfaces, such as the PMS and YANG interfaces.

**Built-in AI Engine and Domain API –** standard southbound interfaces and real-time data collection allow the Resource Engine to visualize network-level data online. By reporting output to operations support systems (OSS) via the northbound API, resource-layer applications can improve automatic root-cause locating and intelligent cross-domain issue diagnosis.

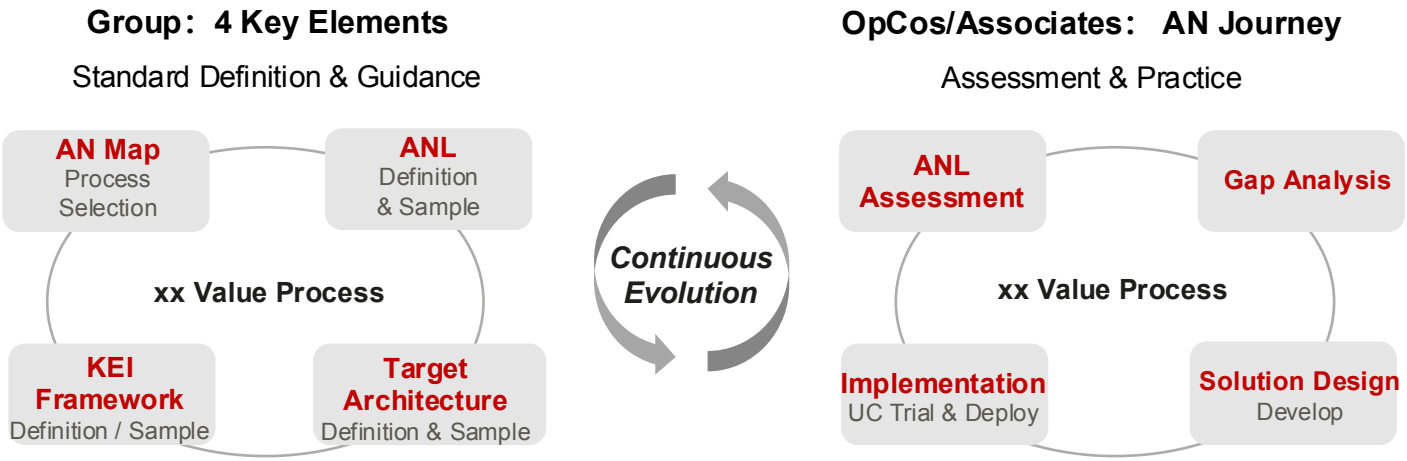
## SINGTEL GROUP AND OPCOS' AN PRACTICE COLLABORATION

Singtel Group owns or has a stake in several operating companies (OpCos) in the Asia-Pacific region including Optus in Australia, Bharti Airtel in India (and Africa), Globe Telecom in the Philippines and AIS in Thailand. Singtel and its OpCos are also part of the Bridge Alliance, a mobile alliance with 35 member operators collectively serving more than 1 billion customers in Asia-Pacific, the Middle East, Africa and Europe.

Based on TM Forum's AN Framework and methodology, Singtel and its OpCos have developed an innovative approach to group-level collaboration that helps to create benchmarks, exchange best practices and experiences among OpCos, and apply best practices across the group.

Singtel Group selected AIS, which is a leader among the OpCos in AN practice for incident management, as AN coach to systematically lead the other operators to align on the definition of the four key elements of the AN Framework: the AN Map, AN levels, KEIs and target architecture. AIS also supports the OpCos on their AN journeys comprising AN level assessment, gap analysis, solution design and implementation as shown in the graphic below. An explanation of the collaboration process follows.

**Singtel Group's approach to collaboration**




TM Forum, 2024

The teams started by collaborating on alignment of the four key elements with guidance from the AN coach:

- **Value process selection –** a common high-value scenario for the incident management process is identified and agreed on as a pilot scenario across the group to achieve AN Level 3.
- **ANL definition –** the OpCos worked together to define what Level 1 to Level 4 looks like for each process and then adopted these agreed definitions as a unified blueprint across the group.
- **Target architecture –** the group defined a three-layer target architecture, while the OpCos developed their own architectures based on definition and AN strategy.
- **KEI framework –** a KEI framework was defined collaboratively and adopted as a blueprint across the group to guide OpCos in formulating business value improvements through enhancement of AN practices measured by KPIs.

Then, the teams can progress through AN journey with support from the AN coach:

- **ANL assessment –** the OpCos perform their assessment based on their agreed ANL definition. Here the AN coach moderates the ANL scores based on the supporting reasons presented by each OpCo to ensure fair and consistent assessment.
- **Gap analysis and solution design –** benchmarking is done across the group to perform the gap analysis for each OpCo against the AN coach of each operation task. Best practice and experience from the AN coach and any OpCos that score well in their AN level assessments are exchanged with other OpCos as capability references so that they can plan their target AN level, identify gaps and design solutions.
- **Solution Implementation –** based on the reference design, the lead OpCo pilots the solution deployment and shares the results with other OpCos, who can then use the pilot insights to speed up their own deployment.

*Through a collaboration approach, OpCos can benefit from the group's collective experience and apply proven techniques to achieve quick wins.*

Through this collaboration approach, OpCos can benefit from the group's collective experience and apply proven techniques to achieve quick wins. As an example, AIS shared their implementation of a use case on RAN CPRI risk prevention and prediction as a reference to the group. (CPRI, which stands for Common Public Radio Interface, defines the key internal interfaces between radio equipment and radio equipment controllers in base stations.)

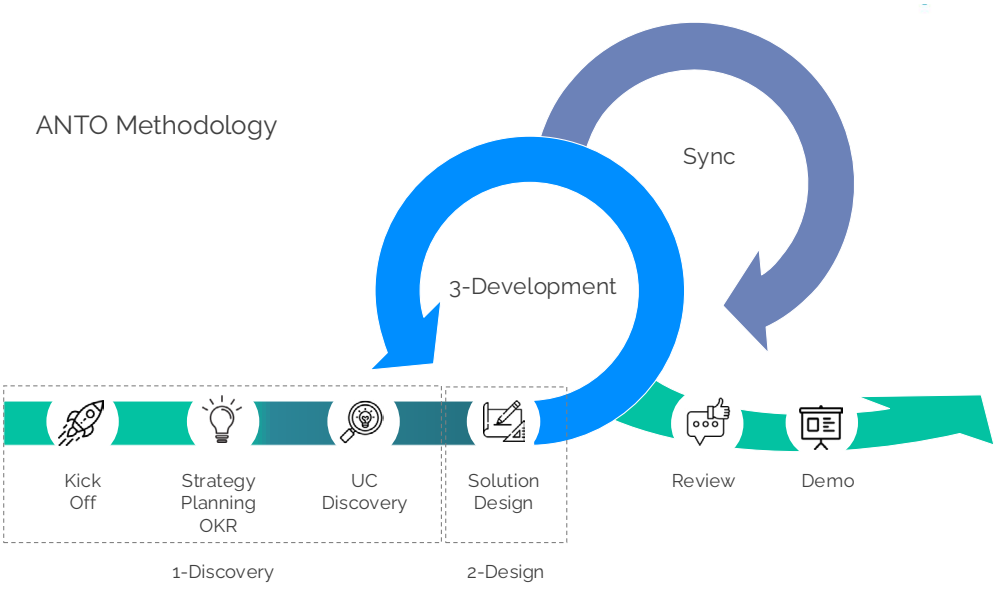
Telkomsel then picked up this use case for implementation using the reference from AIS. As a result, Telkomsel was able to shorten its solution design and implementation time significantly.

### TELECOM ARGENTINA'S AN USE CASE SELECTION AND DEVELOPMENT

Telecom Argentina's AN Transformation Office, ANTO, has adopted an Agile approach to accelerate network transformation. The implementation of this methodology aims to promote the deployment of prioritized use cases developed collaboratively among various departments in the company.

Telecom Argentina's process involves an iterative design of minimum viable products (MVPs) and their increments. The stages are shown in the graphic on the next page, and a description of each follows.

**Telecom Argentina's ANTO methodology**




TM Forum, 2024

1. **Discovery –** in the first phase the owners of the different technological domains come together to present high-impact use cases, evaluating the necessary effort and possible benefits of their development. The main objective is to obtain a prioritized list of use cases.
2. **Design –** this stage includes analysis of the use cases to evaluate the processes involved and potential changes; associated infrastructure and proposals; operating logic; and KPIs for improvement. Then, an objective level of autonomy is presented. All technological domains with a concern in the closed loop are involved and the scope of the functionalities that will be developed is defined. At the end of this stage, the team must have the definition of the necessary epics to obtain an MVP of the proposed UC.
3. **Development –** at this stage the development of the use case is carried out. The technical domains are involved and are assisted by ANTO.

In the next section, we look at the latest examples of AN use cases and scenarios.

# Innovation in autonomous networks – examples of AN use cases and scenarios

Section 5

For every AN guide, we solicit contributions from CSPs about their experiences implementing use cases and scenarios, which are use cases that combine an operation flow and a network domain (for example, fault management in the RAN). This year we received 38 contributions, all of which are available on the AN Project website.

Here we highlight 12, chosen for their focus in one of four areas: enabling verticals, improving customer experience (CX), increasing O&M efficiency and green energy (power savings). It is not surprising that the majority of these commercial use cases/scenarios focus on O&M efficiency, when rising O&M costs are outpacing telco revenue growth. Multiple research firms have found that while O&M costs typically increase at a compound annual growth rate of around 3% to 5%, revenue growth remains stubbornly stagnant at 1% or less.

Not all the use cases featured here focus on Level 4 high-value scenarios, but operators expect the learnings from them to help them get there.

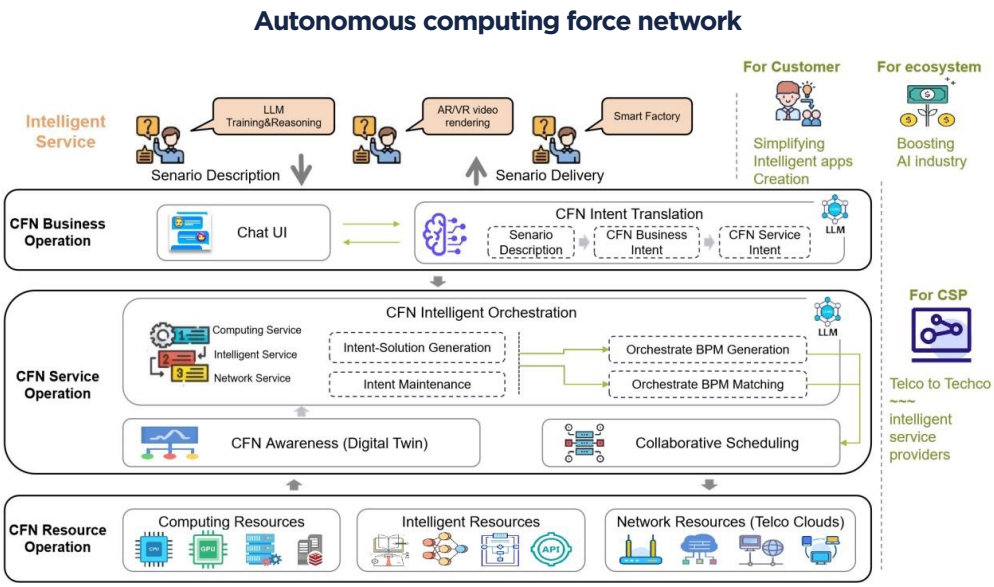
## ENABLING VERTICALS: CSPS JOIN FORCES IN AUTONOMOUS COMPUTING FORCE NETWORK CATALYST

As GenAI and LLMs become integral to many telecoms processes and services, the demand for computing power is escalating exponentially. This makes efficient allocation of resources critical.

To address this challenge, China Mobile, China Telecom, China Unicom and Telecom Malaysia have been collaborating in a TM Forum Catalyst proof of concept with multiple technology suppliers to streamline the use of computing power and network resources. This requires aligning customers' original intentions with the capabilities and services of the computing network.

The GenAI empowers computing force network Catalyst won a 2024 award in the Outstanding Catalyst – Innovative & Futuristic category for its creation of an AI-native computing force network (CFN) operation system to help CSPs schedule computing and network resources across a cloud-edge network. The CFN enables them to provide a one-stop intelligent business marketplace through intent-driven services.

The solution (shown on the next page) uses advanced LLMs, multi-agent collaboration and automated code generation to understand, ask questions about, and supplement the customer's business scenarios and stipulations. The idea is to autonomously create a customized computing and networking integration proposal that precisely meets the customer's requirements. Then, the customer can refine it using an intuitive chatbot, which replaces the conventional product catalog.

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The solution integrates diverse resources from hyperscale cloud providers, telco clouds and third-party services to deliver zero-touch customer experience and zero-wait and self-provisioning capabilities. This will allow CSPs to develop a unique ecosystem with a revenue-sharing business model.

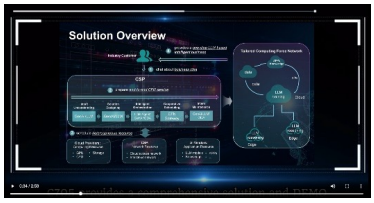
Here's how it works:

**Business layer –** the LLM is used to convert the user's natural language scenario description into CFN business intents and subsequently into CFN service intents. It replaces traditional product catalogs with a more intuitive chat interface and tailors solutions to meet each customer's specific needs.

**Service layer –** the solution is decomposed and matched with a set of corresponding business process management (BPM) systems. If a solution component lacks a matching BPM, the intelligent orchestration module automatically generates the necessary BPM using LLM. Resources are then collaboratively scheduled. The CFN awareness module continuously monitors the state of resources. In the event of performance degradation, the intent maintenance module adjusts the solution in real time to ensure the intent is correctly sustained.

**Resource layer –** there are three distinct types of resource coordinators. The computing coordinator is responsible for managing computational resources, which encompass CPUs, GPUs, storage, servers, etc. The intelligent coordinator is responsible for the intelligent resources including knowledge bases, computational models, applications, APIs, etc. The network coordinator administers network resources, covering access networks, inter-cloud networks, core networks, etc. The resource layer conducts the resource intents and reports the status of various kinds of resources.

**See the CFN Catalyst in action:**



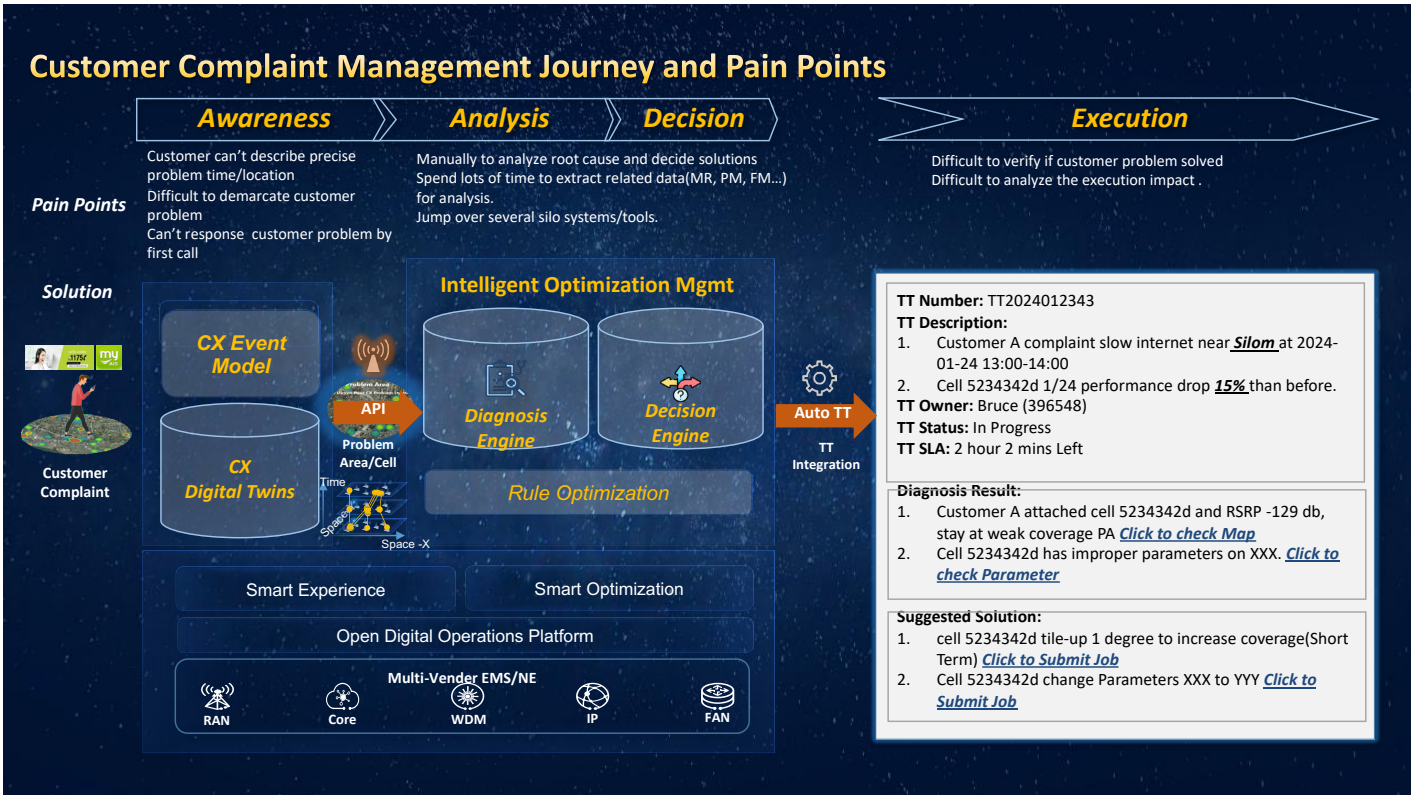

AIS

**IMPROVING CX: AIS'S CX-DRIVEN OPTIMIZATION EVOLUTION**

AIS is looking at how to leverage AI models to proactively identify mobile customers' poor experience and then use an intelligent analysis decision engine to pinpoint the root causes of problems and resolve them automatically.

The graphic below shows the pain points customers often face and how AIS aims to resolve them. A brief explanation follows.

**AIS's customer complaint prevention**

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## CX event model

AIS's CX event model uses geo-temporal CX digital twins – advanced models that combine geographic (spatial) and temporal (time-based) data to simulate and enhance CX in real time. AIS uses a probe solution to capture customers' network experience-related records (for example, time, location, device, behavior, and control and user plane data). This is integrated with network-related data such as MR, performance data, alarm data and configuration data in the convergent data model.

Based on customer experience events such as call drops, slow internet, inability to connect to the network, etc., AIS identifies the pattern of network-related data from geo-temporal CX models. Then, customers' potential problems are output with "4W" information (who, when, where, what happened) with two measurable performance indicators (correctness and completeness). This output can be integrated into call centers and touch points such as the MyAIS app to assist in customer complaint inquiry and to be integrated into the network optimization engine for further trouble shooting.

## Intelligent optimization management

**AI-based diagnosis engine:** based on AIS's rule engine and convergent data platform, the network optimization team can build a scenario-based diagnosis rule with data to automatically diagnose the root cause of radio problems such as weak coverage, interference or congestion. The team also plans to adopt an AI engine to build a root-cause analysis model to identify potential root causes.

**AI-based decision engine:** once the root cause of the potential radio network problem has been identified, AIS can create policies based on the decision tree to determine a solution to the problem. The diagnosis and next-best-solution results then can be integrated into the trouble ticket system automatically to improve the operational efficiency and reduce mean time to repair (MTTR) for customer complaint handling.

**Auto execution and verification:** based on next-best actions the system can automatically design a solution to the problem and create auto-verification scripts.

Using this solution, AIS expects to be able to reduce mobile customers' complaints by proactively informing them about problems and by increasing first-call resolution, improving auto-optimization tickets, and reducing the average customer complaint handling time from weeks to days. Through the use of CX digital-twin technology, AIS will be able to discover more unknown problem areas than before and based on business priority proactively expand or optimize network quality before customers complain. This will improve customers' overall satisfaction.

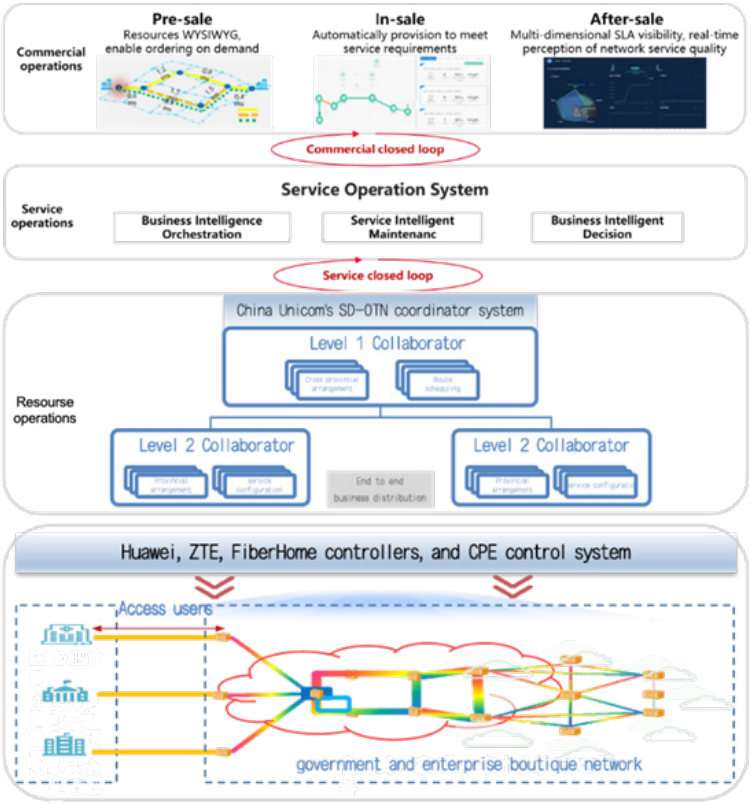
中国联通 China unicom

### IMPROVING CX: CHINA UNICOM AUTOMATES AND IMPROVES ALL-OPTICAL PRIVATE LINE SERVICES

China Unicom provides high-bandwidth, low-latency and high-reliability all-optical private line services to B2B customers in key industries such as finance, healthcare and government. These customers need to be able to self-adjust private line speeds, and China Unicom needs to be able to automate provisioning and provide service level agreements (SLAs).

China Unicom's three-layer network architecture to support these capabilities is shown below, and a brief description follows.

**China Unicom's AN architecture for high-quality private lines**

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**Business layer –** a customer service system provides online business ordering, adjustment capabilities and customer line management capabilities. User-generated service orders are delivered to the service layer through the API interface.

**Service layer –** a service operation system with intelligent scheduling and operation monitoring capabilities receives the dedicated line open request and adjustment requirements from the business layer. Service orchestration supports the end-to-end opening of dedicated line services, with the opening process and links visible. It can collect the running status of the resource layer network and present the running status of all optical lines.

**Resource layer –** an intelligent management and control system is deployed, with intelligent orchestration and control capabilities at the resource layer. API interfaces are provided, and resources are automatically allocated and configured based on service layer requirements. Implementation of customer premises equipment is plug and play.

China Unicom Hebei has deployed this solution on a large scale, covering more than 900 nodes across 12 cities. This is the largest provincial government and enterprise private network within the China Unicom Group.

The intelligent management and control system has achieved end-to-end automatic configuration and intelligent monitoring of routing throughout the entire process by integrating and adapting to controllers from Huawei, ZTE and FiberHome as well as CPE control systems nationwide. China Unicom has completed the integration of 84 sets of manufacturer controllers and CPE control systems in its network throughout 31 provinces and is managing more than 100,000 network elements. By adopting a distributed, two-level architecture with multi-protocol adaptation and a unified, cross-domain and cross-manufacturer approach to orchestration, the China Unicom OTN network is achieving collaborative innovation and capability openness.

中国电信 CHINA TELECOM

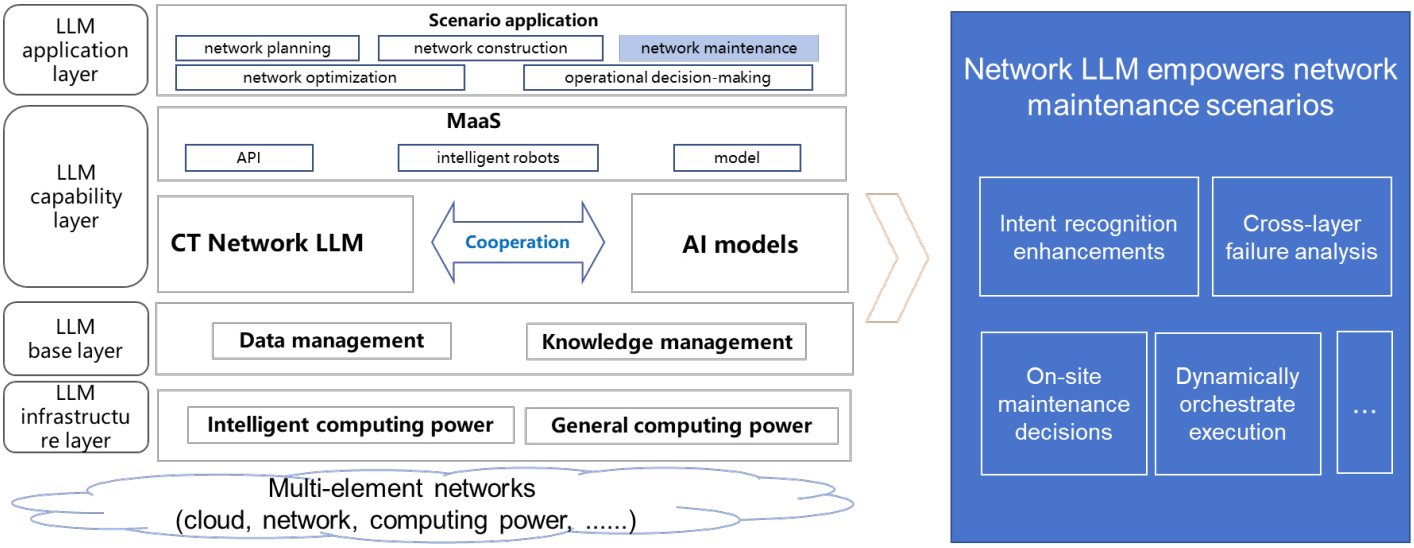
### EFFICIENT O&M: CHINA TELECOM USES ITS OWN LLM IN NETWORK MAINTENANCE SCENARIO

China Telecom is developing a network LLM to address network maintenance challenges such as how to identify and convey users' requirements in the form of intents, how to accurately locate cross-layer network faults and shorten the time it takes to locate them, and how to increase knowledge dissemination for on-site maintenance operations.

China Telecom's network LLM uses large-scale, high-quality network production data and knowledge for training. It is used for intent creation, management and processing as well as to improve analysis of ingested and inferred data and enhance decision-making and execution in AN closed-loop network maintenance scenarios. By learning telco-specific professional knowledge and business rules, the LLM is enhanced with application-specific knowledge and understanding.

The graphic on the next page shows the operator's network LLM solution. Business rules teach it intelligent scheduling and help improve its decision-making. Since network maintenance is made up of multiple specialized applications, this overall solution can scale via a mixture-of-experts model and finetuning mechanisms to effectively empower network AI applications and improve the value of network operations.

**China Telecom's LLM for network maintenance**

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Natural language makes O&M more accessible to business users, improving data-query efficiency by enabling them to understand data and relationships between it. The LLM can assist in finetuning the context for a query, which produces more accurate results. It can also seed the knowledge of the LLM and knowledge graph by incorporating expert knowledge from maintenance personnel.

**Promising results**

China Telecom's network LLM portal is available in China's 31 provinces and is being applied with an average accuracy rate of more than 80% in scenarios such as the network operations and business domains; network status awareness; emergency support; knowledge retrieval; fault classification and disposal; on-site comprehensive maintenance; work order quality audit; wireless network optimization; and IP traffic prediction.

The network LLM supports the use of mobile phones to query multi-system equipment and professional network management indicators anytime and anywhere, with results returned within 10 seconds. Cross-layer fault locating is improved to the minute level, and fault neutralization efficiency is increased by 20%. The time it takes for on-site installation and maintenance has dropped by 50%, and the automatic completion rate of work orders to resolve complaints has increased by 10%.

中国移动 China Mobile

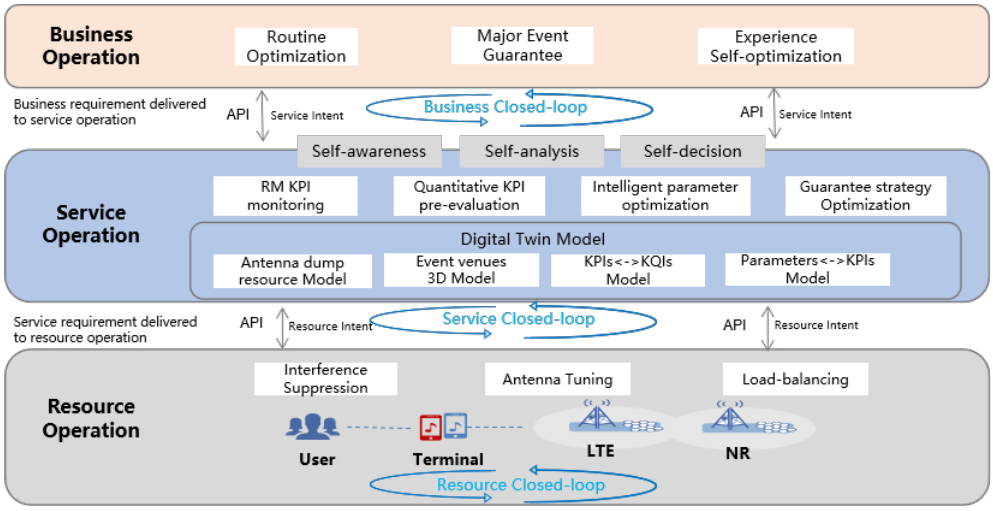
## EFFICIENT O&M: CHINA MOBILE'S DIGITAL TWIN-BASED INTELLIGENT NETWORK OPTIMIZATION CLOSED LOOP

Wireless networks are complex for many reasons. The behavior of radio signals, which are affected by physical objects and environmental conditions, can lead to issues like interference and fading, while managing the limited radio frequency spectrum adds complexity because it requires efficient allocation to avoid interference. Plus, users are constantly on the move, requiring seamless handovers. In this environment, traditional network optimization methods are costly, inefficient and risky.

China Mobile Fujian is working with its equipment provider ZTE to address wireless network complexity using an intelligent network optimization closed-loop solution based on digital twins. A digital twin is a virtual model that replicates network infrastructure and systems, allowing operators to monitor, simulate and optimize the network in real time.

By utilizing AI-driven and digital twin technology, the solution builds high-precision twin models to conduct quantitative pre-evaluations on KPIs such as network coverage, capacity and interference. China Mobile Fujian's solution is shown in the graphic, and a description follows.

**China Mobile's intelligent network-optimization closed loop**

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**Service and resource layers –** the service operation layer receives business requirements from different scenarios and constructs a series of high-precision models based on digital twins, including network antenna resources, event venues, relationships between KPIs and KQIs, and relationships between network parameters and KPIs. It then realizes real-time network indicator monitoring, quantitative pre-evaluation of KPIs (such as coverage, interference and capacity), intelligent parameter optimization and optimization of event guarantee strategies within the network twin. Based on the quantitative analysis and decision results from the twin system, the resource operation layer achieves automatic closed-loop network optimization through methods such as parameter adjustment.

**Resource closed loop –** based on the results of intelligent decision-making and parameter optimization from the digital-twin system, resource closed-loop actions such as antenna tuning, load balancing and interference suppression are executed to support the closed loop of service demands.

**Service closed loop:**

- **Twin model –** leveraging AI-driven and digital-twin modeling methods that integrate data and business knowledge, high-precision twin models are built to form the network twin body through innovative model-orchestration technology.
- **Real-time KPI monitoring –** real-time performance of wireless MR data is optimized throughout the entire process of data sourcing, location estimation, cluster data cleaning and rendering.
- **Quantitative pre-evaluation of network indicators –** through the network twin body, the impact of optimization scheme changes on network coverage, capacity, interference and other KPIs is quantitatively pre-evaluated. Based on business needs, China Mobile Fujian quantitatively formulates optimization goals and constraints for multiple cells and multiple KPIs, achieving precise control of the optimization process.
- **Intelligent parameter optimization –** combining the network twin body with intelligent decision-making algorithms, the company is able to systematically pre-evaluate the effects of parameter optimization schemes and their effects on surrounding sites.

- **Optimization of guarantee strategies –** prior to implementing major event guarantees, China Mobile Fujian simulates user experiences in various scenarios based on high-precision 3D venue models and the network twin body. By combining this with intelligent decision-making algorithms, optimal guarantee strategies can be created to minimize risks during the guarantee period.

**Business closed loop –** collaboration between the resource- and service-operation layers supports the business-operation layer to achieve closed-loop business demand fulfillment in scenarios such as routine optimization, major event guarantee and experience self-optimization.

**Promising results**

Compared with traditional methods, China Mobile Fujian's digital-twin approach has reduced labor costs by about 25%. The cost of vehicles and equipment is down 29%, and the number of dispatching field work orders has been reduced by 34%. In addition, the network optimization cycle has been shortened by 70%.

China Mobile Fujian has applied its digital twin-based AN solution in a variety of settings. For example, it has been used to improve and enhance the network performance of major traffic intersections. After optimizing the networks of 25 intersections covering 30,000 users, users' network speed has increased from an average of 12Mbps to 18Mbps, and the number of complaints per 10,000 users has dropped from five to two.

The company has also provided experience guarantees for 15 large-scale sporting events or concerts. Digital-twin technology enables rapid and precise locating and handling of network problems, reducing the delay of network monitoring and poor-quality locating from an average of 60 minutes to just 10 minutes. The solution also has reduced the cost guarantees from 1,200 person-hours to 300, ensuring zero user complaints in major event guarantee scenarios.

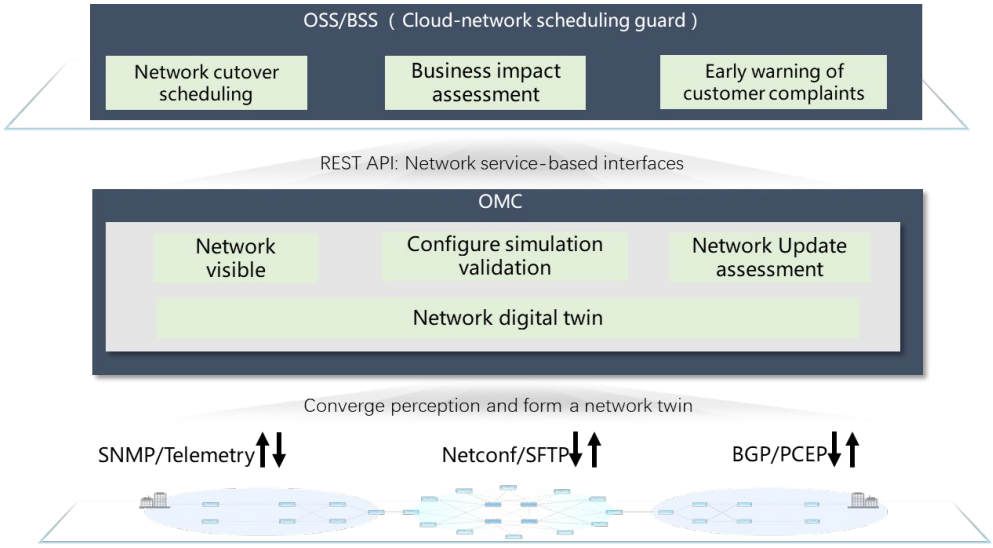
中国电信 CHINA TELECOM

## EFFICIENT O&M: CHINA TELECOM REDUCES IP NETWORK FAILURES WITH ONLINE INTELLIGENT SIMULATION

IP networks carry a large number of voice and data services across different regions, so minor network-configuration errors can cause huge economic losses and social impacts. Indeed, more than 70% of major IP network failures are caused by manual configuration errors, according to multiple industry sources. One way to reduce network failures is by using online simulation and verification tools to assess proposed network configuration risks in advance.

Incorrect quality of service (QoS) configurations can adversely affect millions of users by causing service outages, network congestion, poor service (due to increased latency, jitter, and packet loss) and the introduction of security vulnerabilities. To address this, China Telecom has created an automated and intelligent online simulation solution for IP network changes (see graphic on the next page).

**China Telecom's IP network intelligent-simulation architecture**

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China Telecom is using digital-twin technology with an embedded high-precision simulation system that generates data to assess the risk of proposed network changes. The network risk assessment is carried out by using CPV/DPV (Control and data plane verification).

Highlights of the solution include:

- A network digital twin provides a realistic digital verification environment, records the status and behavior of the digital twin in real time, supports the traceability and playback of historical data, and greatly reduces the cost of trial and error.
- High-precision network protocol simulation supports multi-vendor devices that use more than 20 mainstream routing protocols to generate realistic traffic simulation. The impact of changes on routes, traffic paths, link loads and other pertinent factors affecting performance can be identified in advance.
- A network verification algorithm formalizes network verification intents and rules for network-wide connectivity, loop verification, problems and anomalies, and outputs verification reports.

**Promising results**

China Telecom completed pilot verification of the solution in a prefecture-level new metropolitan area network and mobile carrier network. It was shown to effectively take care of IP network security, increasing the accuracy rate of preventing network change risks by more than 80% in advance. It also intercepted high-risk operations with very good results, avoiding economic losses and social impacts. It is expected to prevent economic losses of more than $140 million annually when applied nationwide.

MTN

## EFFICIENT O&M: MTN BUILDS A HIGH-EFFICIENCY IP+OPTICAL AUTONOMOUS NETWORK

MTN Group's consumer and enterprise businesses are growing rapidly, leading to a need to provide end-to-end O&M and reliability of the transport network. MTN has a massive footprint in Africa with operations in more than 16 markets, with tier 1 operations in South Africa and Nigeria. The company is adding automation and software-defined networking (SDN) in its core network as it seeks to deliver the best possible customer experience in alignment with its Ambition 2025 strategy, which is driven by its PACE (platforms, agility, connectivity and experience) framework.

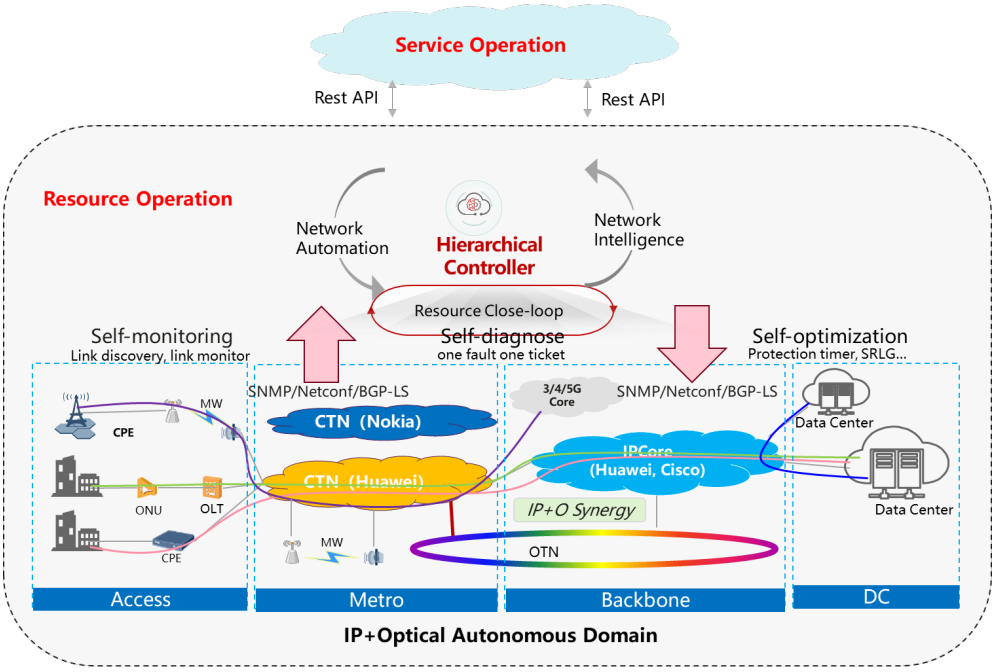
To fulfill these ambitions, MTN has adopted another framework for the transport network domain called CASSI (converged and congestion free, always-on, scalable, simplified and intelligent), which seeks to ensure that network design and planning pays attention to the key performance parameters of the transport network: availability, reliability and latency.

MTN has been aggressively driving the adoption of SDN as part of its network automation efforts, with OpCos deploying domain controllers in the IP, optical and microwave networks, together with critical, value-driven use cases. MTN opted for the hierarchical controller approach to enable abstraction, network slicing and end-to-end orchestration, with multivendor and multidomain visibility.

The key use case MTN is targeting is IP+Optical synergy, which is being implemented in MTN's South Africa operations, bringing together three main technology providers: Huawei, Cisco and Nokia. The need to improve fault management in a multivendor environment makes the case for a hierarchical controller.

In the past 12 months, MTN OpCos have experienced more than 4,000 faults and over 3,000 fiber cuts, with it typically taking a day to demarcate faults and another 3 days to rectify them. To address this, MTN Group developed its SuperConnect IP+optical collaboration AN solution based on its Level 3 AN architecture. MTN is working with its suppliers to implement network self-monitoring, self-healing and self-optimization as shown in the graphic below. A description follows.

**MTN Group's IP+optical domain architecture**

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MTN builds self-assuring capability in the resource layer to ensure efficient resource operation in network monitoring, fault handling and transport-network optimization:

- **Self-monitoring –** multi-layer link in one topology. In the past, MTN's IP and optical networks had separate network management systems, so synergy between them could not be managed properly. Now, multi-layer link resources between IP routers and optical network terminals can be discovered automatically and created through a Link Layer Discovery Protocol (LLDP) and traffic pattern comparison algorithm. With 100% accurate cross-layer link information, the resources (such as the link utilization, port queue unitization, latency via Two-Way Active Measurement Protocol, port status, optical channel utilization) are monitored and associated to one map automatically.
- **Self-diagnose –** one fault, one ticket. In the past, faults were handled by IP and optical network teams independently in different systems. Now, multi-layer faults are diagnosed, demarcated and located automatically in one system. The fault-compression algorithm is the base of intelligent correlation of alarms in both IP and optical domains. The system automatically identifies instant root cause of optical-layer SLA degradation, fiber cuts and port failures, shortening troubleshooting duration from one day to five minutes, and it dispatches one ticket per fault.
- **Self-optimizing –** best protection parameter recommendation. The system identifies an end-to-end, cross-layer network protection mechanism and provides optimization suggestions on protection parameters in order to avoid unnecessary protection and network flapping during physical link failures. It also identifies the shared-risk link group (SRLG) and shared boards, providing alterative best protection paths to reduce the potential risk of network.

**Promising results**

MTN South Africa has deployed the IP+Optical AN solution with the following results:

- **One screen achieved 360-degree, multi-layer, end-to-end topology visualization –** more than 12,000 IP Radio Access Network sites and over 200 optical transport sites are based on real GIS-based topology, and the end-to-end path is fully visualized.
- **Cross-layer link auto-monitoring –** more than 150 cross-layer links have been automatically created and monitored.
- **Multi-layer fault demarcation –** fault demarcation time has been optimized from one day to five minutes, shortening the mean time to response of the overall transport network.

telecom

## EFFICIENT O&M: TELECOM ARGENTINA OPTIMIZES WI-FI IN THE HOME

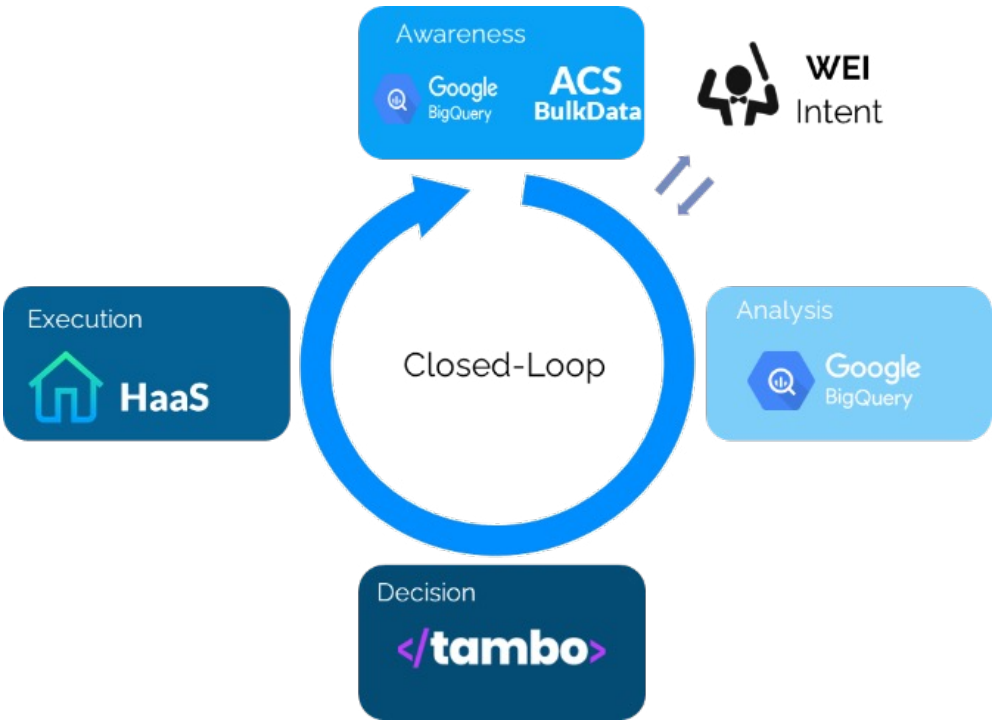
Telecom Argentina wanted to reduce the number of call-center complaints it was receiving for problems related to Wi-Fi service in the home. Initially, one use case was identified: optimizing the Wi-Fi channel used. But the company later added two more use cases: preventive reset and Wi-Fi restoration.

As its intent source, Telecom Argentina used data collected by a Wi-Fi user experience index (WEI) to identify affected users. The Wi-Fi channel optimization use case aims to identify and remediate customers' devices that are experiencing navigation problems due to the use of a non-optimal Wi-Fi channel. Once the device is identified, actions are carried out so that it makes a channel change and can operate in more favorable conditions.
In the preventive reset use case, the company monitors the CPU and memory usage of customers' devices, rebooting them to maintain optimal performance when they exceed predefined thresholds. Action is taken when low CPU and MEM performance is detected on the device.

In the Wi-Fi restoration use case, Telecom Argentina detects when a device is reset to factory settings, verifies that this change is unwanted, and from a backup restores the SSID and password settings. This avoids complaints and allows the customer to continue using the service.

These processes are executed through a closed loop spanning from data collection to action, using a combination of Telecom Argentina's internal platforms such as its TAMBO automation platform and Home as a Service (HaaS) platform, as well as external platforms like Google's BigQuery. The graphic illustrates the closed loop, and an explanation follows.

**Telecom Argentina's Wi-Fi optimization closed loop**

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**Awareness**
Detection of devices outside optimal Wi-Fi conditions with separation according to each sub-use case:
1. According to the WEI, data is collected and CPE using a non-optimal channel is detected
2. Data collection of memory and CPU usage from CPE
3. Detection of CPE in factory reset conditions

**Analysis**
Devices are separated according to the sub-use case:
1. Comparison of levels in the WEI and selection of CPE that should be optimized
2. Based on the predefined trigger, CPE that must be restarted is identified
3. Multiple validations to apply restored logic

**Decision**
Telecom Argentina's internal automation platform, TAMBO, has multiple decision-making modules. They are separated according sub-use case:
1. CPE that needs Wi-Fi channel optimization is selected
2. CPE that exceeds thresholds are selected for restart
3. CPE that needs SSID and password restoration are selected

**Execution**
In the HaaS platform, execution of the Decision Module is performed:
1. Automatic forcing of the autochannel module in selected devices
2. Reboots are applied to selected devices
3. SSID and password restore are applied to selected devices

Telecom Argentina is seeing good results when comparing the number of customer-complaint calls where the action has been applied versus not: a 9.7% drop in calls for channel optimization, 7.9% for preventative restoration and 7% for Wi-Fi restoration.

Telkomsel

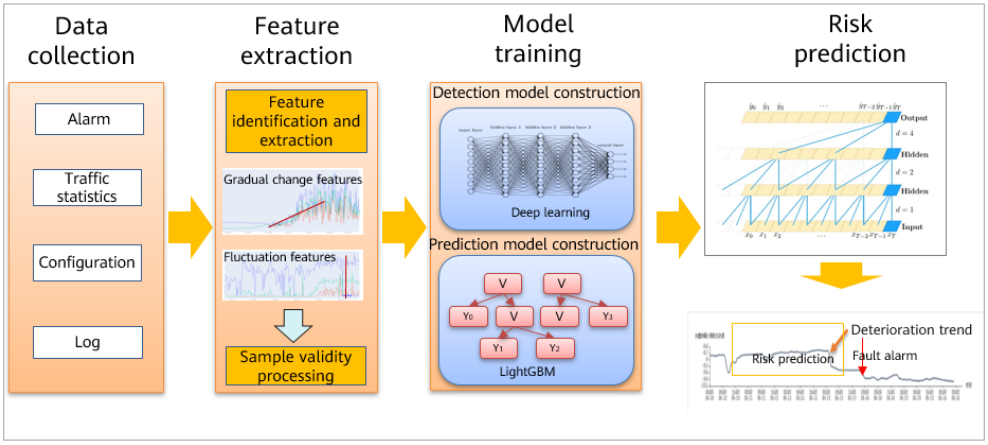
## EFFICIENT O&M: TELKOMSEL'S CPRI OPTICAL LINK FAULT PREDICTION AND PREVENTION

CSPs use CPRI optical link fault prediction and prevention as a strategy to proactively prevent failures in the optical links that connect the baseband unit and remote radio head over the Common Public Radio Interface (CPRI). These links are critical for high-speed transmission of data, so maintaining them and preventing faults is essential for network reliability and performance.

To reduce cell out-of-service and ensure user experience, Telkomsel is planning and designing a fronthaul risk prediction system. Based on fronthaul optical link data, the operator constructs risk-prediction models for various fronthaul fault scenarios to effectively prevent cell out-of-service caused by fronthaul optical link faults. By some estimates, these tickets make up approximately 70% of total fault tickets.

The fronthaul risk prediction system (see graphic) collects online data about wavelength, optical fiber length, transmission mode, temperature and inventory configuration over a 15-day period. It then intelligently reconstructs the fronthaul topology network, builds risk-prediction models for various fronthaul fault scenarios and predicts potential faults on wireless networks to achieve zero faults.

**Telkomsel's fronthaul risk-prediction system**

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The system deeply explores the bottom-layer logic of network alarms and fronthaul optical links. It detects and analyzes network risks online, proactively predicts network faults and improves the online rate of base stations.

Specifically, it extracts features on online historical data based on basic network element data and then balances training by performing sample balancing on the training data and model training. Then, based on the network-wide optical link fault prediction model, the system collects real-time data, predicts whether fronthaul optical links of base stations will be faulty in the future and outputs fault information.

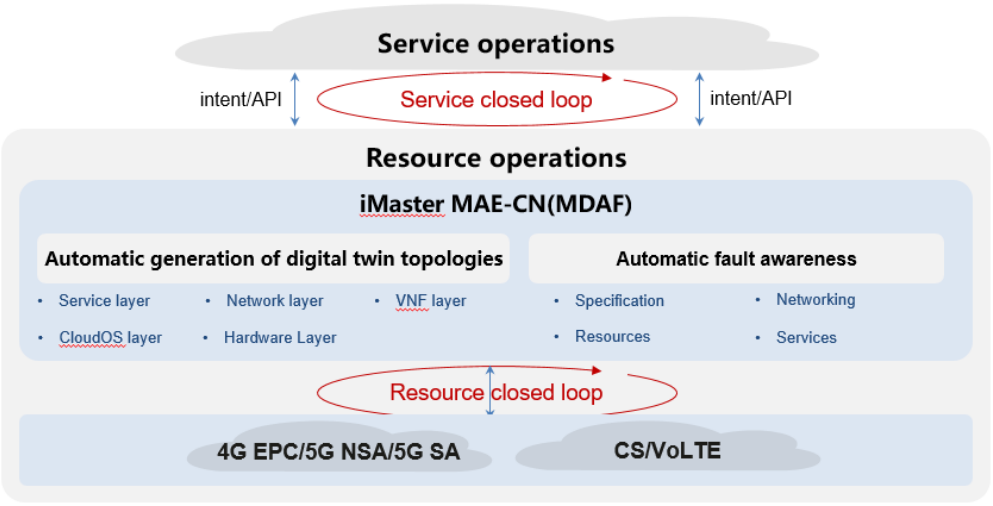
The accuracy of fronthaul risk prediction using the system is higher than 80%, and risk handling is integrated into routine troubleshooting. Based on the statistics, the rise in potential risk tickets is essentially equivalent to the decline in fault tickets. This implies a shift from reactive out-of-service fault management to proactive risk management.

## EFFICIENT O&M: stc's DIGITAL TWIN-BASED CLOUD-NETWORK TOPOLOGY VISUALIZATION AND ANALYSIS

With the continuous evolution to cloud-native networks and full convergence, the core network is becoming increasingly complex. Because of the lack of automation and intelligence methods, it's difficult for operators to view the cloud-based layered topology and network status directly. In addition, fault awareness and demarcation are low efficiency. As a result, faults cannot be quickly handled, which is affecting network reliability.

stc in Saudi Arabia is developing a digital twin-based cloud-network topology visualization and analysis solution to build an end-to-end intelligent fault management system (see graphic). The goal is to make the cloud-based core network visible, manageable and controllable to achieve zero-trouble, one topology visualization and health awareness of infrastructure, networks and services in all scenarios. This will assist monitoring and problem analysis, improving O&M efficiency. The graphic shows the approach, and a description follows.

**stc's approach to cloud-network topology visualization and analysis**

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Here's how it works:

- **Automatic generation of digital-twin topologies –** based on the digital-twin technology and resource visualization modeling algorithm, a twin network of a physical network entity is created. The O&M engineers can view a five-layer topology directly, including services layer, networks layer, network elements layer, cloudOS layer and hardware layer. The five-layer cloud-network topology is dynamically refreshed, and all resource objects and link relationships are dynamically updated, greatly improving network monitoring and O&M efficiency.
- **Automatic fault awareness –** Precise modeling and a mapping algorithm are implemented for the health of objects at five layers from four dimensions (resource, communication, specification and service), shortening fault-awareness duration from hours to minutes. In addition, fault analysis based on topology-based spatiotemporal association is implemented based on the health result and object topology relationship.

stc's solution is currently undergoing testing in a staging environment. The next step will be to initiate a digital twin-based signaling storm simulation. This refers to the use of digital-twin technology to model and simulate events that could cause service disruptions or failures – for example, network misconfigurations, software bugs or a large number of devices trying to connect simultaneously.

中国移动 China Mobile

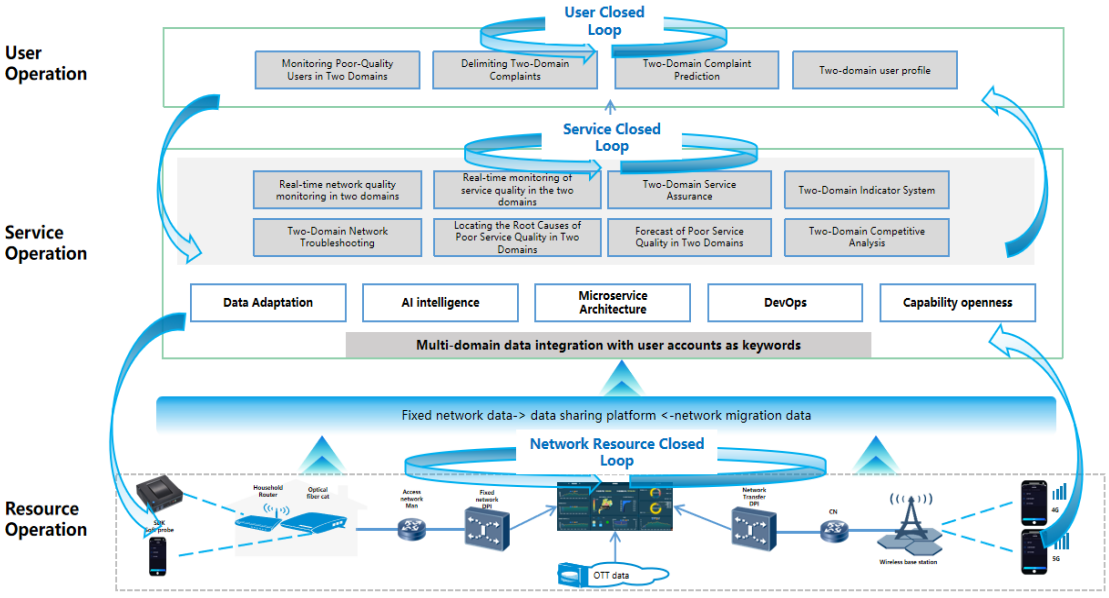
## EFFICIENT O&M: CHINA MOBILE'S DIGITAL AND INTELLIGENT CONVERGENCE OF DUAL-DOMAIN NETWORK O&M

Shaanxi is a leading province in western China, with China Mobile's network there evolving towards full-service and integration. By 2023, 52% of users were using converged fixed and mobile network services, with an increase in the number of network elements (NEs). However, traditional analysis methods fell short, plagued by siloed systems, data fragmentation and high opex costs. Dual-network management indicators were not unified, end-to-end O&M methods were lacking and maintenance efficiency was low. The lengthy complaint-handling process significantly impacted customer satisfaction for integrated services.

To address these challenges China Mobile Shaanxi has collaborated with equipment manufacturers to develop a new intelligent-management system, leveraging big data and AI technologies for fixed-mobile convergence.

The operator created a dual-domain, integrated-operation "intelligence brain" in the province and is enabling unified, intelligent closed-loop management of user, service and resource operations in the dual-domain network. The graphic shows the architecture, and a description follows.

**China Mobile's dual-domain network O&M architecture**

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**Autonomous closed-loop perception –** the system fulfills the requirements of China Mobile's customer perception-oriented network quality-management capability and improves user perception through dual-domain user perception modelling, monitoring, complaint handling, complaint prediction and work order distribution.

- **Active identification of poor-quality users:** through dual-domain service link establishment and service attachment procedures, etc., a unified QoE-KQI-KPI indicator system identifies users experiencing poor experience.
- **Intelligent complaint analysis and demarcation:** the next steps are drilling down into the indicator information and service flow of the dual-domain NEs, delimiting the problem cells and associating the software collection/network performance data in order to locate poor quality.
- **Forecast of complaint users based on service tracks:** the system provides single-user service tracks in the three-network scenario through the association of services, cities and time. It displays users' real-time service perception based on the time, network and NE; associates historical data of complaint users; and identifies potential high-complaint users.
- **Dual-domain network coverage black points:** the algorithm accurately identifies user locations by pinpointing resident cells and B-domain information. It associates user addresses and floor information to uncover indoor coverage black spots, utilizing service perception data, wireless MR data and OTT Wi-Fi data.
- **Work order assignment:** finally, the system interconnects with the work order system and wireless single-domain OMC (operations and maintenance center) to implement manual work order assignments and automatic problem packet transmission.

**Self-closed-loop service –** the data collection and integration of dual-domain Internet services form end-to-end service quality analysis, meeting the requirements for the calculation of various key service indicators in each domain involved in the mobile and fixed services. Based on the topology inference fault-propagation model, a decision tree is built based on the correlation between poor quality events to trace the first problem of poor-quality call detail records and delimit poor quality.

- With OTT data, cross-operator user experience, network coverage and KPI-match analysis can be implemented.
- Based on the integrated ONEID idea, it's possible to identify the ownership of devices and accounts, form ONEID data sets, and accurately identify the relationship between entities and family information.
- Interconnects with the work order system and wireless single-domain OMC implement manual work-order assignments and automatic problem packet transmission.

**Resource autonomous closed loop –** this loop enables deep diagnoses of passive optical network (PON) alarms in work orders.

- PON network hardware faults are found, and hardware is replaced through alarm association and secondary root-cause diagnosis.
- Inter-domain APPC and AAX interconnection is used to rapidly handle radio-network alarms, load imbalance and antenna weight configuration, thus rapidly improving service quality and user experience.

**Promising results**

China Mobile's dual-domain approach is delivering promising results. In February 2024, the average initial video delay for mobile network users decreased 3%, while the average download rate increased by 4.7%. The monthly video data traffic for MiGu App users increased about 2.7%.

One of China Mobile's suppliers, ZTE, developed an AI model for network system switching identification and poor-quality root-cause digging to automatically delimit video jamming in the home-wide scenario and rectify low quality for 32 affected users. An algorithm for locating the indoor perception black point was developed to improve the indoor vertical-positioning accuracy to 92% in a specified area. This helped increase the number of distribution sites in a cell to 25 and reduced the number of unsatisfied users in the cell.

Finally, the average service perception optimization time was shortened from one week to two days, increasing the efficiency by nearly 90%.

HKT®

**GREEN ENERGY: HKT'S NETWORK EVOLUTION AIMS TO INCREASE SUSTAINABILITY**

The government of Hong Kong has set a goal of achieving carbon neutrality before 2050. In the interim, it has set a 2035 decarbonization target to reduce carbon emissions in the region by 50% when compared with the 2005 level. HKT is also committing to these targets, with a focus on reducing energy consumption in the central office (CO).

There are several pre-requisites to achieving AN Level 4 and carbon neutrality in CO's as shown in the table.

**HKT's initiatives for sustainability in the central office**

| Initiative | Carbon neutrality = Renewable energy + energy-saving central office initiatives | How to get there |
|---|---|---|
| Solar panels | Establish renewable energy for central offices | Need to calculate the sizing for carbon neutrality |
| Lithium batteries | Storage of renewable energy | Prolong the use of renewable energy by releasing it from batteries to support the CO |
| Data-center solution | Align racks to 'hot aisle' and 'cold aisle' to improve energy efficiency and prevent the mixing of cold and hot air | Optimize cooling, reduce costs and contribute to sustainable energy practices |
| Free-cooling solution | When the air near servers becomes hot, it's released into the environment (either entirely or partially), with fresh, cooler outside air replacing it | Harnesses natural air temperatures to enhance efficiency, reduce costs and keep digital infrastructure cool |
| IoT sensor + Digital twin/AI platform | Use IoT sensors to collect various parameters within the CO and feed into digital twins for 3D/2D simulation; use AI to calculate the optimal period to control the cooling systems and power systems for maximizing energy saving | HKT uses a supplier's platform to perform data analysis and maximize energy saving through the control of systems within the CO |
| Network modernization | Use low-energy consumption equipment to replace legacy (high-energy consumption) gear; examples include use of optical networking and 10G-PON or above | Reduce the number of racks and use low-energy consumption equipment |
| Equipment re-classification | Re-define equipment environment requirements and re-group equipment (certain equipment can function at a higher temperature) | After grouping, certain COs will work at a higher temperature and reduce cooling effort |

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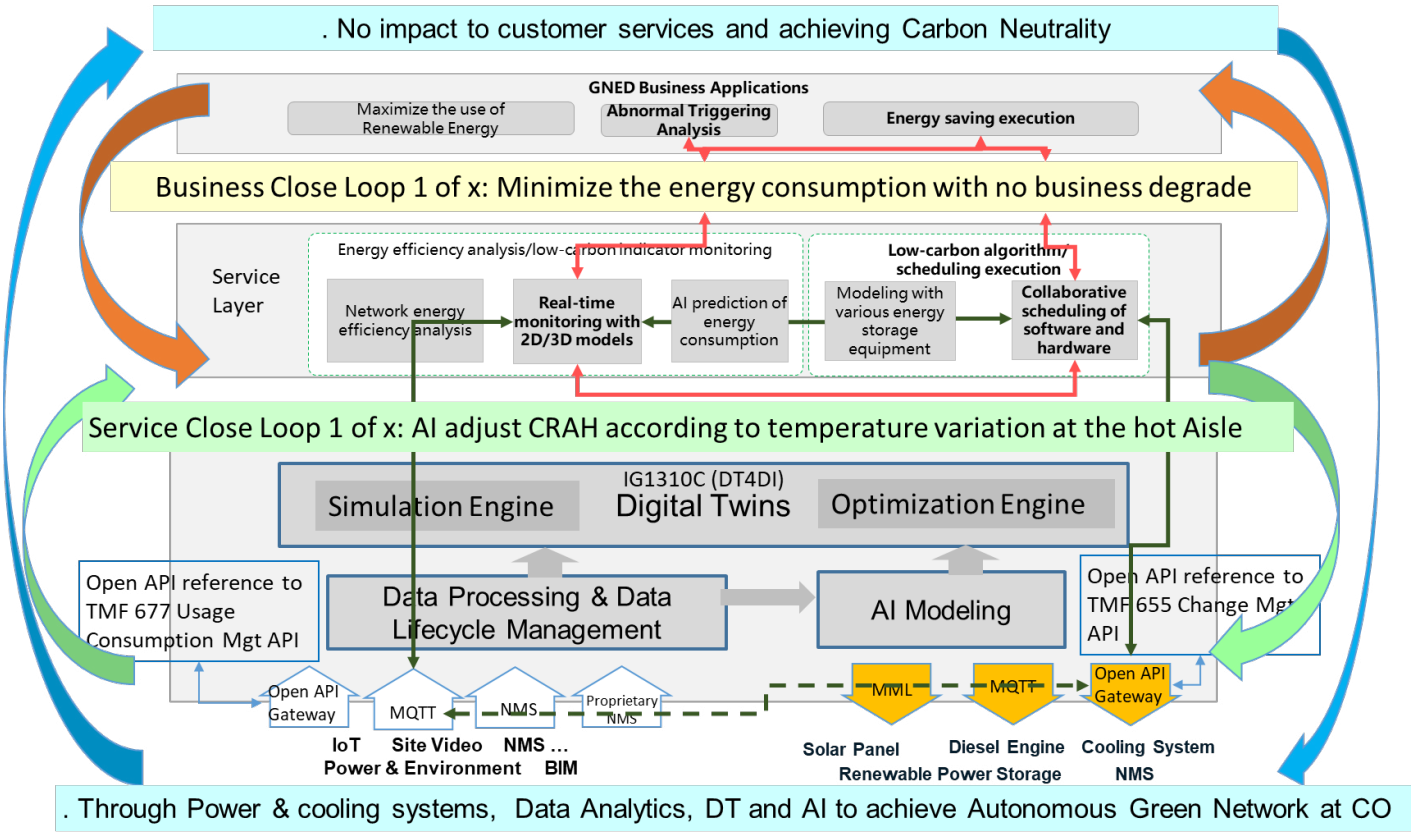
The graphic below shows HKT's central office initiatives and the digital-twin platform forming an autonomous network to achieve the business intent, which is to have zero impact on customer service and achieve carbon neutrality.

**HKT's closed-loop approach to energy optimization**

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The autonomous optimization loop continuously tries to improve energy efficiency. The platform gathers data from various sources and then performs analytics to maximize the use of renewable energy and minimize energy consumption by scheduling changes to cooling and power systems.

In this example, the business application is connected with the service layer to minimize energy consumption with no business degradation, as shown by the red lines. The service closed loop uses AI to adjust the computer room air handler (CRAH) according to the temperature variation at the hot aisles, as shown by the green lines.

The IoT sensor and the cooling system help to close the service loop. If the sensor detects a higher temperature, the CRAH will increase its circulation output to reduce the temperature in hot aisles, while if the sensor reports that hot aisles have a lower temperature, the CRAH will reduce air exchange rate. With the variation of temperature, the AI engine can tune the CRAH to save energy.

**Business benefits**

This green network can achieve AN Level 4 as it is able to work independently once all the hardware and digital-twin platform connections are established. In addition to deploying AN technology, HKT is adopting renewable energy and has installed a wide range of energy-management solutions in more than 30 local central office buildings to gradually reduce energy consumption. In 2023, the company saved 21 million kWh of electricity.

# AN standards update

Section 6

Development of standards to advance autonomous networks is happening industry wide. Many of the companies participating in TM Forum's work to develop AN standards and best practices are also participating in other SDOs such as 3GPP, CCSA, ETSI, IETF among others.

Together, these groups have initiated more than 100 AN standardization projects across the telecoms industry. Collaboration among them seeks to ensure that work is not needlessly duplicated.

TM Forum primarily focuses on developing best practices and standards that are domain agnostic. This includes developing business requirements and business architecture, high-level technical architecture, methodologies for determining AN levels and effectiveness indicators, and APIs. Technical-domain SDOs like 3GPP and ETSI define technology-specific autonomous domain architecture and level evaluation standards, as well as key enablers and APIs.

Current standards-development projects industry wide highlight three important advancements:

- **Efforts shifting from generic to domain-specific standards.** 3GPP CCSA and ETSI have released AN level standards for wireless, core and IP networks, while ETSI F5G is continuing to advance the development of transport network AN level standards. As noted in Section 3, TM Forum is collaborating with 3GPP specifically to assess AN levels for fault management in the RAN and core. In order to perform an assessment, a set of fault management tasks had to be defined. So, TM Forum utiilized 3GPP's TS 28.100 specification to create a task list and then added weighting for each task. ETSI and IETF are being consulted to create task lists for assessing processes in other domains such as IP and transport networks. TM Forum is also launching pilot programs for CSPs' ANL evaluations and standards definition.

- **Acceleration of the development of standards for key enabling technologies and intent APIs.** TM Forum, CCSA and ETSI have all defined standards based on technologies such as GenAI and digital twins. 3GPP (in its Release 19), IETF and other organizations are also accelerating the development of AN Level 4 use cases and intent API standards.

- **Improvement of standards related to AN evaluation, planning, deployment and implementation.** As explained in previous sections, TM Forum has summarized CSPs' AN experience, released a comprehensive AN implementation methodology in the AN Framework and established AN KEIs. A new effort called Focus on Value: Operators' Key Requirements for Autonomous Networks (IG1339) is defining CSPs' requirements for AN Level 4 high-value scenarios, while the Autonomous Network Effectiveness Indicators guide (IG1256) is defining business value and key capability indicators.

The table below shows the main AN standards that have been defined by SDOs, with a link for each where most of the documentation can be found.

The Multi-SDO, or MSDO, initiative is a joint collaboration facilitated by TM Forum, bringing together several leading SDOs to address the complexities of AN. Its goal is to remove overlaps, fill gaps and ensure alignment across different standards to create a cohesive framework for AN standardization. Topics that have matured through this initiative include intent-driven management, key effectiveness indicators and autonomy use case sharing.

## AN standards defined by SDOs

| tmforum | ETSI | 3GPP | IETF | CCSA |
|---|---|---|---|---|
| General | Key Enablers/Fixed Network | Mobile Network | Fixed Network | General/All Domains |
| **AN Framework and Requirements**<br>• IG1218 Business Requirements & Framework<br>• IG1218F AN Framework<br>• IG1339 CSP AN High Value Scenario Requirements<br>**CSP AN Practice**<br>• IG1218B CMCC Practice on AN<br>• IG1218C AN Realization Studies<br>• IG1218D AN Best Practice of Level-evaluation<br>• IG1218E AIS Practice on AN<br>• IG1218G Orange Practice on AN<br>**Reference Architecture**<br>• IG1230/A/B AN Technical Architecture<br>• IG1251 AN Reference Architecture<br>**AN Level Evaluation**<br>• IG1252 ANL Evaluation Methodology<br>• GB1059 ANL Evaluation<br>• GB1059A RAN Fault Management Questionnaire<br>• GB1059B Core Fault Management Questionnaire<br>**AN Key Effectiveness Indicators**<br>• IG1256 AN Key Effectiveness Indicators<br>**Key Enablers**<br>• IG1253 Intent in AN<br>• IG1345 Generative AI in AN<br>• IG1369 GenAI Use Cases | **E2E MD/MD Referenc Architecture**<br>• ZSM002 Reference Architecture<br>• ZSM003 E2E Network Slicing<br>• ZSM008 Cross-Domain E2E Service Lifecycle Management<br>**Fixed Network Domain Architecture**<br>• F5G004 F5G Network Architecture<br>• F5G006 F5G E2E Management<br>• F5G024 F5G-A Architecture<br>• F5G027 F5G-A E2E Management<br>**Fixed/IP Network Domain AN Level**<br>• F5G019 F5G AN Level Definition<br>• ENI035 IP Domain AN Level Definition<br>**Key Enablers, UCs and Interfaces**<br>• ZSM009-1/2/3 Closed-loop Automation<br>• ZSM011 Intent-Driven AN<br>• ZSM012 AI Enabling Technology<br>• ZSM016 Intent-driven Closed Loops<br>• ZSM017 Closed-Loop Automation Security aspects<br>• ZSM018 Network Digital Twin for enhanced ZSM<br>• NFV-IFA 050 v0.0.1 Intent Management Service Interface and Intent Information Model Specification | **Mobile Network Domain Architecture**<br>• TS 28.533 Management and Orchestration Architecture Framework<br>**Mobile Network Domain AN Level**<br>• TS 28.100 Mobile Network-Levels of autonomous network<br>• TR 28.909 Study on Evaluation of Autonomous Network Levels<br>**Mobile Network Domain Key Enablers, UCs and Interfaces**<br>• TS 28.104 Management Data Analytics (MDA)<br>• TS 28.313 Self-Organizing Networks for 5G networks TS 28.310 Energy efficiency of 5G<br>• TS 28.535/6 Management Services for Communication Service Assurance<br>• TS 28.312 Intent Driven Management Services for Mobile Networks<br>• TS 28.105 Artificial Intelligence/ Machine Learning Management<br>• TS 28.557 Management of Non-Public Networks<br>• TR 28.914 Study on intent driven management service for mobile network<br>• TR 28.915 Study on management aspect of Network Digital Twin | **IP Network Domain Architecture**<br>• RFC8969 Service and Network Management Automation Framework<br>• RFC8309 Service Model Explained<br>**IP/Trans Domain Key Enablers, UCs and Interfaces**<br>• RFC9315 Intent Based Networking<br>• RFC8453 ACTN Framework<br>• Digital Twin Network Concepts and Reference Architecture<br>• Service Assurance for Intent-Based Networking Architecture<br>• RFC8299 L3VPN Service Model<br>• RFC8466 L2VPN Service Model<br>• RFC8632 Alarm YANG Model<br>• RFC8795 TE Topology Model<br>• RFC9094 WDM Topology Model<br>• RFC9182 L3VPN Network Model (L3NM)<br>• RFC9181 L2VPN Network Model (L2NM)<br>• RFC9408 Service Attachment Point Model<br>• Network Slice Service YANG Model<br>• Network Resource Partition Network Model<br>• Network Incident Model<br>• Attachment Circuit Model | **Architecture**<br>• Functional architecture<br>• Technical architecture<br>• Data architecture<br>**AN Level**<br>• Generic AN Level Definition<br>• IP Network AN Level Definition<br>• SPN AN Level Definition<br>• Transport Network AN Level Definition<br>• Access Network AN Level Definition<br>• Wireless Network AN Level Definition<br>**AN Effectiveness Indicators**<br>• AN Key Effectiveness Indicators<br>**Key Enablers, UC and Interfaces**<br>• AI & Large Model<br>• Network Digital Twin<br>• Network Digital Map<br>• Knowledge Graph<br>• 5G RAN Optimization<br>• 5G RAN Energy Saving<br>• Transport/Access Network Maintenance<br>• Transport/Access Network Optimization<br>• Transport/Access Network Operation<br>• IP Network Maintenance<br>• ..... |

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# What's next for autonomous networks?

Section 7

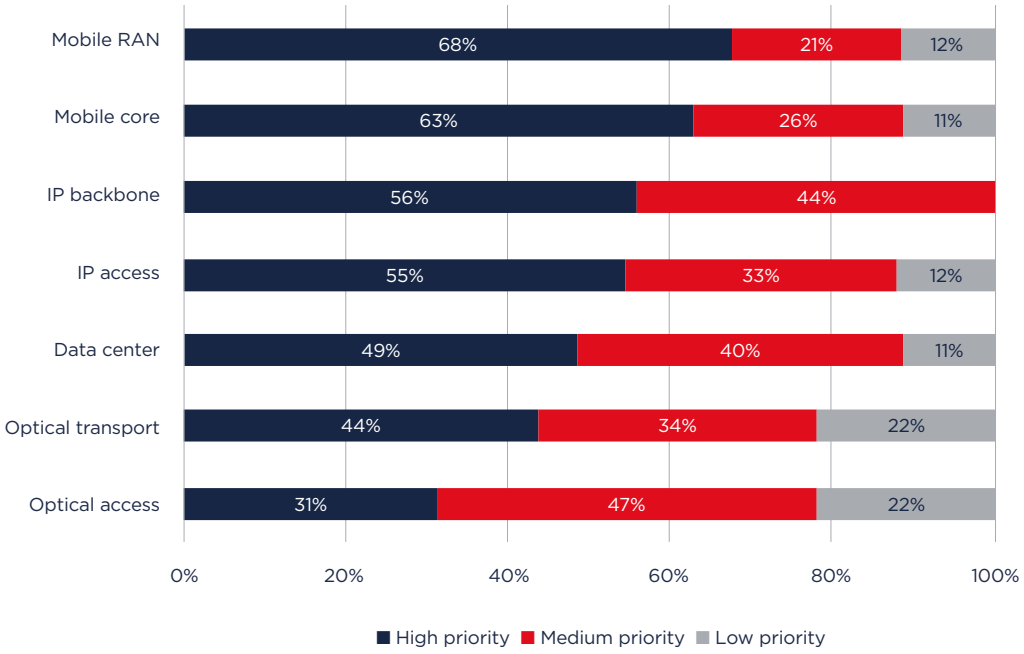
While the table in Section 3 provides a snapshot of where CSPs are on their AN journeys overall, a handful of operators are already adopting TM Forum's AN Level 4 high-value scenarios, specifying their planned evolution paths from 2025 to 2027. The table below shows the domains and processes these CSPs intend to target.

**CSPs' plans for evolving Level 4 high-value scenarios**

| CSP | 2025 | 2026 | 2027 |
|---|---|---|---|
| AIS | • Fault management<br>• Customer-complaint management | Additional sub-scenarios and cross-domain scenarios in fault management and customer-complaint management | Addition of:<br>• Network optimization<br>• Network configuration |
| 中国移动 China Mobile | • Service delivery<br>• Network change | • Service-quality optimization<br>• Energy-efficiency Optimization | • Troubleshooting<br>• Complaint handling |
| 中国电信 CHINA TELECOM | • 5GC troubleshooting<br>• Routine inspection: wireless and IP networks<br>• Wireless network planning and construction<br>• IP network and service quality optimization | • Cutover maintenance: 5GC, IT O&M<br>• Troubleshooting: IP network, IT O&M<br>• Wireless network quality optimization | • Optical network troubleshooting<br>• Cloud-network data governance<br>• IP cutover maintenance |
| 中国联通 China unicom | • Service provisioning: optical network, private line, 5G private network, IoT, cloud networking<br>• RAN network operations efficiency improvement | • RAN troubleshooting<br>• Broadband access network troubleshooting<br>• Individual service - business optimization<br>• Broadband Service - business optimization<br>• RAN optimization | • Individual service-complaint handing<br>• Home broadband service complaint handing<br>• Troubleshooting: core, optical and data networks |
| Singtel | • Innovation and piloting for value scenarios: fault management and customer complaint management<br>• Implement for those value scenarios<br>• Continual innovation for value scenarios: RAN energy saving, network optimization and more | | |
| Telefónica | • O&M (high value) in all domains (RAN, transport, IP, core, IT cloud and fixed access<br>• Optimization and configuration in RAN (high value), transport, IP and IT cloud domains<br>• Testing in transport, IP and IT cloud domains<br>• Deployment in RAN, transport, IP (high value) and IT cloud domains<br>• Planning in RAN, transport (high value), IP and IT cloud domains | | |
| telenor | N/A | • Service delivery: private line and 5G2B<br>• Service assurance: private line and 5G2B<br>• RAN fault management<br>• RAN energy saving | • Service delivery: private line and 5G2B<br>• Service assurance: private line and 5G2B<br>• Fault management: RAN, core, access, IP and transport networks<br>• Network change: RAN and core network<br>• Quality optimization: RAN and IP network<br>• Energy saving: RAN, core access and data center networks |

The operators' plans are supported by preliminary data from TM Forum's latest AN survey, which was still being conducted at the time this guide was published. Initial results show that RAN, wireless core and IP backbone are the top three domains CSP respondents are addressing first, while fault management, service assurance and quality optimization are the top processes.

**Which network domains are you addressing first?**

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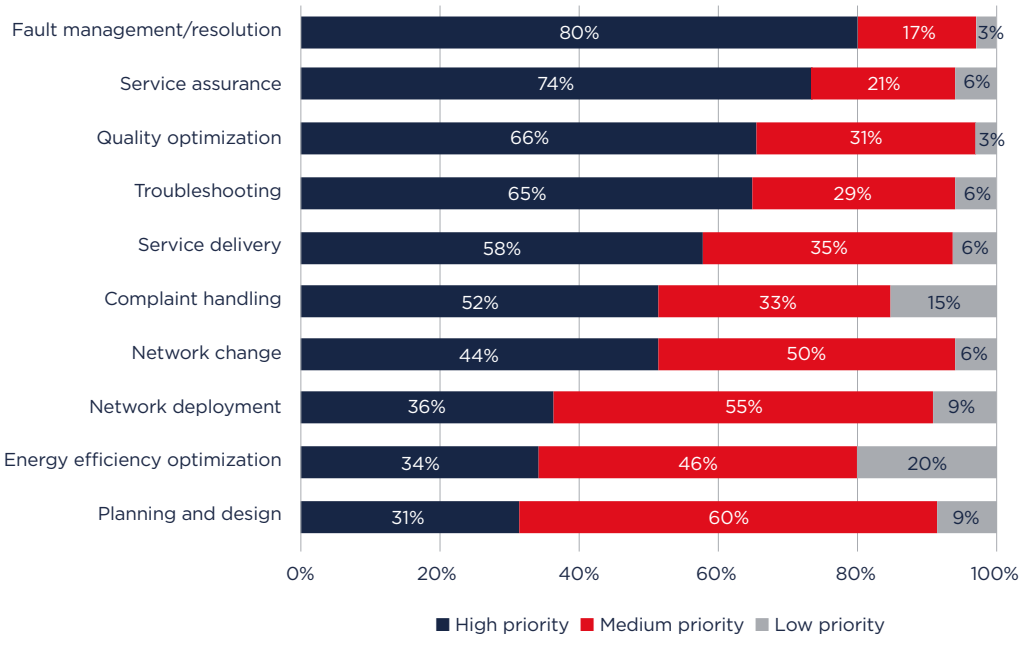
**Which processes are you addressing first?**

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As discussed in previous sections, TM Forum's AN level assessments are starting with fault management in the mobile network (RAN and core) because operators participating in the evaluations found these scenarios to have the highest value in terms of either cost savings or revenue generation. The other high-value use cases they identified include fault management and network optimization in the IP network, and change management in all domains.

## SIZING THE OPPORTUNITY

As AN evolves from Level 2/3 to Level 4, the value of implementation is expected to grow exponentially. Many research and consulting firms are exploring the potential by evaluating AN strategy and vision, architecture, emerging technologies, markets for solutions, and the new revenue that could result from transformation.

Last year, Accenture conducted in-depth research on the social and business value of AN and published its results TM Forum's AN journey guide. The research found that by 2035, AN could enhance 12 key industries valued at $57 trillion and accounting for 36% of global GDP. Over the next 20 years, Accenture predicts that AN will create $9 trillion in social value, impacting public governance and well-being and reducing carbon emissions.

Analysts at Appledore Research have conducted comprehensive research into the concept of "single-domain autonomy and cross-domain collaboration". Their findings suggest that future autonomous networks will need to be designed as independent, autonomous domains linked by cross-domain service orchestration. The firm has also discussed work distribution and the evolution path for technology, advocating for a federated and distributed approach where each technology domain has its own autonomous controller/orchestrator.

Omdia has predicted that the value of the telco network and service automation market will hit $2.7 billion by 2028. The company's survey-based research offers these recommendations for CSPs:

- Accelerate network automation to manage cloud and 5G complexities.
- Integrate network engineering and software development teams to create a synergistic skillset for network automation.
- Adopt a common automation framework to standardize protocols and interfaces to address concerns about interoperability and integration.

A new report from STL Partners projects that the implementation of AI and automation in the network will result in $650 million in annual capex and opex savings for an average CSP (defined as an operator with "about $15 billion in annual revenue, 31 million mobile customers, and 12 million fixed-line subscribers"). On top of this, the research firm predicts that an additional $144 million in value will result from revenue increases because of faster and more profitable service innovation. The combination of these financial benefits amounts to about 5% of an average CSP's revenue, according to the research firm.

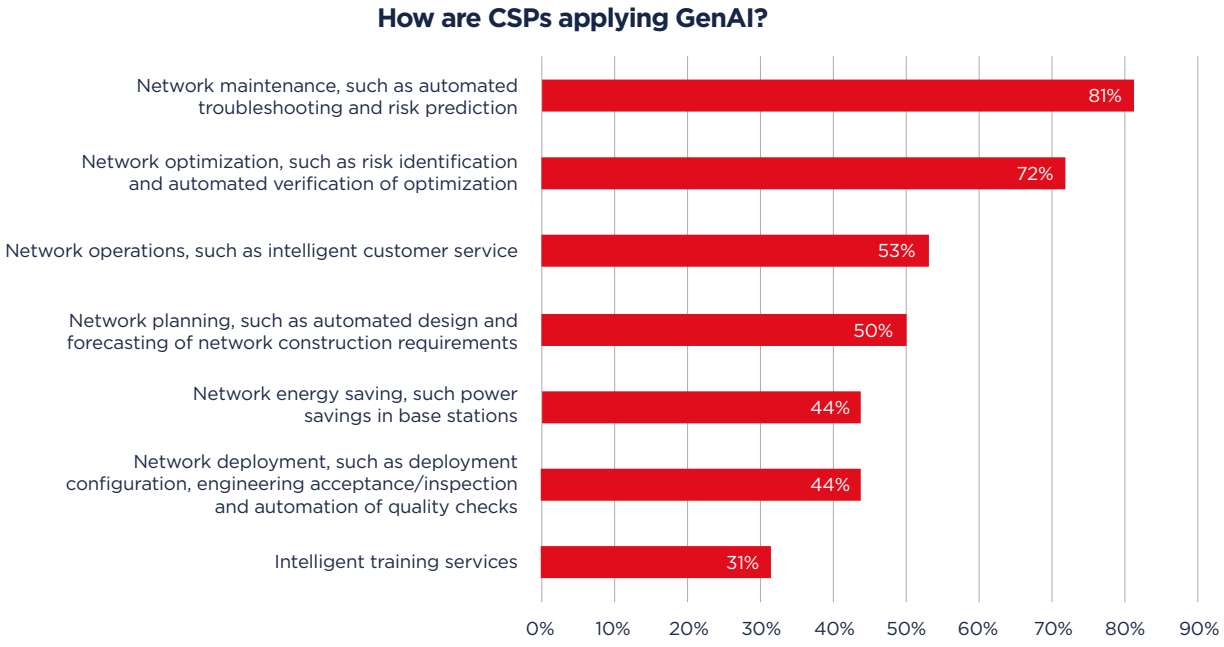
STL also finds that resource management, service assurance and network planning are the processes where AI and automation will have the biggest impact, noting that 30% of the predicted cost savings and revenue increase will depend on the implementation of sophisticated AI and automation in high-level scenarios.

## GENAI'S IMPACT

CSPs increasingly view GenAI and its large language and action models as crucial for achieving high levels of network autonomy. As this guide demonstrates, successful deployments of scenario-based applications are already improving customer experience and operators' internal operations.

Analysts are bullish about the potential for GenAI to speed AN transformation and lead to new revenue. McKinsey estimates that GenAI will result in significant growth and could contribute between $2.6 trillion and $4.4 of additional value to the global economy. In telecoms alone, the firm expects the impact of new GenAI use cases to be between $60 billion and $100 billion.

TM Forum's AN benchmark survey asks CSPs' about their use of GenAI. Preliminary results show that network maintenance and optimization are key uses, with more than 70% of respondents saying they're relying on Gen AI to support those processe. Final results of the survey will be published in the AN benchmark report in January 2025.

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## NEXT STEPS

In the coming year, TM Forum's AN Project will continue its work to define AN standards and best practices. Key goals are to:

1. **Accelerate Level 4 standards development** by focusing on phased development of Level 4 standards. The AN project will collaborate with CSPs and SDOs across different domains to define key Level 4 scenarios, establish an AN effectiveness evaluation framework and promote multivendor interoperability standards.
2. **Fast-track Level 4 technological breakthroughs** by promoting the advancement of key technologies such as GenAI, digital twins and telecom foundation models, particularly in AI security and trustworthiness. We aim to ensure the reliability of intent understanding, analysis, inference, decision-making and execution. We also will facilitate industry-wide technological upgrades by defining the architecture and collaboration responsibilities for multiple large language and action models and agents, followed by integration and verification of interoperability.
3. **Expedite Level 4 application innovation and planning** by driving the commercial use of Level 3 applications and initiating pilot verification for Level 4 commercial applications. We will focus on value creation and implement innovative practices throughout the entire network lifecycle, accelerating the formation of an industry value closed loop to speed transformation.

## ADDITIONAL RESOURCES

To learn more about the important work TM Forum is doing to speed adoption of autonomous networks, visit the website and join one of our collaboration projects, or contact Olta Vangieli.

You can read all the best practice and use case/scenario contributions here.

TM Forum members can download AN guides, toolkits and other resources here.