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A WHITEPAPER ON

autonomous networks

Empowering Digital Transformation

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OBJECTIVE(S):

To set out the updated business requirements, architecture, capabilities and collaborative industry activities for Autonomous Networks and to illustrate industry best practice and reference implementations

Our Contributors

Editors and Contributors

EDITORS

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

CONTRIBUTING COMPANIES & CONTRIBUTORS

AsiaInfo	**Da Wang, Gang Zeng, Zhihai Xiao**
Beyond by BearingPoint	**Andreas Polz, Susan Backhaus**
BT	**Andy Corston-Petrie**
China Mobile	**Ninglun Gu, Liwei Liu, Yuan Yao, Lingli Deng, Kaixi Liu, Chengcheng Feng, Zhiyi Luo**
China Telecom	**Sun Qiong, Liu Linjun, Zhang Le, Zhang Ke, Ziting Zhang**
China Unicom	**Ren Fei, Wan Yuhai, Wang Lei, Qiao Zizhi**
China Unitechs	**Liguang Hao, Song Gang**
Clarity Global	**Ali Mozaffar, Seyed Zoee, Mohammad Reza Anbiyaei, Adel Hosseiny**
Cognizant	**Arun VS, Pramathesh Bhurangi**
Eastcom	**Mao Guang, Yi Hongpeng**
Ericsson	**Ignacio Más, Jörg Niemöller**
ETIYA	**Thierry Reynard**
Futurewei	**Dong Sun, Min He**
GuoChuang	**Zhao Long**
HKT	**Derek Chen, Kam-Shing Fung**
Huawei	**Yongming Lin, Yining Wang, Ji'ang Li, Hui Li, Guangying Zheng, Xu Wang, Jian Wang, Dan Deng**
IBM	**Dharmendra Misra, Subrata Ghosh**
Infosys	**Anuroop Awasthi, Ankur Goel, Ankur Goyal**
MTN	**Mohamed Salah, Daniel Smith, Lloyd Mphahlele, Nkosinathi Nzima, Thembinkosi Ndebele**
NBNCo	**Brad Peters**
NEC	**Junko Iwasaki**
Netcracker	**Andrei Chekalin, Manoj Nair, Abinash Vishwakarma**
Nokia	**Neetu Singhal, Lei Li, Li Jin**
NTT	**Takayuki Nakamura, Kiyotaka Mizuno**
Orange	**Christian Maitre, Sophie Nachman**
Robi Axiata	**Mohammed Fahim Momen, Mohammad Rubbyat Akram**
stc	**Khalid Mohamed Attia**
Telecom Argentina	**Gaston De Arriba**
TEOCO	**Yuval Stein**
TM Forum	**Aaron Boasman-Patel, Dave Milham**
UBiqube	**Hervé Guesdon, Naveen Kumar M J**
Wipro	**Vinay Devadatta**
ZTE	**Hao Wang, Yong Wang, Fan Yingying**

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1. Executive Summary

Digital transformations are increasingly becoming new engines for global economic recovery and growth. COVID-19 has driven an acceleration of digital transformation in global enterprises adopting new innovative technologies such as 5G, AI, big data, cloud, edge computing and digital twins. This is not only spurring enterprise growth but it is giving communication service providers (CSPs) the opportunity to unlock at least $700 billion in new revenues[1] from industrial 5G and B2B2x opportunities. By 2025, the adoption of these new technologies, the proliferation of devices connected to the internet and the way in which businesses and societies interact may exceed current forecasts and expectations which include:

- **GSMA forecasts that the total IoT connections worldwide will reach 24.0 billion by 2025, of which 8.57 billion are mobile connections and 1.8 billion are 5G connections[2].**

- **IDC's "FutureScapes 2020[3]" predicts that 85% of enterprises' new digital infrastructure will be deployed in the cloud by 2025.**

- **IDC predicts that 45% of repetitive work tasks will be automated and/or augmented by using "digital co-workers," powered by AI, robotics, and RPA by 2022[4].**

IDC predicts that the global data volume will reach 175 ZB by 2025[5]. Data will become an important production factor and drive enterprises to transform production, operation, and management modes. Legacy network capabilities and operations methods cannot meet the requirements of digital transformation as described above and handle the complex processes needed to ensure end-to-end service lifecycle for this new wave of digital services and applications. Recognizing this, in 2019 TM Forum established the Autonomous Networks Program to provide an industry-led approach to end-to-end network automation to enable CSPs to simplify service deployment and achieve Self-X network capabilities such as self-serving, self-healing and self-assuring. Autonomous Networks will also provide zero-x experience for businesses and end-users which will deliver simplicity to customers and leave complexity with the service providers. This approach gives operators the ability to innovate with their business models and network services, enabling a new generation of digital products, both in the business to consumer (B2C) marketplace, but most importantly in vertical industries (B2B2x) such as smart health, manufacturing, autonomous vehicles, smart cities where major revenue opportunities lie. Autonomous Networks (AN) are therefore no longer an option or even a consideration for CSPs but are instead vital to deliver truly connected enterprise B2B2x digital services which depend on massive connectivity, low latency and high reliability.

In addition to improving operational efficiency and increasing network performance, Autonomous Networks are also expected to provide new network features such as online self-service for buying new products, providing new services on demand, enabling differentiated service level agreement (SLA) assurance as well as enhancing data security, preventative maintenance and simplifying visual management of operations.

Since the Autonomous Networks Project began in 2019, broad consensus has been reached on the "vision, framework, six Autonomous Networks Levels (ANL) and the core concepts (such as autonomous domain, closed-loops and intent driven interactions). We have continued to grow the number of service providers, vendors, and standards organizations (SDOs) involved in the work to enable more standardization and thus the promotion and rapid development of Autonomous Networks. We will continue this work and now enter a new phase of large-scale pilot verification and enterprise-wide deployments. The focus will remain on unifying technical standards, accelerating use case promotion, the evaluation and maturity of network transformation and to ensure all standards are continually evolving as the use cases become more established.

This whitepaper serves as an industry update to the previous TMF AN whitepapers (Rel1[6] and Rel2[7]) and summarizes the latest industry best practices, frameworks, methodologies and achievements of the Autonomous Networks Projects as well as that of other SDOs who are working in this space. The main updates which this paper will address includes the updates to the different levels of automation criteria, the implementation methodology, reference business cases & solutions as well as the latest industry trends and progress. It is designed to support CSPs and accelerate their deployments of Autonomous Networks.

Reference:

[1] *https://www.ericsson.com/en/5g/forms/5gforbusiness-2019-report*
[2] *https://www.gsma.com/mobileeconomy/wp-content/uploads/2020/03/GSMA_MobileEconomy2020_Global.pdf*
[3] *https://www.idc.com/getdoc.jsp?containerId=US45599219*
[4] *https://mediabriefcom/45-of-repetitive-work-tasks-will-be-automated-by-2022-idc/*
[5] *https://www.networkworld.com/article/3325397/*
[6] *https://www.tmforum.org/Autonomous Networks whitepaper (Rel 1)*
[7] *https://www.tmforum.org/Autonomous Networks whitepaper (Rel 2)*

2. Market Trends and the need for Autonomous Networks

2.1 INDUSTRY DEVELOPMENTS, MARKET OPPORTUNITIES AND CHALLENGES

As 5G begins to take hold and businesses continue to adapt and change to take advantage of the digital age fueled by a fast-growing digital economy, CSPs need to respond to stay relevant as well as monetize the opportunities offered by key enabling technologies such as 5G, cloud, and edge computing.

Enterprises have been investing heavily in digital technologies for years, to increase efficiencies and reduce costs while expanding their own businesses and enabling new business models. Many enterprise use cases not only require low latency, high reliability, and massive amounts of connectivity traffic, they also have the need for other functionalities which CSPs can provide such as advanced analytics, image recognition, and location-based services. To tap into this $700 billion of new industrial 5G and B2B2x revenues[8] CSPs need to deploy Autonomous Networks and they need to act fast particularly as these new business opportunities require more stringent and diversified requirements which adds additional complexity to network management and operations.

As well as helping CSPs address new business opportunities, Autonomous Networks can also help operators address many of their current challenges, such as improving customer experience, reducing costs and improving operating performance.

The deployment of Autonomous Networks, therefore, plays an increasingly important role in CSPs IT and network transformation strategies. Some key examples of the strategic use of Autonomous Networks are outlined in the table below.

CSPs clearly understand the importance of deploying Autonomous Networks as shown in a recent survey by TM Forum, where 95% of all respondents stated they had a clear approach to automation. 38% stated that they were taking a pragmatic approach to automating as many of their existing domains as possible, whereas 56% stated they had an integrated vision for automation within their organization[9]. This is a big shift from a year ago, when a TM Forum report on the use of AI for network automation found that 43%[10] of CSPs were concentrating their automation efforts simultaneously on the four key areas listed below but were not necessarily integrating them.

- Self-configuring, self-healing, self-optimizing and self-evolving network infrastructure
- Zero-wait, zero-touch, zero-trouble services
- The best possible user experience
- Service lifecycle automation and maximum utilization

It is therefore clear that CSPs are moving in the direction of a centralized enterprise-wide effort towards AN which is critical to successfully deliver enterprise-grade services.

CATEGORY	DESCRIPTION	EXAMPLE OF STRATEGIC USE OF AUTONOMOUS NETWORK
Experience Challenge	Need for consistent, seamless experience across all dimensions e.g., location, mobility, quality, service type	Intent extraction from user behavior, experience metrics, profile and real-time adjustments in configuration
Business Strategy Challenge	Market penetration strategy, expansion strategy, product strategy, pricing strategy	The agility provided through Autonomous Networks for making strategic decisions
Financial Challenge	Lowering infrastructure cost, lowering operational cost, optimal utilization	Autonomous controllers to respond to real time capacity needs and deployment
Operational Challenge	Fault avoidance, quality metrics, degradation avoidance, performance consistency	Predictive and cognitive operations management, intent driven decision making and implementation in network/system
Integration & Collaboration Challenge	Real time service discovery for innovative and evolving use cases. Enabling such service delivery through discovery and collaboration in partner's ecosystems	Service capability analysis for the use case, discovery, tailoring and deployment based on business needs
Environmental Challenge	Increasing energy needs, dense networks	Adaptive operational adjustments to reduce energy need based on business intent
Safety, Security & Privacy Challenge	Protecting privacy in data exchange among partners, national and social safety	Identifying and predicting needs for customer proprietary information (CPNI) in data exchange. Predicting hazardous communication & data exchange for national security.

Table 1: examples of strategic uses for Autonomous Networks

Reference:
[8] *https://www.ericsson.com/en/5g/forms/5gforbusiness-2019-report*
[9] *https://inform.tmforum.org/research-reports/autonomous-networks-business-and-operational-drivers/*
[10] *https://inform.tmforum.org/research-reports/network-automation-using-machine-learning-and-ai/*

Another interesting shift is that CSPs are beginning to think about Autonomous Networks from a business perspective more than just making the operation of their networks more accurate and efficient (although this remains important). The key drivers for Autonomous Networks today are improving the customer experience, delivering new services, reducing costs and time to market. The past year has seen some impressive AN deployments and results with the USA operator Windstream Communications reducing the cost of network monitoring and troubleshooting by more than 80% using automation. The company also fully automated its order-to-activation lifecycle management process and reduced overhead expenses by two-thirds. Windstream also claims to have automated 100% of its processes from subscriber registration to service activation. This programmable, autonomous domain architecture lets consumer and enterprise customers define, manage and prioritize their own services, such as SD-WAN, business broadband, managed security and Wi-Fi[11].

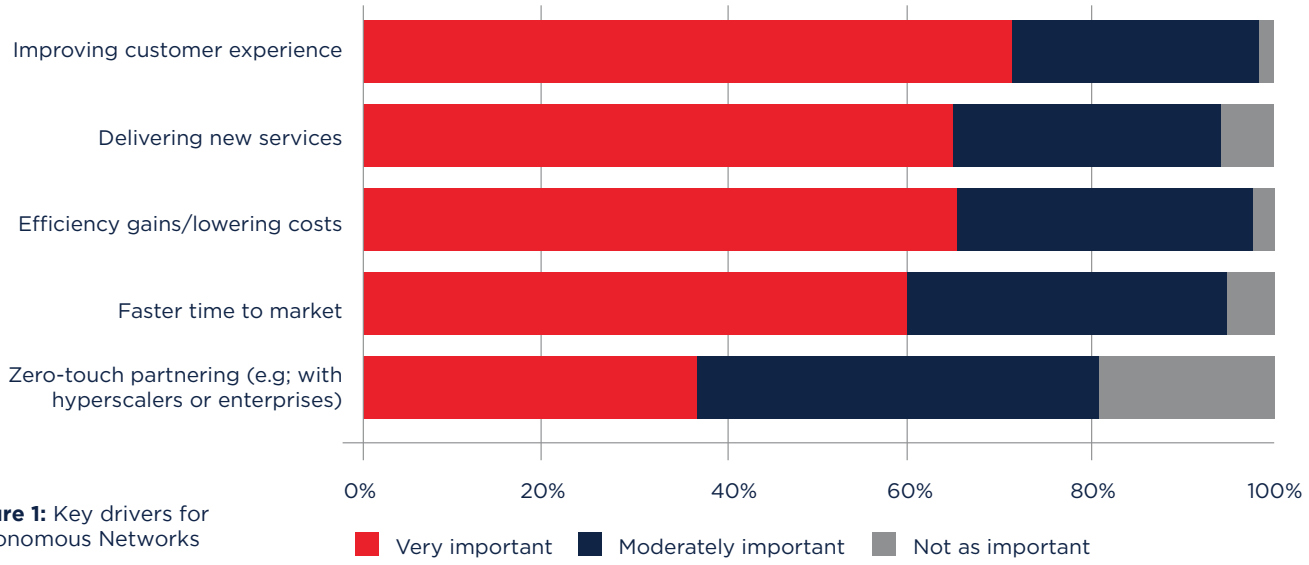

Figure 1: Key drivers for Autonomous Networks

In the Middle East Etisalat is focusing on automating its transport network domain. The company's CTO, Haitham Abdulrazzak said in November 2020, that the company's transport network is at the heart of all Autonomous Networks, and by reducing manual operations and automating order-to-service processes, Etisalat was able to reduce the time it takes to introduce new services by 70% to 90%[12].

The next section of this report will further address the market opportunities and the demands they place on CSPs networks.

2.1.1 MARKET OPPORTUNITIES AND DEMANDS PLACED ON CSPS NETWORKS

5G for enterprise services, cloud network convergence and sustainability (green policies such as energy reduction) have been the main focus for CSPs in recent years which have all placed new requirements on the network, ICT and O&M capabilities which we will explore in detail below.

Enterprise 5G: According to the Keystone Strategy report, the global enterprise 5G market will reach $60.2 billion by 2025[13]. As previously discussed, enterprise services pose higher requirements on networks performance such as connection density, rate, latency, reliability, and positioning accuracy. In addition, the following requirements are raised for network capabilities:

- One single network supports highly differentiated connection requirements.
- Real-time, online, one-stop, on-demand subscription and provisioning.
- End-to-end determined SLA.

Cloud-network synergy: Gartner predicts that the total expenditure of end-users on public cloud services worldwide will reach US$39.75 billion in 2022[14]. In the past two years, cloud-network convergence has become an important choice for enterprises to access the cloud. Vertical industries have the following requirements for cloud and network capability upgrade:

- **3D networking:** Quick and intelligent hybrid networking of networks and public and private clouds worldwide.
- **Cloud-network integration:** Provides customers with integrated supply, operations and services.
- **Intelligent scheduling:** The system intelligent scheduling meets differentiated requirements of customers such as convenience, quality, cost, and security.

Green economy: The EU estimates that the global ICT industry accounts for 5 - 9% of electricity consumption and over 2% of greenhouse gas emissions[15]. The activities will focus on site and DC energy conservation and emission reduction, covering operators and industries. Three capabilities are required to improve energy consumption: self-defining policies, self-configuration of parameters, and network-wide coordination for energy saving.

Reference:

[11] *https://inform.tmforum.org/research-reports/autonomous-networks-business-and-operational-drivers/*
[12] *https://www.intelligentcio.com/me/2020/11/26/etisalat-takes-major-step-towards-an-autonomous-network-with-blue-planet/*
[13] *https://www.thepaper.cn/newsDetail_forward_9800444*
[14] *https://www.gartner com/2021-04-21-gartner-forecasts-worldwide-public-cloud-end-user-spending-to-grow-23-percent-in-2021*
[15] *https://tele.ofweek.com/2021-05/ART-8320500-8500-30501082.html*

2.1.2. IMPROVEMENT IN SERVICE PROVIDER AND MARKET AWARENESS

The progress of the TM Forum AN project shows that more operators and vendors are jointly carrying out application innovation and pilot verification related to Autonomous Networks, focusing on technologies, systems, processes, organizations and talent.

- **Technology:** technologies and concepts such as Segment Routing V6 (SRv6), flow-based detection, and full-stack AI are introduced to simplify network complexity, utilize intelligence capabilities, as well as reducing network integration and O&M complexity.Az
- **Systems:** network middle-platforms are built to explore the value of operation data and evolve to proactive and preventive maintenance.
- **Process:** RPA technology and DevOps are introduced to try to implement integrated business operations across the entire life cycle.
- **Organization:** adapting to digital business development and cloud-network integration operations, accelerating the adjustment of operation organizations, and strengthening the capability of supporting business response.
- **Talent:** the role changes and technology improvement of traditional O&M personnel are accelerated, and man-machine collaborative O&M is enhanced.

2.2 CHALLENGES TO LARGE-SCALE AUTONOMOUS NETWORK DEPLOYMENTS

Since the release of the first Autonomous Networks whitepaper in 2019, the focus has shifted from the "why" and "what" of Autonomous Networks to the "how", including how and where do we get started? How do we evaluate the levels of automation, how do we address the new skills needed for their operation and understanding what is the evolutionary path to achieve full-scale automation? The following six key points continue to remain a barrier that needs to be addressed before large-scale autonomous network deployments can take place.

1

How to and where to start building Autonomous Networks?

Do we start with single-domain autonomy then cross-domain collaboration? Or the implementation of specific services for business agility? Do we start with OSS reconstruction? Or do we start with network upgrade? Finding the most appropriate entry point to promote Autonomous Networks is a common challenge for the industry.

2

How to evaluate the value of implemented AN?

What business value can L2 network autonomy bring? How much does it contribute to revenue generation, cost reduction and efficiency improvement? Those challenges are one of the keys to influences of operator's decision whether to continue to promote Autonomous Networks.

3

How can promote the verified innovations?

Different sub-networks are different in terms of network status, architecture, vendors, organization, and O&M process. Many practical problems need to be resolved, such as architecture mismatch, unifying specifications and technologies, excessive customization and development, and unadaptable organizational processes.

4

How to collaborate for business close-loop?

Autonomous Networks require multi-party collaboration between network and NE, OSS and BSS to streamline the entire process. The standardization of network automation is characterized by fragmented and low-efficiency collaboration. Service providers are always trying to overcome the difficulty of implementing a large user (commercial) closed loop.

5

How to deploy the super-intelligent system of Autonomous Networks?

The Autonomous Networks evolution is essentially a super-complex system to a super-intelligent system. What is the target state of the Autonomous Networks super-intelligent system? Is the evolution towards a super-intelligent brain that commands the entire network? Or is it a distributed cluster of highly efficient and collaborative brains?

6

How to transform organization and talent skills?

It is difficult for the existing operations system to adapt to the Autonomous Networks O&M mode. How to transform the organization architecture, optimize the process system, change the roles and improve the skills of talent? It is another big topic for Autonomous Networks and CSPs.

In addition to the above six questions that need answering there are other challenges that CSPs will face as they migrate away from legacy systems. Indeed, as CSPs networks continue to transform, new issues and challenges will arise that need to be addressed as well as relooking at existing challenges around business models and the business case which seldom go away.

The main challenges still faced by CSPs in the modernization and automation of their networks are the complexity, cost and feasibility across the existing large footprint of legacy networks which are still generating the larger portion of current revenues. While CSPs are geared up to invest more money to upscale their networks, they need to clearly understand the business case and how they can maximise the return on investment. At present, there are only a handful of proven use cases for which telcos and enterprises can detail, implement, and monetize to their full potential. Another factor, in this era of new services and platforms, is the return on investment is being shared with new-age players like hyperscalers, over-the-top players (OTTs) etc. Multiple players are onboarding the same business model based on their own strengths, vision and objectives, and in some cases are using telcos just as a connectivity pipe. OTTs are creating multiple solutions around use cases like security and smart solutions with multiple hyperscalers and CSP combinations.

Additionally, OTTs are coming up with their business models around autonomous ICT services using multiple original equipment manufacturers (OEMs), systems integrators (SIs), Hyperscalers and CSPs.

One important aspect to note is while CSPs, OEMs, OTTs, and hyperscalers are working to conceptualise and implement the autonomous network architecture, there is also a need to consider the transition duration and scenarios from legacy networks to Autonomous Networks. Not every element/domain of a network is capable of implementing key principles and requirements of the autonomous network concept (i.e., Zero-X experience, Self-X capabilities), sometimes just the physical nature of the network element or device leading to scaling, availability and reliability limitations. We need to understand how the legacy world and new world can be connected together and work seamlessly to achieve the business outcomes that CSPs are looking for.

On the technology front, there are many new concepts being evolved at the proof-of-concept (PoC) level such as declarative modelling, intent driven, dynamic orchestration but their at-scale use case realization and technology evolution is still pending. AI/ML Frameworks are still limited to labs and proof-of-concepts. The time and effort required by domain SMEs are huge and CSPs have not seen enough return on investment yet. OEMs come up with specific solutions to solve a specific problem or requirements given by CSPs and these solutions are not generic in nature which can be implemented cross-domain.

On the standardization front there is still a lot of work required to evolve from abstraction to specific use case realization covering all network domains, cross-domains, elements, OEMs etc. There is work required for the adoption and governance of these standards in the B2B2X ecosystem across CSPs, OEMs, OTTs, and hyperscalers. This is critical to deliver B2B2X use cases with faster speed, larger scale and value to other industry verticals.

3. Vision and Framework of Autonomous Networks

This chapter summarizes the baseline of Autonomous Networks, from the vision to the overall framework and key capabilities, which are based on TM Forum publications including IG1218[16] "Autonomous Networks – Business requirements & framework" as well as other publications (list of TMF publications on Autonomous Networks[17]).

3.1 VISION

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

3.2 AUTONOMOUS NETWORKS FRAMEWORK AND CAPABILITIES

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

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

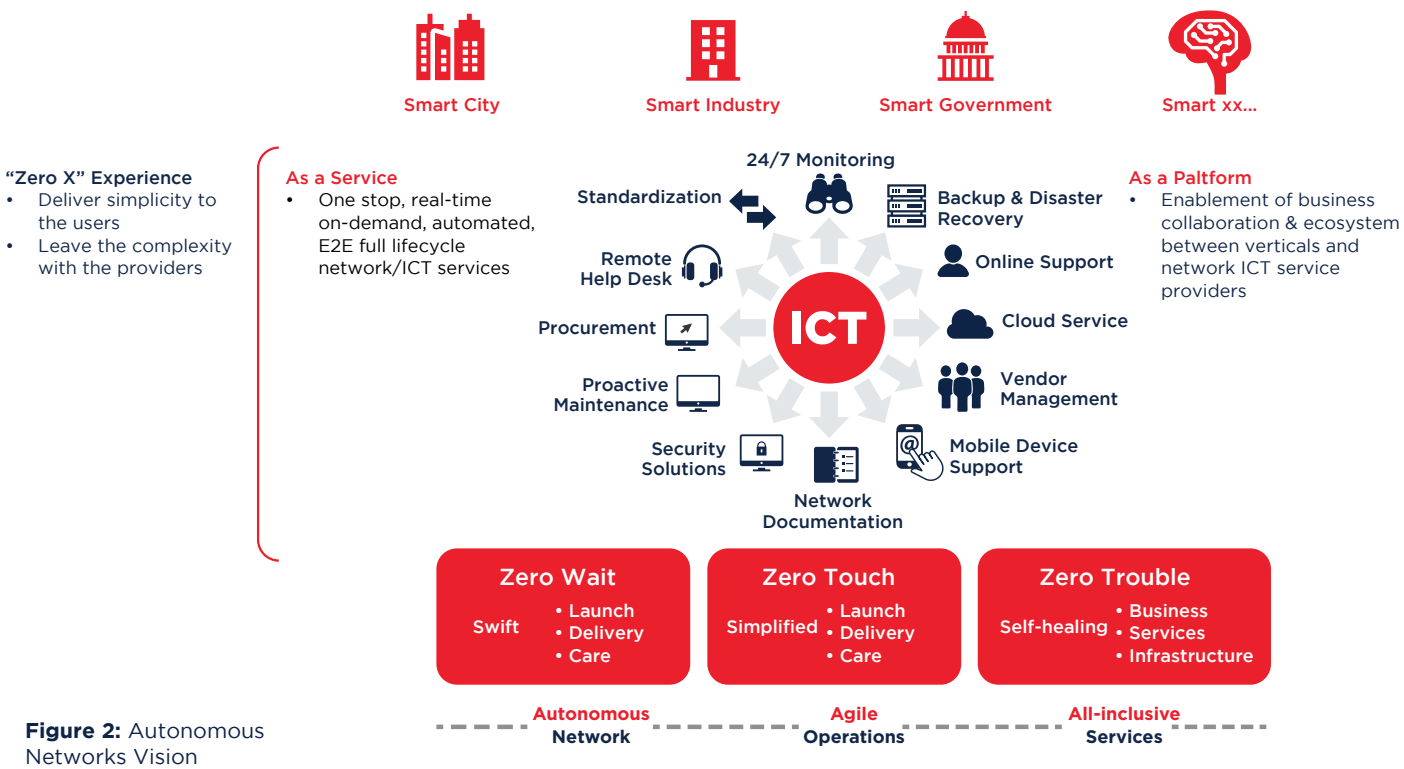

Figure 2: Autonomous Networks Vision

Reference:

[16] *https://www.tmforum.org/resources/how-to-guide/ig1218-autonomous-networks-business-requirements-and-architecture-v2-0-0/*

[17] *https://www.tmforum.org/resources/toolkit/autonomous-networks-toolkit/*

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

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

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

Figure 3 illustrates the rationale of correlation and interaction among the closed loops of different layers. The user closed loop is the main thread to streamline the business/service/resource closed loops while each of the business/service/ resource closed loops addresses the interaction between adjacent layers. The interaction between adjacent layers is simple, business driven and technology/implementation independent, i.e., communicating and fulfilling the intents (business/service/ resource) rather than technology-prone commands based on the intent mechanisms and interfaces. The different intents are used for the interactions of different layers, i.e., business intent, service intent and resource intent.

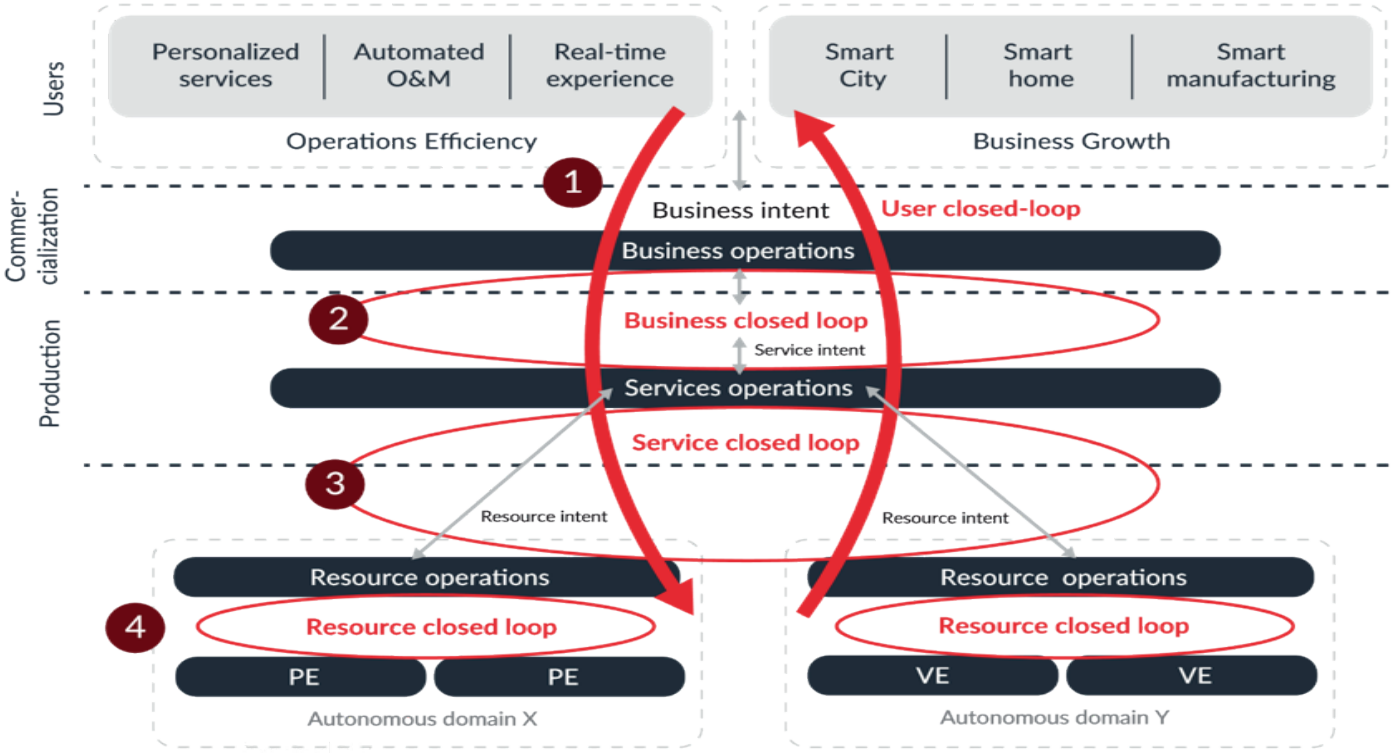

Figure 3: Autonomous Networks framework

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3.2.1 AUTONOMOUS NETWORKS LEVELS

To fulfill and measure customer experience and SLA, the Autonomous Networks Levels (ANL) are defined to guide network and service automation and intelligence, evaluate the value and benefits of Autonomous Networks services, and guide the intelligent upgrade of CSP and vendors.

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

Table 2: Autonomous Networks Levels (ANL)

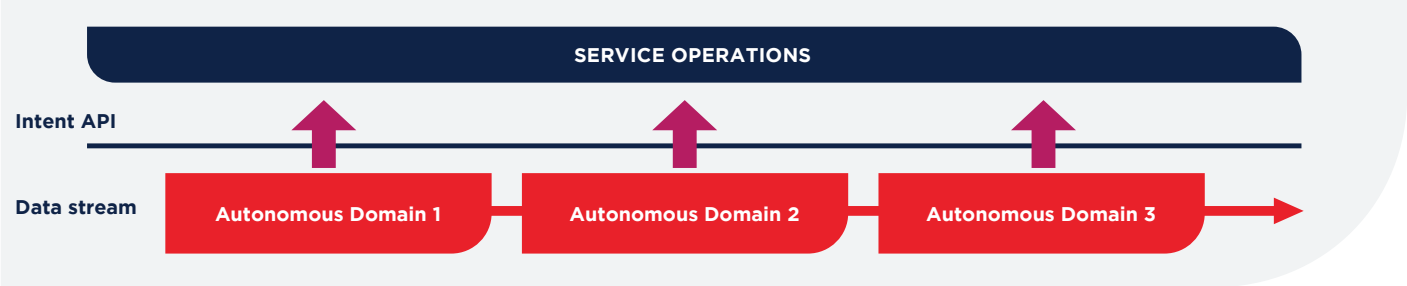
- **LEVEL 0 - manual management:** The system delivers assisted monitoring capabilities, which means all dynamic tasks have to be executed manually.
- **LEVEL 1 - assisted management:** The system executes a certain repetitive sub-task based on pre-configured to increase execution efficiency.
- **LEVEL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

The technical work of ANL evaluation methodology is published in IG1252[18], which describes Autonomous Networks Level evaluation approach and operation flows, tasks evaluation criteria, scoring method etc.

3.2.2 AUTONOMOUS DOMAINS

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

Figure 4: Example of Principles of autonomous domains



Reference:
[18] *https://www.tmforum.org/resources/standard/ig1252-autonomous-network-levels-evaluation-methodology-v1-1-0/*

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

The basic principles of the operations of autonomous domains are:

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

The technical work of AN reference architecture is published in IG1251[19]

3.2.3 INTENT DRIVEN INTERACTIONS

Intent is introduced in TM Forum Autonomous Networks project as a way to express users' requirements, goals and constraints, and then interact with those with various domains in a way that allows a system to adapt its operation accordingly. In the lower and medium levels of ANL (e.g. 0~3), user's requirements, goal and constraints can be reached using policy driven operation and requirements carried over existing interfaces. Systems with higher level of ANL (e.g. 4~5) will be able to adapt their own behavior with reduced need of human adaptation through intent driven interaction. This capability would translate into business flexibility by introducing new and customized service offers without human intervention.

The high-level descriptions on intent are defined in IG1281[20] and the technical work published in the IG1253[21] set of documents including; Responsibilities, Intent Expression Model Federation Lifecycle Interface and Interaction, aims at providing the basis for the use at higher levels of ANL (e.g. 4~5) while allowing the subsequent introduction of the respective capabilities.

3.2.4 SELF-X OPERATING CAPABILITIES

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

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

Table 3. Self-Operating (Self-X) capabilities requirements

Reference:
[19] *https://www.tmforum.org/resources/standard/ig1251-autonomous-networks-reference-architecture-v1-0-0/*
[20] *https://www.tmforum.org/resources/standard/ig1218-autonomous-networks-business-requirements-and-architecture-v2-0-0/*
[21] *https://www.tmforum.org/resources/how-to-guide/ig1253-intent-in-autonomous-networks-v1-0-0/*

4. Realizing Autonomous Networks

This chapter addresses the realization of Autonomous Networks, from the overall approach to practical implementations on the usage of Autonomous Networks to help business success.

4.1 AUTONOMOUS NETWORKS REALIZATION APPROACH

Autonomous Networks realization is a systematic project through a continuous iteration process with the following key elements:

The key elements: 3+1

- THREE aspects: top-level design, capability development, and Value measurement metrics,

- ONE evolution loop, and

- Complementary enhancements

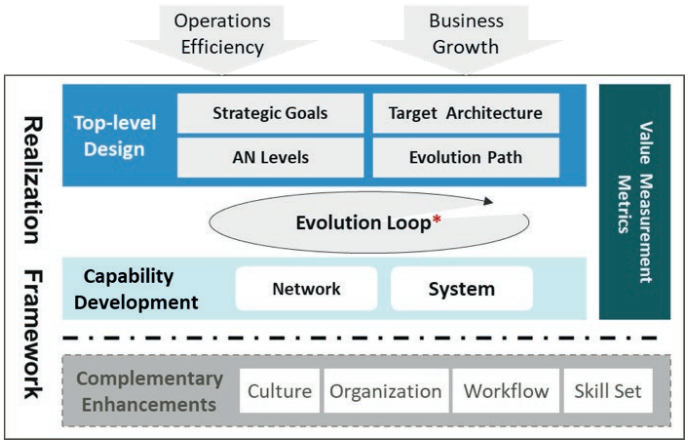


Figure 5: Autonomous Network Realization approach — Framework

THREE aspects:

1) Top-level design: it undertakes two AN business objectives of "Operations efficiency" and "Business growth".

Based on the assessment of AN levels, output the key contents of the AN Top-level design, providing "strategic goals, targeted architecture and evolution path".

In the actual production network, the resource operation layer of the architecture, may be further decomposed into two more sub layers; the network management layer and the network element management layer. This presents the resource layer as a simplified interface towards the upper layer (service operation layer) and it can also shield the complexity of cross-vendor or cross-domain resource management.

2) Capability Development: it is the core of autonomous networks realization, include the network capability development and system capability development.

- **Network Capability:** to improve the network/network equipment automation and intelligence through protocol optimization, capability improvement, and architecture reconstruction.
- **System Capability:** to build systems/tools to improve O&M automation and intelligence capabilities, including planning, engineering management, service support, O&M support, customer experience management, and resource management, via network platforms such as NaaS or network middle platforms, and AI and big data technologies.

3) Value measurement metrics: are a "yardstick" to measure the effect of autonomous network capability improvement on AN business objectives and ensures that the capability improvement direction meets the requirements of business value and development of the enterprise.

ONE evolution loops:

Provides an iterative path where the quantitative evaluation works as an indicator to measure the effectiveness of the realization of autonomous network system, which in turn, triggers its further development. As shown in figure 6, the autonomous and intelligent capabilities of network operation and maintenance are continuously improved, through cyclic iterations composed of the following three steps:

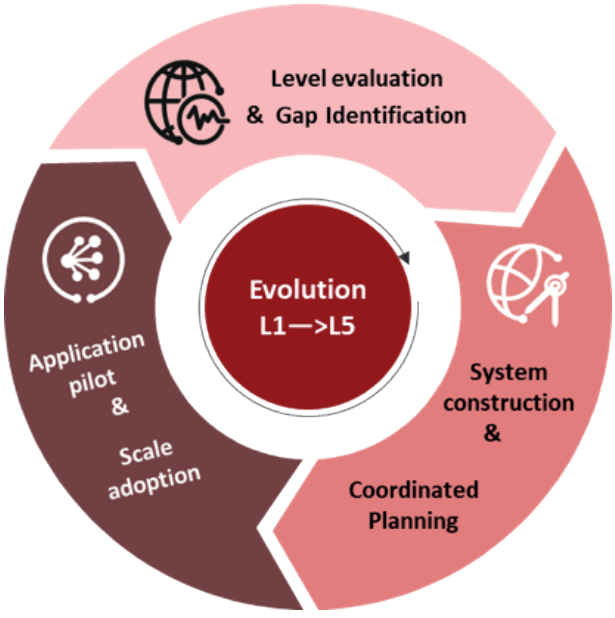


Figure 6: AN Realization Approach—Evolution Loop

STEP 1

Level Evaluation and Shortcoming Identification: Based on the quantitative evaluation of scenario-based autonomous capability for O&M processes, common problems and shortcoming differences could be identified, targeted measures and deployment plans could be developed.

STEP 2

System Realization and Coordinated Planning: In terms of network management systems, coordinated plans could be made to accelerate the systematic renewal in heterogeneous networks. In terms of network equipment, general function specifications in all domains could be further detailed to guide network equipment suppliers to achieve higher equipment autonomy.

STEP 3

Application Pilot and Scale Adoption: Advanced automation and intelligent technologies are actively introduced in collaboration with network equipment suppliers and network management system integrators. Pilots are carried out in selected regions before rolling out in scale. And then the loop enters the secondary evaluation to improve the autonomy capability iteratively.

Complementary Enhancements:

The workflow, organizational structure, staff skill sets and culture for network O&M would also adapt to the deployment of the autonomous networks.

4.2 AUTONOMOUS NETWORKS REFERENCE BUSINESS SOLUTIONS

This section focuses on a number of use cases that have implemented the Autonomous Networks framework. They illustrate the usage of AN capabilities and mechanisms with related business outcomes and across the lifecycle. Additional cases could be found in IG1218A[22].

The selection of reference business solutions is based on a combination of technical feasibility, business orientation, capability promotion and value priority. These cases systematically demonstrate the role of AN in various business scenarios of network operations.

4.2.1 ENABLING VERTICAL INDUSTRIES

Use Case: Autonomous Networks Hyper Loops enabling Smart-X industries - Smart Agriculture

New, disruptive and innovative digital services that are completely autonomous and designed for zero-touch and zero-fault operations could revolutionize the future of how we do business and interact with society. These new digital services offer a great opportunity for service providers to increase their revenue through new services they can offer to their customers. To be able to offer many of these digital services such as smart industry, cities or health, CSPs need to automate their operations and gain efficiencies so that they can be delivered at a cost point the market requires.

Autonomous Networks with zero-wait, zero-touch and zero-trouble capabilities empower CSPs to monetize & support the diverse set of vertical use case requirements. Once Autonomous Networks are in place service providers, B2C customers, digital service providers (DSPs) and telecom service providers will benefit from better, seamless experiences and improved operational efficiencies. In addition, the end-to-end lifecycle complexity will be hidden away from the user and self-assurance will be inbuilt.

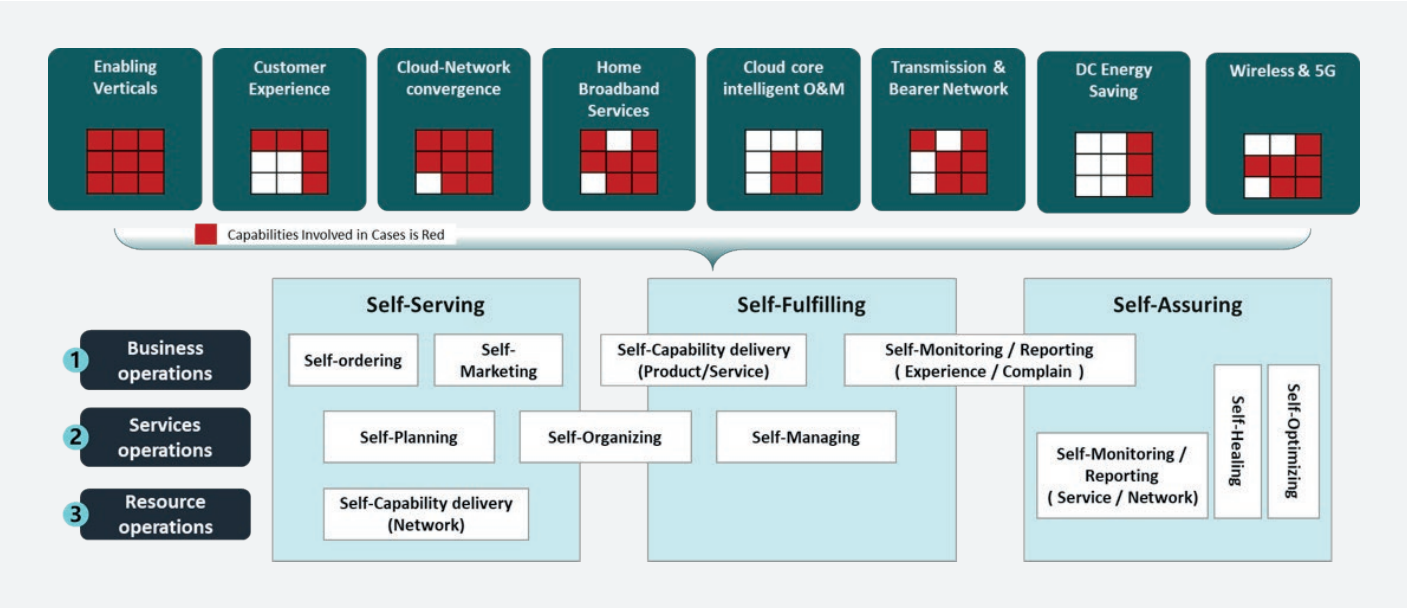


Figure 7: Example usage of AN capabilities in reference business solutions

Reference:
[22] *https://www.tmforum.org/resources/how-to-guide/ig1218a-autonomous-networks-case-studies-v1-0-0/*

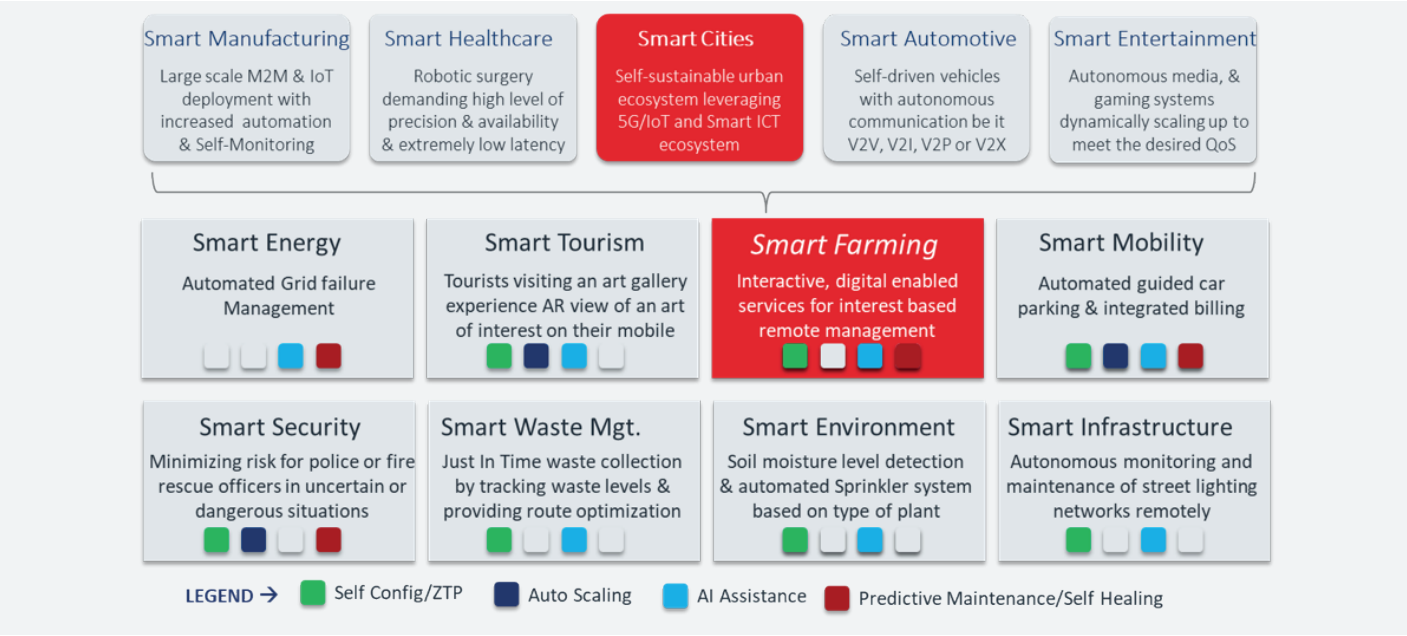


Figure 8: Examples of vertical use cases that benefit from Autonomous Networks

From the vertical examples listed above, smart agriculture is a paradigmatic use case where Autonomous Networks are key for CSPs to deploy smart agriculture solutions and services that can help farmers become more efficient and increase their profitability by managing crops and livestock in real-time. These solutions will require the connection of many IoT devices spread over large and complex areas gathering lots of information such as tractor location, weather forecasts and soil moisture levels.

A good example of smart agriculture being currently explored by one CSP is how they can improve rice planting with autonomous drones, to optimize seed use, avoid planting during unfavorable weather as well as improve worker efficiency. The drones will be connected to a wireless access network and collect lots of data from sensors and sources such as weather reports and then collate all of this data as well as stream back live video feeds to the farmers via an app on their smartphone. Machine learning and AI will use all of this information to recommend the best time to plant the seeds as well as to pick out the most favorable locations to increase yield and reduce the risk of disease by spotting the disease signs early and recommending immediate actions.

Solution Architecture powering Autonomous Networks

To achieve Autonomous Networks for vertical use cases (as described above), maturity is required across the Resource Loop, Service Loop, Business Loop and User Loop. The simplified architecture to achieve this maturity is as shown below

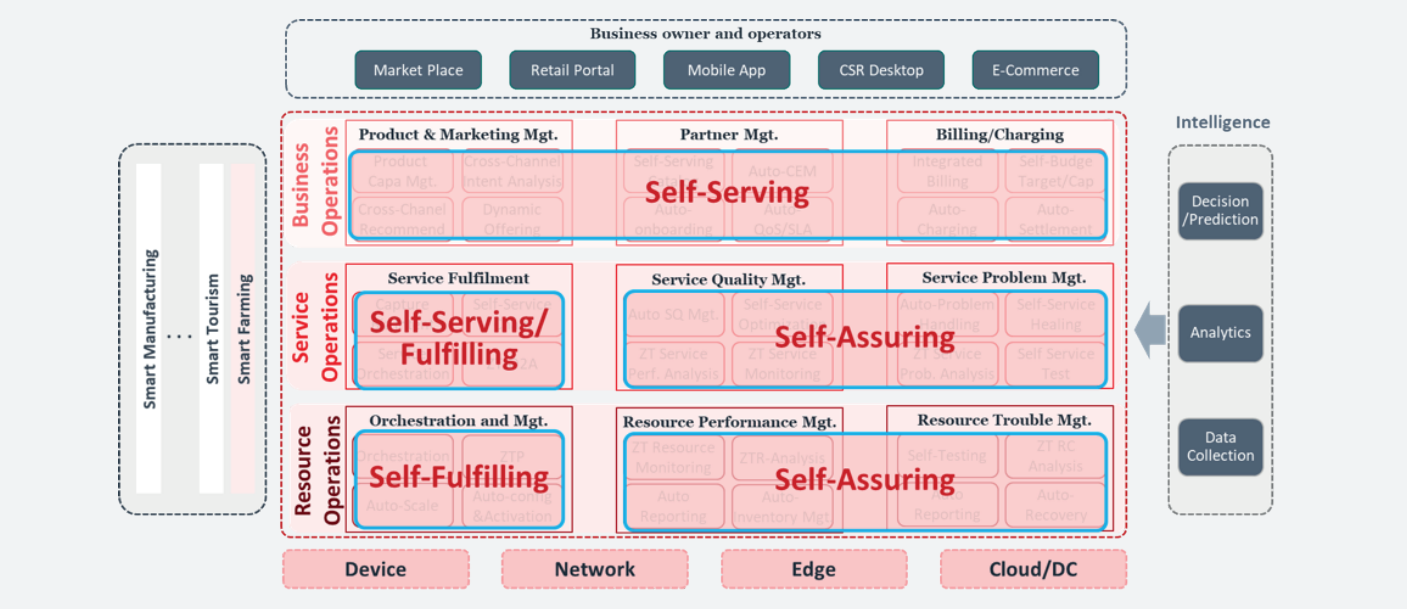


Figure 9: Simplified Solution architecture of Autonomous Networks

Business Operations (BO) – This layer presents the Business rules and Business Intent for enabling Self-planning & Self-marketing capabilities to facilitate zero-friction products towards their end-users and business partners. It defines the master product catalog, which will drive the business intent decomposition into service intent and to centrally manage the autonomous order management process i.e., Self-ordering, including autonomous order-2-activation.

Service Operations (SO) – This layer represents autonomous service life cycle management comprising of Self-ordering, Self-organizing and Self-managing capabilities in addition to Self-Assuring. It captures business intent and provides autonomous service orchestration, self-service assurance, etc. to govern the accurate translation of service intents to resource intents.

Resource Operations (RO) - This layer represents autonomous resource management functions to Self-organize, Self-manage and Self-Assure the physical, virtual and logical resources in order to fulfill the resource intents and address the customer requirements. RO defines and governs the resource instantiation, configuration, resource life cycle management (LCM) and performance metrics.

CSPs can monetize and support Smart-X industries like – Smart Cities (Smart Tourism, Smart Farming, Smart Energy), Smart Manufacturing, Smart Healthcare by leveraging the above vertical/domain agnostic technical architecture.

CSP enabling Smart Farming

CSPs can monetize the Smart Farming use case to empower farmers with cost & time efficient management of farms leveraging Zero-X experience based on the AN business and technical architecture across the layers including the edge at Turtlebot/Drone with Video capability, edge container, virtualization, automated to autonomous, AI & insights analytics, 5G.

The reference architecture to achieve AN for Smart Farming is depicted below:

This Smart Farming use case described above aims to demonstrate autonomous behavior across all 4 loops as described in chapter three (Resource, Service, Business & User) with 5G network as the connectivity backbone and video analytics capabilities at the edge. Autonomous self-service assurance is depicted below as an example of usage of Autonomous Networks capabilities, the detailed information can be found at TMF catalyst project - Autonomous Networks Hyper Loops (ANHL[23]) and related whitepaper[24].

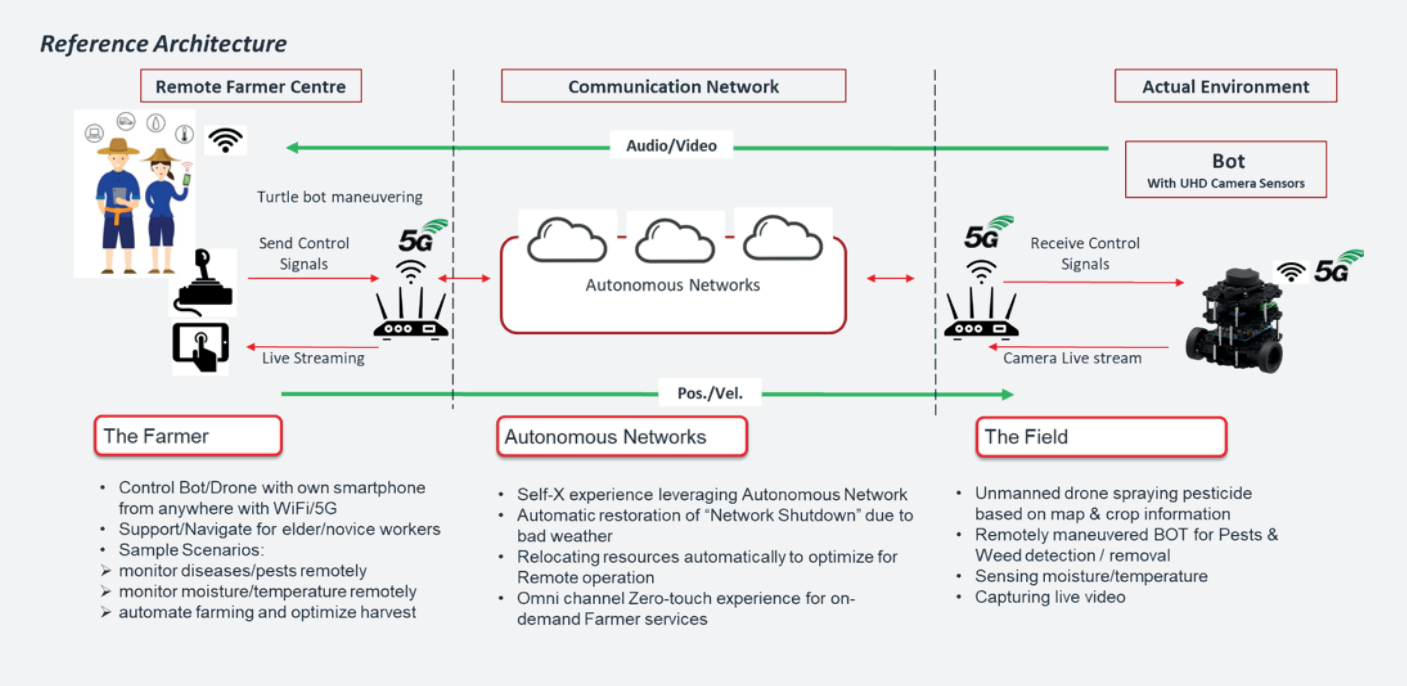


Figure 10: Smart farming use case

Reference:
[23] *Autonomous networks hyperloops - Enabling self-X digital services for smart-X verticals Phase II - TM Forum*
[24] *Whitepaper_AN_Enabling_Self_X_Digital_Services_for_Smart_X_Verticals.pdf (tmforum.org)*

Autonomous Self-Service Assurance

One of the key elements of providing seamless autonomous services to farmers is zero trouble service assurance. It's a leapfrog transformation in the quality of service from manual and reactive troubleshooting to resolve workflows to autonomous predictive/preventive self-optimizing and self-healing networks. Autonomous self-service assurance workflow aims at zero impact to services extended to farmers and optimizing the total cost of ownership (TCO) for the service provider in managing the promise of zero-trouble/zero-impact services.

The autonomous workflow depicted below aims at zero-friction services to farmers. The key elements of autonomous service assurance workflow are[25]:

- Service & Resource usage monitoring (QoS/QoE/SLA)
- Autonomous Service instance (PM & FM) Analysis
- Zero-touch service incident reporting and LCM
- Autonomous Root cause analysis
- Dynamic Resource Scale In/Out & Optimization
- Closed-loop remediation with Intent
- Automated temporary/permanent fix

Self-Monitoring – Zero Touch Service/Resource Monitoring: Leverages Service/Resource performance and availability Management, Pro-active service/resource monitoring capabilities to monitor the services against defined Quality of Service & SLA and predictive reporting of the service/resource status for preventive actions.

Self-Monitoring/Reporting – QoS/SLA Management: Leverages Self-Monitoring capabilities to manage the service & resources of the network against defined SLA and report the service/network resource status through automated incident management & its lifecycle management (LCM) using intent driven interaction, which will be handled by resource operations layer and service operations layer accordingly.

Self-Optimizing/Healing – Service Quality/Problem Management: Leverages automated hidden risk prediction & automated fault identification capabilities to autonomously manage the Service quality, Service/Network problem.

Self-Optimizing – Zero Touch Service Performance Analysis: Based on the service performance trend and risk predictions, the system leverages AI/ML capabilities to assess the efficiency of resource/service allocation and to autonomously suggest preventive optimization actions.

Self-Healing – Zero Touch Service Alarm Event Analysis: Based on the generated incidents and the predicted service instance problems, the system leverages AI/ML capabilities to predict/depict resource impacts, service impacts and autonomously arrive at Root Cause Analysis to enable further actions.

Self-Optimizing/Healing – Closed Loop Remediation: Based on the Service Performance Analysis and/or Service Alarm Event analysis, the system leverages Self-Optimizing and Self-Healing capabilities with Self-testing to relocate or assign resources (e.g. Scale-in or Scale-out) autonomously to provide intent-driven service assurance.

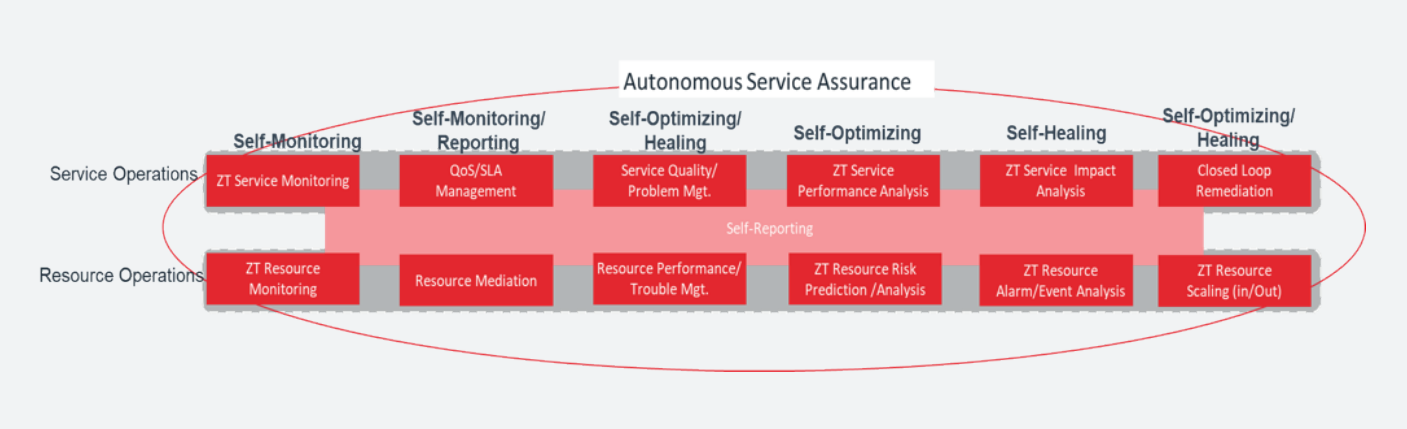


Figure 11: Autonomous Service Assurance workflow

Reference:

[25] *Assumption: Service operations layer interacts with resource operations layer based on Resource Intent which is decomposed from Business & Service Intent*

4.2.2 CUSTOMER EXPERIENCE

HKT use case: Customer Experience Intelligence (CEI+) - At the very center of the AN closed loop

The use case described here demonstrates how Autonomous Networks (AN) can help improve the customer experience. The developed solution is called CEI+. It can understand 'Users' and can set 'Commercialization' and 'Production' to create the right output.

1. CEI+ supporting the 4 closed-loops

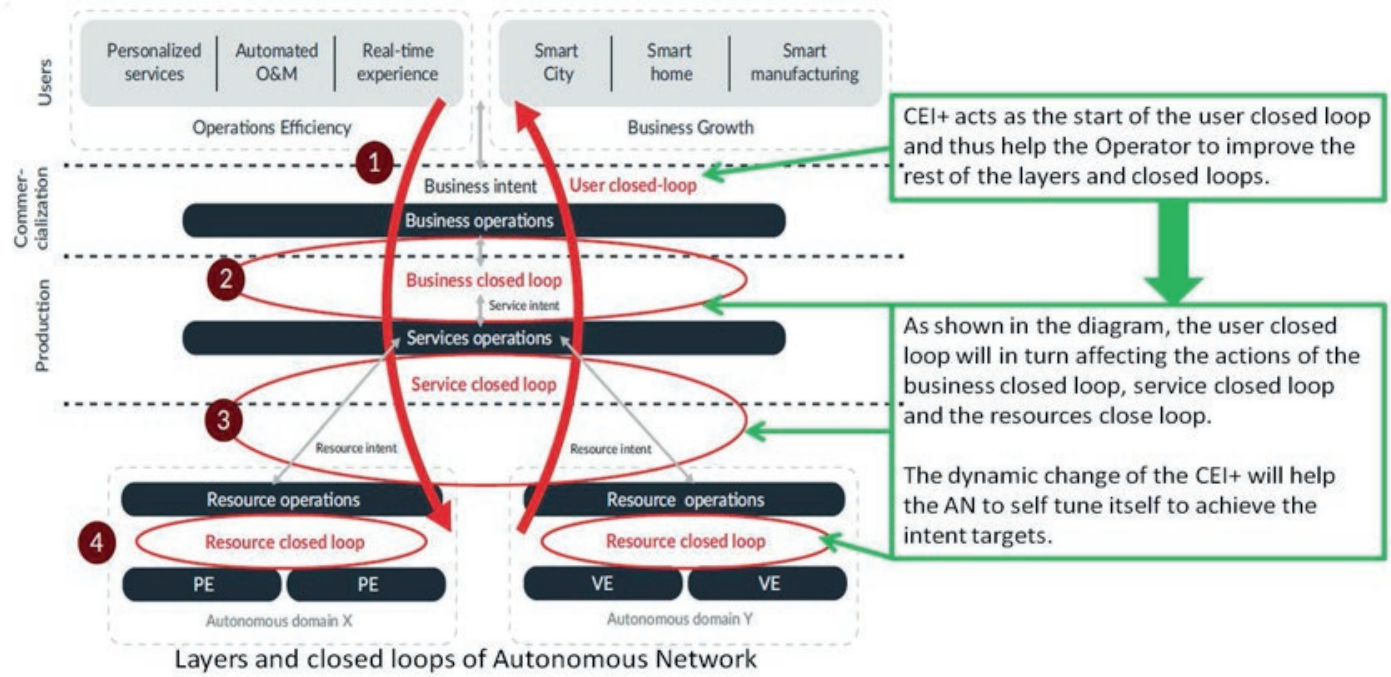


Figure 12: CEI+ providing closed-loop support

From the Autonomous Network Framework perspective, figure 12 shows how CEI+ is providing vital support to the 4 closed loops.

CEI+ is able to provide near real-time customer experience scores of all customers as a whole, target groups and even individual scores in their interaction with business and services. CEI+ acts at the start of the user close loop and helps to improve the Business Operations, Service Operations and in turn, maximize the Resources Operations. The user closed loop is the main thread to streamline and drive the E2E lifecycle of services.

Two cases ('Lower CEI+' for 5G network extension and 'Higher CEI+' for 5G up-selling) are described below:

- For Lower CEI+ for 5G network extension: at the start of the user closed-loop, VIP and target groups with low CE scores are identified and root causes are provided. Relevant improvement actions are then considered at the business, service and resources operation layers. One example is that a customer having low CEI due to changing of a residential site that has no 5G coverage, although the customer subscribed to a 5G plan.
- From the perspective of business operations, the list of customers out of the 5G range but having a 5G plan will trigger actions to evaluate the justification to extend 5G coverage to that area from the service operation layer and resources operation layer.
- The service operations layer will check on customer subscription plans and confirm their entitlement. It will also notify the resources operations layer to prepare the necessary 5G coverage.
- Resources Operations layer gained information from the service closed-loop and will prepare the 5G coverage with enough capacity in that region. In case the respective autonomous domain is not able to fulfill the requirements at a specific time, it will provide notifications as well as alternative solutions that can be considered by business and service operations (i.e., grant extra data usage to customers).
- After implementing the necessary improvements, the customer CE scores are being monitored by the CEI+ solution. The output of the new CE scores will again feed to the user closed-loop and help all the other closed loops to align to improve the customer experience. Such process flow achieved the capabilities of self-fulfilling and self-assuring.
- For Higher CEI for 5G up-selling: user closed loop will be involved in the automated marketing activities on personalized promotion to achieve self-serving. One example is to promote high CEI customers that are using 4G to upgrade to 5G.
- The customer list (promote 4G customers to 5G) will first check the Resource Operations Layer to see if the customers are available to access a 5G service.
- Information from the Resource Operations Layer is fed into the Service Operations Layer for understanding.
- If any extra investment is required, the Service Operations Layer will pass information to the Business Operation Layers for decision making. Business decisions will then pass back to the Service Operations Layer. If no extra investment is needed the business operations can start the campaign.

As a summary, CEI+ is vital in the implementation of fully Autonomous Networks in that it is a critical part to help the operator to become more customer-centric. It also helps different functional units to reach their business goals by providing them with:

- Smart caring of customer experience will achieve the business intent
- Solid insights for all closed loops to act, make decisions and perform analysis
- Critical information that can speed up their execution of task and operations

2. Business benefits and outcomes

The Autonomous Network case study above was implemented by the Asian operator HKT. HKT was able to achieve operational efficiency with tangible business outcomes in 1H 2021 using the solution. The number of 5G users continues to show positive growth and is on target to achieve 20% growth by the end of 2021 (5G launched in Apr 2020). HKT has also been able to further reduce its churn rate (from the year 2020 to 1H of 2021: from 0.9% per month to 0.7% per month).

With the Solution, Telecom Argentina (TA) is able to have one unified language talking about user experience for network, market and customer experience. The autonomous CEI Monitoring, Demarcation and Root Cause solution enables TA to improve their operational efficiency, combined with establishing a customer-centric culture, organization with integrated processes.

Another successful operator in the Middle East is stc which started using the Customer Experience Index (CEI) then upgraded to CEI+; which enabled them to customize the user experience per customer towards 5G and 4G subscribers. CEI+ is a pivot for stc's strategy towards the 'new Normal'.

3. Next Step/Forward Looking

CEI+ currently focuses on operational efficiency in the area of 'Autonomous Networks Operations' by building a platform-based and flexible production operations. The CEI+ solution helped HKT to reach level 4 in the area of user closed loops.

In the future, HKT will target CEI+ to support 'Autonomous digital enabling services' in vertical industries. (e.g. in HKT's medical service platform): HKT has already developed a new medical platform and will apply CEI+ to support the platform to understand customer experience. China Mobile (An Hui province) is also doing research in using CEI+ into their operations to improve user closed loop.

4.2.3 CLOUD-NETWORK CONVERGENCE

Since 2020, global enterprises have accelerated their business migration to the cloud, and gradually moved their key information systems and core production systems to the cloud.

Cloud-network convergence is a network architecture reform and network capability upgrade which is driven by business requirements and technological innovation. It is a concept that operators put forward which aims to take advantage of their infrastructure such as "wide area network, large-scale DC, and territorial services" and provide end customers with cloud-network convergent business and services.

BUSINESS SCENARIOS		CUSTOMER EXPECTATION	CAUSE ANALYSIS OF THE GAP
Smart operation of cloud-network convergence	**Service provisioning**	• Access to the cloud anytime, anywhere. One network into the multi-cloud • One-stop on-demand ordering and change of cloud-network business; instant activation	• Cloud and Network service is provisioned separately for one customer order • Cross provincial service is provisioned segment by segment. Lack of cross service, cross domain orchestration and collaboration • Work order scheduling and business configuration activation has a lot of manual participation
	Quality management	• Differentiated SLA • End-to-end deterministic SLA can be guaranteed	• The integration of SLAs of all segments of the network does not equal the end-to-end SLA • The end-to-end SLA monitoring and predicting autonomy is weak
	Fault management	• Zero interruption of customer-side business • Fast fault repair	• The mapping relationship between networks and services is complex, and cloud special lines require multi-segment pipeline splicing to achieve end-to-end service connection • Insufficient business/fault self-repair capabilities, interprofessional fault root cause analysis is still a problem
Cloud Private line		• Online self-service • Fast TTM of new service • Guaranteed differentiated SLA • Zero-X operational experience	• Complex protocol, inefficient manual cloud and network configurations • No support of network slicing • Inconsistent and unpredictable service experience • Inefficient fault location, prediction and analysis

Table 4: Overview of challenges and expectations of cloud-network convergence

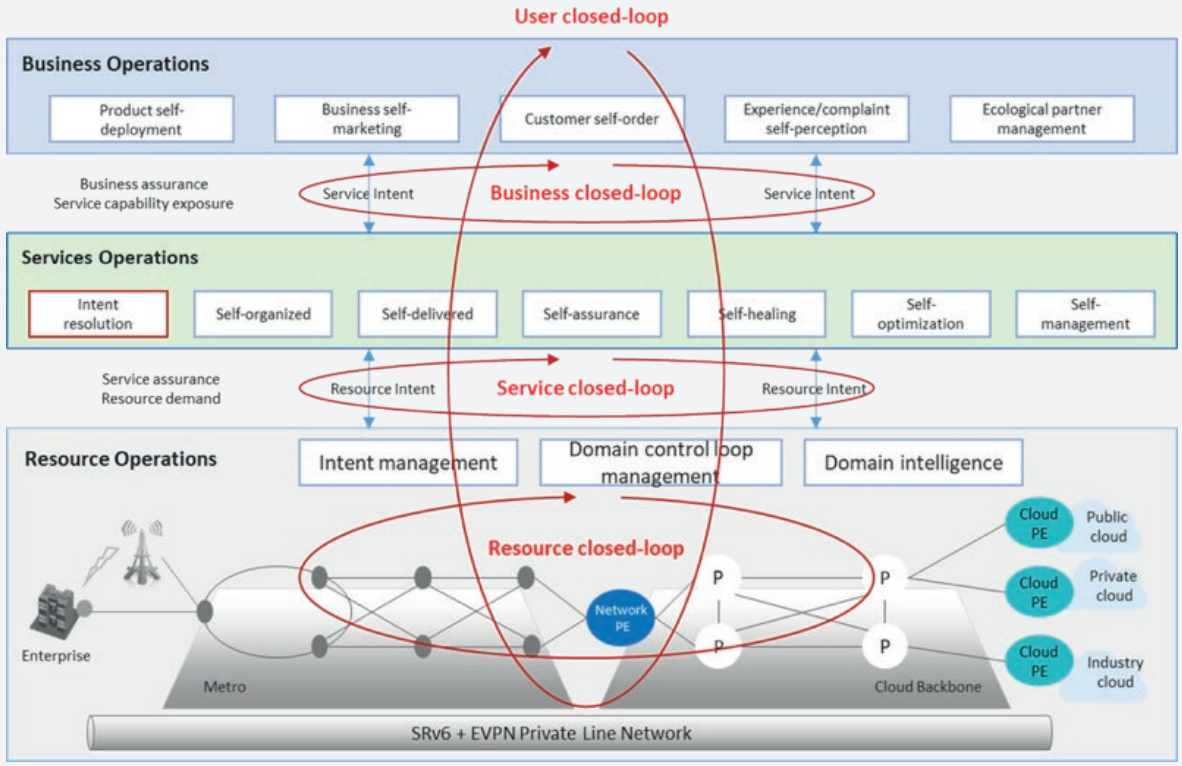


Figure 13: Intelligent Cloud-network convergence business solution

China Telecom use case: Smart operation of cloud-network convergence

Cloud-network convergence has become a top priority for many governments and enterprises when they migrate to the cloud. However, in production scenarios such as "service provisioning, quality management, and fault management", there are still problems such as "inconvenient ordering, long provisioning cycles, inconsistent cloud and network experience, difficult end-to-end SLA guarantees, and slow service repair/fault handling", which is still far from the expectations of customers.

The cloud-network convergence smart operation solution adopts the architecture and concept of " network moving with the cloud and cloud-network integration", It introduces "SRv6, flow detection, AI and cloud-network intelligence and other ICT technologies and cloud-network operation systems to comprehensively improve multiple automation and intelligence capabilities such as "real-time self-awareness of cloud-network resource topology and status, unified and self-organized resources, self-generated SLA policies, self-configured service activation, self-organizing, self-guarantee, self-healing and self-optimization of service quality and cloud-network failure". The business scenarios below show which autonomous network capabilities are used:

- **Service provisioning:** The business operation layer provides industry templates for government and enterprise customers. It can take customers' orders and change cloud-network services in one-stop and on-demand. It integrates customer requirements for "SLA and cost", automatically generates SLA strategies and drives service and resource operation layers for configuration. The service operation layer is based on the cloud-network unified operation support system, integrates the capabilities of each segment of business activation, and self-organizing cloud and network resources in a unified manner to achieve customer-oriented one-click activation. Finally, the resource operation layer deploys cloud-network points of presence (PoPs) to support users to enter the cloud quickly and from any location. The resource layer opens the underlying capabilities to realize the automatic configuration of VPNs, tunnels, slices, etc., to support the rapid opening of services.
- **Quality Management:** Service quality and customer experience drive the single-domain autonomy and cross-layer link in the closed-loop of the service and resource operation layer. The business operation layer provides cloud and network business visualized self-management clients for government and enterprise customers. These enable internal operation and maintenance, and they build a comprehensive view of cloud and network information, supporting intelligent marketing, agile activation, and cross-domain collaborative operation and maintenance. The service operation layer collects the resource status and service quality information of each segment of the network (autonomous domain) in real time, visually presents the service SLA situation, realizes end-to-end SLA analysis and prediction and self-guarantee. It also automatically generates self-healing or self-optimization strategies.

According to the service requirements, the operation layer can sense, analyze, and report the quality of each segment of the network in real time based on technologies such as telemetry and flow detection, and realize self-healing or self-optimization of the network based on SRv6 technology.

- **Fault Management:**(1)The Service operation layer provides mapping relationships between the business and the network, aggregates the cloud and network service information of each segment and triggers the service fault recovery intent. (2) The Resource layer translates the intent through the cloud and network resource orchestration and scheduling with zero interruption. Each autonomous domain of the resource operation layer automatically reports alarms/faults and completes self-healing actions such as resetting and restarting for rapid fault recovery.

For high-level autonomy capabilities, the "intent resolution module" is developed to build general intent resolutions and reverse translation capabilities to provide capability support for the three operation layers to achieve 4 intent based closed loops.

The cloud-network integrated agile opening and smart operation solution adopts a unified planning, single-domain autonomy first and then cross-domain collaboration for pilot verification and production network deployment. At present, large-scale deployments of the three scenarios of "service provisioning, 5G service quality management, and fault management" has been achieved, with the following results:

- **No waiting, hour-level service provisioning:** 5G slice configuration and number signing are automatically activated throughout the entire process, which has been implemented in more than 30 customer projects in the four provinces of Beijing, Guangdong, Jiangsu and Zhejiang. The entire process of product deployment and launch, from order acceptance to opening is automated. Product loading has been upgraded from monthly/weekly to hourly level, saving more than 20 man-days per project on average. The autonomous network level has been upgraded from L2.1 to L3.0.
- Differentiated, end-to-end SLA guarantee: Through 5G full-service intelligent perception and diagnosis capabilities, it can realize linkage alarm dispatch and end-to-end self-closed loop. At present, the first-level system has been deployed in China Telecom's 31 provincial subnets, and it has begun to run, analyze and process data from 31 provinces, and carry out SLA monitoring and assurance. The autonomous network level has been upgraded from L1.9 to L2.7.
- Zero-failure, minute-level business recovery: AI automatic identification of cloud-network hidden dangers have been deployed in China Telecom's 29 provincial subnets, realizing hidden risks minute-level discovery, business minute-level recovery and fault hour-level processing. The failure automatic processing rate reached 40%, the major incident business automatic recovery rate was 60%, and the processing efficiency increased by 85%. The autonomous network level has been upgraded from L1 to L2.

MTN use case: Cloud Private Line Convergence

Cloud Private Line convergence needs to be established to support online self-service for subscribers, supporting network slicing, guaranteeing differentiated SLA, and supporting zero-X operational experience. However, gaps still exist due to complex protocols, complex cloud network configurations, lack of service visibilities, and operational difficulties in fault detection and analysis. To successfully implement cloud-private line convergence, automation and autonomy are required to guarantee network readiness and augment operation services.

The 3-layers with 4-closed loops framework (see figure 11) is applied in the lifecycle of cloud-private line convergent processas detailed below:

- **Resource layer closed-loop:** hierarchical slice based private network is constructed with SRv6+EVPN, programmable and self-optimizing paths, and telemetry-based SLA real time awareness and visualization per service. Network service API interface is enabled to the upper OSS layer for a fast service request.
- **Service layer closed-loop:** Operation service efficiency is improved with zero-X service experience, with self-X capabilities. For example, service fault recovery can be performed with zero-interruptions through complex, cross domain fault demarcation and analysis, which drive self-optimizing and self-healing at the resource layer. The status of the recovery will be reported back to the service layer for smart operation and maintenance.
- **Business layer closed-loop:** This layer is enabled with one-click fast scheduling, one-hop to the cloud, and one-network wide connection business service capabilities. Business intent is driven at the upper business layer and interacts with the lower service and resource layer with open APIs. This drives efficient scheduling of cloud-network resources with AI algorithms, establishes cloud access paths across domains and minute-level multi-cloud access to construct a hierarchical slice based private network providing guaranteed differentiated services for high value customers.

China Mobile use case: Automatic Provisioning of Cloud Network Services towards Enterprise customers

Traditional cloud-networking service provisioning is performed manually and it involves multiple different steps, including service analysis, resource survey, command compiling, verification and testing. End-to-end service provisioning usually takes several days.

China Mobile has developed an IP Maintenance Platform, where AN capabilities are implemented to significantly improve service provisioning efficiency in combination with containerized and micro-service architecture. Using the 3-layer AN framework, the detailed technical path is as follows:

- **Real-time network awareness:** The resource operation layer provides real-time collection of network status and performance in each autonomous domain with several protocols, such as simple network management protocol (SNMP), command-line interface (CLI), NetFlow, telemetry, and two-way active management protocol (TWAMP). The service operation layer makes a high-level end-to-end analysis of autonomous domains.
- **Zero-touch service provisioning:** Based on the overall real-time status of network, the service operation layer dynamically calculates the optimal path and executes automatic configuration. AI-powered network path calculation is adopted to get the result within only a few seconds. The resource operation layer provides dynamic and accurate resource allocation for service provisioning.

- **Self-managing enables high-efficient agile deployment:** The resource operation layer provides atomic abilities with Netconf (a high-efficient & complete-transaction protocol). Common capabilities can be quickly developed on demand and be shared and reused in multiple cases. The service operation layer assembles these capabilities to achieve a service-oriented ability for the business operation layer to invoke.

The IP Maintenance Platform enables AN features such as zero-touch, and zero-wait to the end-to-end process from service subscription to service provisioning, reducing the total time of fulfilling cloud-networking services to only a few minutes. This improves customer satisfaction and increases the autonomous network level of China Mobile from L1 to L3.

4.2.4 HOME BROADBAND SERVICES

China Mobile use case: Intelligent Diagnosis of Network Quality for Home Broadband Services

After the epidemic in 2020, rigid demands for home offices and online education have been activated. The rapid popularity of new applications such as video live broadcast, XR games, and smart home has further promoted the development and popularization of home broadband services, especially gigabit broadband. The diversity of requirements and services raises higher requirements on broadband rates, latency, availability, and fault rectification. Therefore, how to comprehensively and accurately perceive the service experience of each home broadband user, provide certain service assurance, and obtain greater business value through precision marketing of value-added services are the key issues that operators need to address in the operation of home broadband services.

- **Experience assurance:** Existing problems such as insensitive perception, inaccurate positioning and untimely processing, could greatly affect the user experience of home broadband services.
- **Value improvement:** Users' requirements for value improvement services such as quality improvement (different SLA assurance), home networking, and smart home cannot be accurately identified.

China Mobile fully absorbs the concept of "single-domain autonomy and cross-domain collaboration" of autonomous networks and introduces technologies such as Xgboost algorithm, edge computing, telemetry second-level collection, big data analysis, and network topology restoration. Focus on improving Self-X capabilities, such as self-marketing for target customers, self-monitoring/reporting of service quality, self-orchestration of network resources, self-healing of faults, and self-optimization of performance, to achieve precise value improvement and proactive service experience assurance.

- **Self-guaranteed service experience, self-healing and self-optimization:** The service operation layer monitors and reports user experience in real time, proactively identifies users with a poor experience, predicts complaints and prevents mass faults, drives user marketing or retention, and improves service and network quality. The service operation layer automatically analyzes the various code streams of video and games traffic in real time, finely identifies traffic types, and perceives the quality problem of different traffic according to the preset differential threshold. It orchestrates and schedules resources in real time to ensure service quality. It also drives the expansion or optimization of associated networks such as transmission and content distribution and drives content introduction. Based on distributed OLT edge computing and cloud platform AI, the resource operation layer automatically identifies the top 50+ applications with poor quality and reports service or network faults. For the link diagnosed with poor quality, the spectral clustering algorithm is used to analyze the performance index such as optical current, power, bit error rate, quickly locating the end-to-end network problems.
- **Self-marketing for target customers and precise value improvement:** The service operation layer automatically recommends marketing based on user preferences and tariffs and provides self-subscription services. Customers can subscribe to services on demand and flexibly combine services. The service operation layer comprehensively analyzes user services, tariffs, experience, and network information to identify value-added service target customers. The resource operation layer provides the network and resource information of subscribers' locations and provides customer service preference and service experience perception.

After the solution being applied in China Mobile Henan's existing network, 450,000 cases of poor-quality problems, 8,000 poor quality lines and 150 poor quality content sources were actively identified. The diagnostic rate reached 90%. The network problems were dealt with ahead of customer complaints, which effectively improved the satisfaction of home broadband services. The ANL is increased from L2 to L3.

- **Zero interruption and proactive experience assurance:** The accuracy of proactive identification of poor-quality home broadband services is 95%, the user experience is significantly improved by 83%, and the average fault locating duration is reduced from 2.1 hours to 10 minutes. The system accurately identifies network bottlenecks and drives capacity expansion planning, improving the average user rate by 45%.
- **Self-marketing improves quality and revenue:** The target customer identification rate of value-added services reaches 95%. The success rate of smart home networking packages increases by 30%.

4.2.5 CLOUD CORE NETWORK INTELLIGENT O&M

As the core layer of the entire communications network, the core network is the crucial part for enabling digital transformation. The deployment of 5G and intelligent use cases is driving the evolution to Autonomous Networks. With the development of NFV technologies, infrastructure virtualization, and network equipment software transformation, the core network is gradually evolving to the cloud and being centralized. This is causing the following challenges:

- **More difficult to demarcate and locate cross-layer faults on cloud-based networks:** Cloud-based network O&M requires multi-domain and multi-vendor collaboration, Fault locating involves multi-dimensional data analysis.
- **Larger impact scope of risks and faults on centralized networks:** the impact of network faults is increasing, the network architecture is complex, and there is no effective O&M method to detect potential risks in advance.

- **Higher requirements for disaster recovery (DR) capabilities in case of major faults:** it is difficult to identify the faulty network equipment root cause in a short amount of time and consecutive incidents may occur. Disaster recovery switchover during critical incidents becomes one of the most difficult scenarios for O&M teams.

The solution we have deployed dramatically improves the autonomy, self-healing, and self-optimization capabilities of the cloud core network O&M through systematic, autonomous domain AI capabilities that enable intelligent transformation. This feature greatly improves the intelligence of faults and potential risk identification, location and impact analysis, fault recovery, and network change operations. It improves network experience with zero interruption and zero faults.

- **Fault and risk self-identification:** Enhances the single-domain autonomy capability of the resource operation layer. In scenarios such as routine maintenance, re-warning, and network change, AI modeling and dynamic detection are used to identify deterioration indicators.
- **Fault self-location and impact self-Analysis:** AI and big data technologies are used to mine potential risks, analyze alarms, configurations, KPIs, and logs in the space and time dimensions. The system automatically demarcates cross-layer problems, shortening the time for fault diagnosis and handling.
- **Fault self-rectification:** the intelligent disaster recovery assistance capabilities are constructed to quickly identify emergency scenarios, perform signaling shock simulation based on AI and flow control models, and quickly complete switchover evaluation.
- **Network change operation:** automatic multi-dimensional verification is used to check devices in a complete, comprehensive, real-time, accurate, and efficient manner.

The solution has been piloted and verified on the networks of multiple provincial operators in China, such as China Mobile Henan, China Mobile Jiangsu, China Mobile Zhejiang, and China Unicom Jiangsu. According to the pilot result, the solution has brought considerable benefits.

- **Identifying faults within 5 minutes:** Major faults are identified within 5 minutes on average. The system automatically points to typical fault scenarios using AI, reducing manual and wrong analysis.
- **Demarcating faults within 15 minutes:** The average diagnosis duration of typical faults is shortened from 60 minutes to 15 minutes, and the cross-layer fault coverage exceeds 80%.
- **Evaluating DR switchover within 10 minutes:** Major faults can be identified within 5 minutes. The MTTR of major interruption faults is shortened by 35%.
- **Enhancing the autonomous network level:** Improve the network autonomy level and promote the maintenance of the cloud core network to the Autonomous Networks Level ANL3.0.

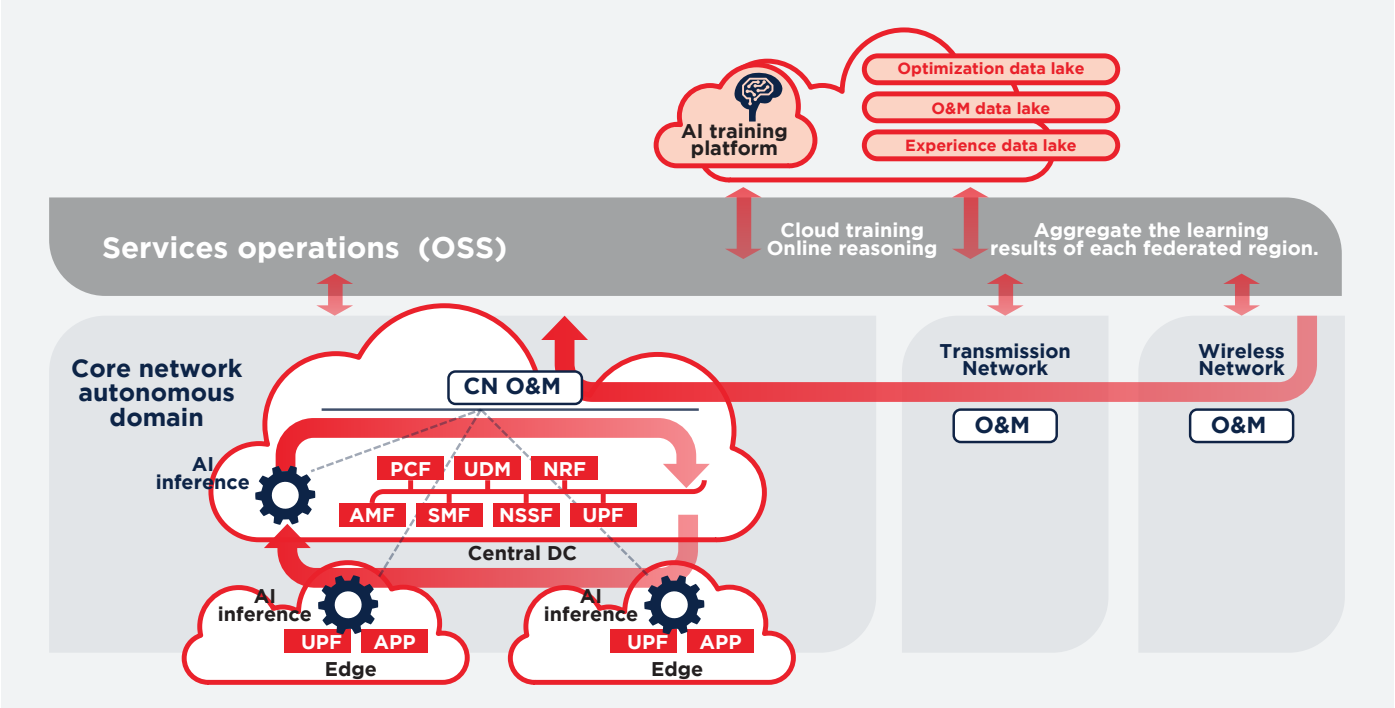


Figure 14: The intelligent O&M solution

4.2.6 TRANSMISSION NETWORK & BEARER NETWORKS

MTN use case: Digital Quick Optical Distribution Network

Autonomous Networks is core for the Fiber To The x (FTTx) business strategy, and Optical Distribution Network (ODN) is the foundation of FTTx solutions. The Digital Quick ODN (DQ ODN) automation solution enables infrastructure resource digitalization, operation efficiency and service experience improvement. For traditional ODN solutions, the ODN network is manually managed, and the operators have no visibility of the resources and topological information. With the DQ ODN solution, the resource layer managed the digitalized resource and topology, and the service layer managed the online provisioning, capacity expansion, and fault management service

1. Architecture and Solution

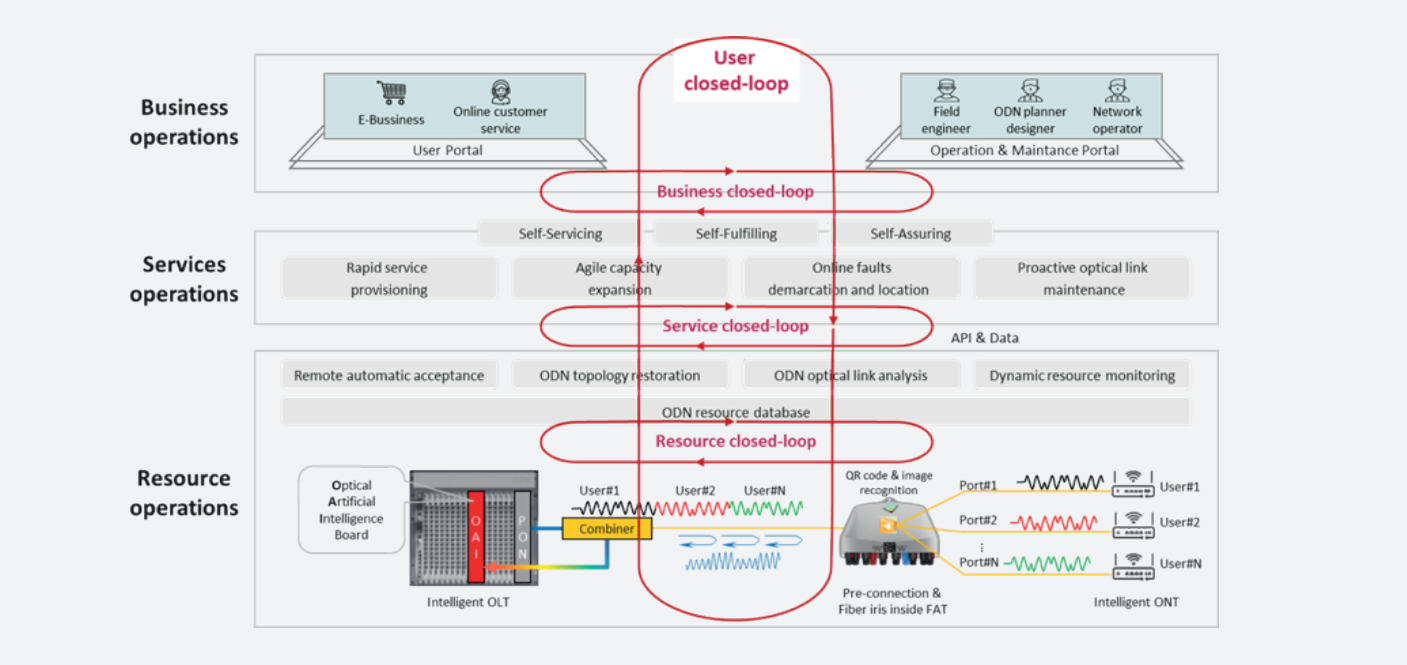


Figure 15: FTTx Autonomous Network with Digital Quick ODN

The Digital Quick ODN solution is implemented based on three innovations: Pre-connected optical cable design, Innovative image algorithm and Optical Iris technology.

With the implementation of the DQ ODN solution, FTTx Autonomous Network is achieved through:

Resource closed-loop:

- **Remote Automatic Acceptance:** The FAT port insertion loss data can be remotely detected and automatically recorded in the ODN management system.
- **ODN topology restoration:** Based on the ODN resource database, the End-to-End topology can be displayed, restored and updated automatically, including PON ports, feeder fiber, FAT ports, distribution fiber and ONT connection.
- ODN optical link analysis: Monitoring and analyzing end-to-end optical link insertion loss data.
- Dynamic resource monitoring: The FAT ports utilization can be monitored remotely and automatically.

Service closed-loop:

- **Rapid service provisioning:** Online checking of the FAT port resource availability and provisioning the service in one site visit.
- **Agile capacity expansion:** Accurately identify areas where FAT ports need to be expanded, preventing invalid expansion and improving resource utilization.
- **Online faults demarcation and location:** Avoid segment by segment onsite fault demarcation and location, shorten the average fault handling duration.
- **Proactive optical link maintenance:** Accurately identify areas that require rectification, and proactively dispatch maintenance tasks.

Business closed-loop:

With 100% accurate inventory information from the resource layer and service layer, the business layer is able to provide dynamic online services including: providing a provisioning map, checking resource readiness for new subscribers in real time, analyzing marketing data, and improving customers take-up rate.

Conclusion:

With the implementation of the DQ ODN solution, the FTTx network planning, construction, operation, maintenance, and marketing processes and activities are more visual, manageable, and autonomous to enable a network with self-x capabilities. This moves us a step closer to evolving to a higher-level of autonomous network operations.

China Unicom use case: Smart Operation of 5G Bearer Network

Zero Waiting Provisioning and Confirmatory SLA Guarantee

With the rapid deployment of 5G networks, the provisioning efficiency and SLA assurance capability of 5G bearer networks are one of the key areas of concern for operators. There are challenges to automating this capability:

To address these challenges, the 5G intelligent operation solution follows the concept of "single-domain autonomy and cross-domain collaboration" and introduces technologies such as AI, on-demand detection, and telemetry to build Self-x capabilities:

- **Service provisioning:** Self-orchestration of resources at the service operation layer and self-configuration of engineering parameters at the resource operation layer implements closed-loop service provisioning.
- **SLA assurance:** Automatic fault reporting at the network resource operation layer + Cross-domain fault locating and service self-recovery at the service operation layer; implementing SLA self-guaranteeing.

	CHALLENGES	REASONS
Service provisioning	• Provisioning is mainly dependent on manual operations. • The workload varies greatly between peaks and valleys, making it difficult to balance the staffing and utilization benefits.	• Offline resource allocation, conflict-prone, and difficult resource recycling. • Many manual configurations are prone to errors. • Work order record input involves data synchronization in multiple systems.
SLA assurance	• The legacy quality test cannot ensure consistency with actual service SLA. • Across the technology domain fault locating takes days or weeks. • Long fault recovery time	• The insufficient capability of automatically monitoring service SLAs • Hop-by-hop fault locating cannot be implemented and difficult. • The switchover is lack of automatic and intelligent optimization methods.

Table 5: Challenges to automating bearer networks

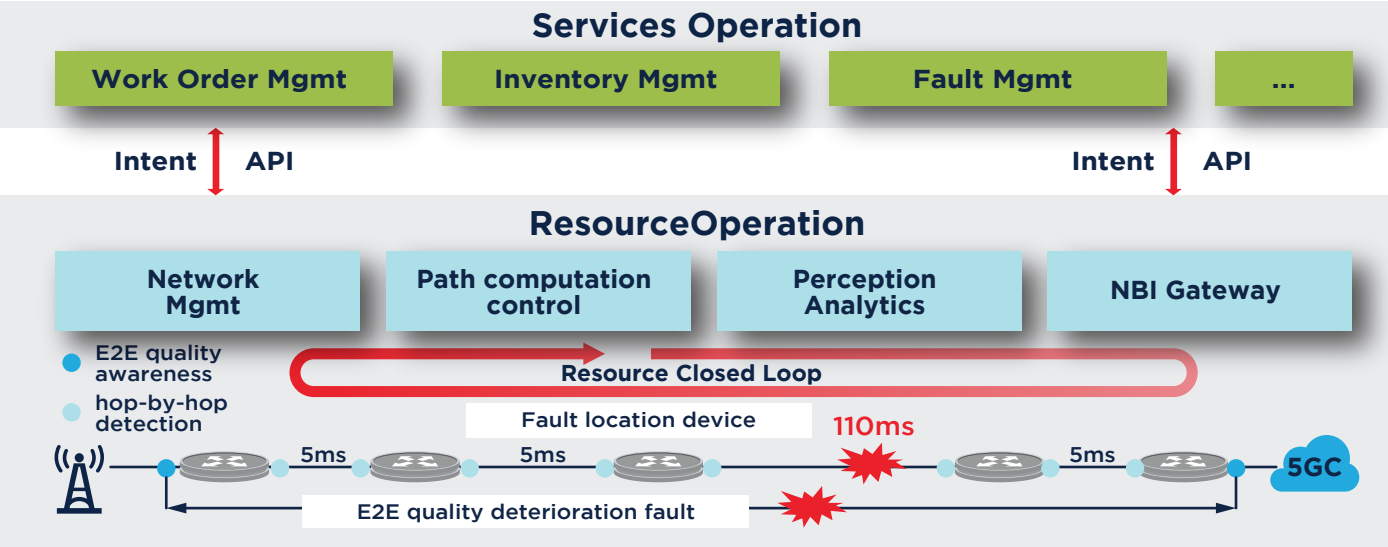


Figure 16: Smart Operation of 5G Bearer Network

This solution has been widely deployed in China, improving the provisioning efficiency and SLA guarantee.

Benefits

- **Zero wait and minute-level provisioning of bearer network:** The activation efficiency of a single line is reduced from 45 minutes to 2 minutes, and the activation accuracy reaches 99.999% without manual intervention. The autonomous network level reaches L3.
- **Real-time service SLA control:** Real-time visibility of 5G bearer service SLAs, supporting multi-dimensional and multi-period statistical analysis of service SLAs.
- **Zero interruption and minute-level service recovery:** Services are automatically repaired within minutes. The time for locating cross-domain poor-quality faults is reduced from hours to 5 minutes. The efficiency for handling base station mass faults is improved by over 60%.

4.2.7 DATA CENTER ENERGY SAVING

China Mobile Use Case: "Smart cooling" Intelligent DC refrigeration

With the rapid development of the global digital economy and the continuous digital transformation of industries, the demand for and the construction scale of data centers in the world are increasing year on year. As a result, the energy consumption of data centers accounts for more than 1.3% of the global energy consumption. The energy consumption of the cooling facilities in the DC center is around 30%. Therefore, effectively reducing the energy consumption of the cooling system and optimizing the power usage effectiveness (PUE) value is important for China Mobile to realize low-carbon innovation, reduce costs and increase efficiency.

The traditional PUE optimization mode of data centers mainly depends on O&M personnel. There are two limitations:

- Limited expert optimization effect: Whether O&M personnel has energy conservation optimization experience has a great impact on the final PUE.
- Long optimization period: Tens of device parameters are involved. It is difficult to find out the software optimization scheme quickly by manual statistical analysis methods due to more than 1,000 parameter combinations in IDC air conditioning systems.

The DC PUE Smart Energy Saving Solution adopts the architecture and concept of "autonomous optimization, Cloud-Premise collaboration, and continuous iteration". It introduces technologies and systems such as automation, AI intelligent platform, and RPA, which adopts multi-index time-space series prediction and deep neural network algorithms, actively predicts the subsequent operating conditions and air-conditioning energy consumption according to the historical data of outdoor temperature and humidity, which comprehensively improves the capability of "autonomous closed-loop energy-saving and self-evolving model". The DC cooling system is optimized and commissioned to achieve the effect of "full automatic, short cycle, and more energy-saving".

- **Automatic closed-loop of energy saving:** (1) The resource layer automatically collects the operating parameters and status data of cooling devices through the group control system. (2) Energy-saving configurations are automatically delivered and executed. The DCIM at the service layer automatically performs energy-saving configuration reasoning. The RPA automatic robot implements seamless interconnection between systems of different vendors. The group control system automatically delivers and executes energy-saving configurations. (3) The energy -saving optimization is self-iterative, the policy updating period is set, and the parameters of the water cooling system are optimized quickly by multiple iterations, to achieve the optimal energy saving state. (4) Visualized energy-saving effect.
- **Automatic energy-saving model evolution:** Cloud- Premise collaboration implements automatic update and closed-loop of DC energy-saving models. (1) Data samples are automatically collected and uploaded to the cloud-based AI platform, and models are automatically retrained. (2) Automatically delivers the updated model to the local DCIM to implement continuous self-evolution of the energy-saving model.

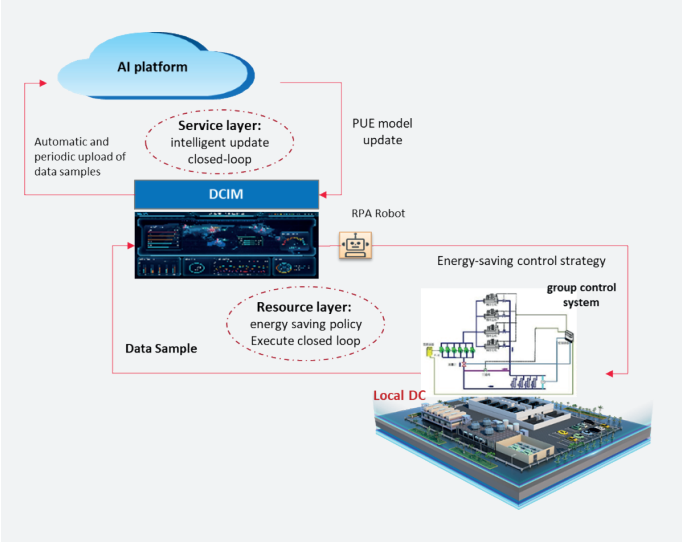


Figure 17: The DC PUE Smart Energy Saving Solution

Compared with the traditional expert mode, the DC PUE intelligent energy-saving solution has higher optimization efficiency and better energy-saving effect. After the pilot application in China Mobile Anhui, the energy consumption of data center refrigeration is further reduced by 8%-15%. An estimated electricity saving of 220 million kWh per year will be achieved after broader adoption.

4.2.8 WIRELESS & 5G NETWORKS

China Mobile Use Case: New Radio (NR) Network Coverage Optimization

Massive MIMO is an evolved form of multiple-antenna technology, which is widely regarded as a key 5G network technology. This technology integrates more radio frequency (RF) channels and antennas to implement three-dimensional precise beam forming and multi-stream multi-user multiplexing. Massive MIMO achieves better coverage and larger capacity than traditional technologies. In contrast with 4G massive MIMO that supports more than 200 broadcast beam combinations, 5G massive MIMO supports thousands of broadcast beam combinations. The pattern adjustment scope varies according to AAU types. Pure manual configuration and adjustment of broadcast beam combinations cannot achieve the optimal performance of massive MIMO due to its complexity. When massive MIMO modules are deployed on a large scale, the adjustment workload is heavy, and it is challenging to complete the adjustment manually.

According to the test results of multiple operators on the live network, massive MIMO intelligent optimization can improve the reference signal received power (RSRP) and user equipment (UE) throughput while maximizing operators' ROI.

To meet the challenges brought by large-scale commercial rollout of 5G networks, the online massive MIMO intelligent optimization solution can automatically collect basic network data, automatically analyze and generate optimization solutions based on drive tests data, and directly evaluate online KPIs in real time. This solution effectively resolves weak coverage, interference, and co-coverage problems, improve coverage gains, and ensures user throughput.

- **Optimization Intent Delivery:** Obtains coverage optimization areas and objectives, such as the proportion of weak coverage areas from the service management layer.
- **Data Self-awareness:** Through the scenario-oriented API obtains drive test data, performance counters, traffic statistics, engineering parameters, configuration parameters and other basic information including electronic maps, antenna patterns, frequency bands, and AAU types.
- **Data Self-analysis:** Creates grids for DT/MR data, identifies problematic grids, and merges them into problematic areas. The RAN Manager selects the best scenario-based beam, azimuth, and down tilt configurations for problematic cells. In this step, antenna hardware must meet the corresponding configuration requirements.
- **Policy Self-generation and Self-execution:** Performs iterative reinforcement AI learning based on the preset optimization objectives to obtain the optimal optimization advice. It automatically delivers the massive MIMO pattern parameter combination, down tilt, and azimuth parameters of problematic cells and their neighboring cells based on the Massive MIMO pattern common AI model.

In a typical operator application scenario, the RAN Manager (wireless resource management layer) interconnects with the network management system (NMS) (service management layer) through an open API. The NMS delivers the network coverage optimization objectives and areas to be optimized to the RAN Manager. The RAN manager sends the final optimization result and optimization advice of each round to the NMS of the operator.

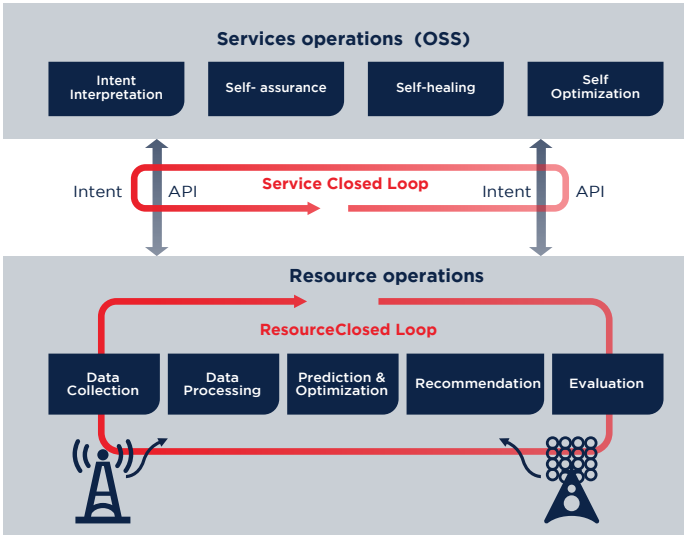


Figure 18: NR network coverage optimization solution

This solution increases the average coverage of 5G massive MIMO cells by 15.8% and the road coverage by 91%. After the application in China Mobile Jiangsu, wireless parameters are automatically configured more than 50 million times a month, with outdoor download rate increased by 13%, indoor download rate increased by 30%.

Use Case: Base station Online Energy Saving

As operators' network energy consumption keeps increasing, reducing the energy consumption of the main equipment is key to delivering energy savings. Reducing the power consumption of the main equipment at wireless sites has become the top priority for all.

The network traffic volume varies greatly during peak and off-peak hours. Despite this, the equipment keeps running, and the power consumption is not dynamically adjusted based on the traffic volume, resulting in energy wastage. In a typical network, the features of different scenarios vary greatly. How we automatically identify different scenarios and formulate appropriate energy-saving policies becomes the key to energy saving.

The solution involves providing automation capabilities for the service management layer and resource management layer. Based on network-level AI-based intelligent energy saving policy management and site energy saving scheduling control, the mobile network energy saving solution implements network scene adaption, one site one policy, and multi-network collaboration for intelligent base station energy saving management. This maximizes network energy saving benefits while ensuring stable network performance and achieves the optimal balance between energy consumption and KPIs.

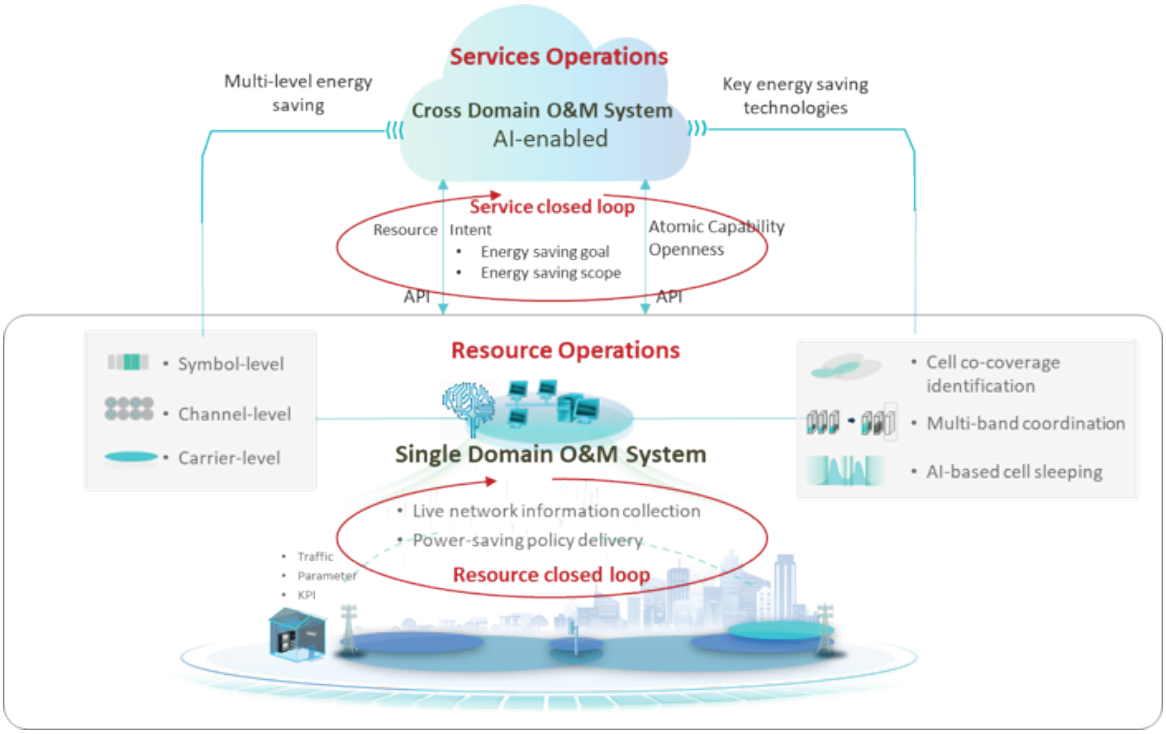


Figure 19: Online energy saving solution

The solution focuses on wireless single-domain and collaborative analysis of cross-domain data. The overall solution is as follows:

- **Data Self-awareness:** Automatically obtains network data from the resource management layer (radio domain) through scenario-based open APIs, including engineering parameters, MR measurement data, historical performance KPI data, and neighbor relationships. It automatically obtains other data that may affect energy consumption from the service operation domain, e.g., multi-dimensional data such as weather and specific events.
- **Data Self-analysis:** Based on big data analysis, AI technologies are adopted to automatically identify network energy saving scenarios, predict network traffic trends, such as traffic busy/idle hours and areas, traffic/energy consumption trends, identify multi-cell co-coverage, and automatically generates energy saving policies.
- **Policy Self generation and Self-execution:** The system automatically delivers energy saving policies and implements network-level intelligent energy saving policy management and coordinated management and control of site energy saving scheduling.
- **Policy Self-adjustment:** real-time monitoring of impact on network KPIs and energy saving benefits is implemented to achieve human visualization and management of energy saving benefits on mobile networks.

Application and Performance

In typical network configurations, the power consumption of base stations can be reduced by 10%–15%, and the emission of about 2 million kg carbon dioxide can be avoided for every 1000 base stations in one year.

The RAN element management system (EMS) can automatically identify different scenarios and optimize energy saving policies for different networking modes and loads, maximizing network energy saving benefits while ensuring KPIs. The overall energy consumption is reduced by 13.59%. The average shutdown duration is 9.88 hours, which is a 57% improvement compared with that when the feature is manually enabled. The tidal effect is obvious in office buildings, business centers, large stadiums, suburban areas, and county-level areas. The average energy consumption is reduced by 16.88%. Globally, online energy saving solutions can help save operators 100 million kWh of power every year.

China Mobile use case: "Zero-touch" Reliability guarantee of 5G network (automated faults handling)

With the rapid growth of 5G networks the average daily network alarms from provincial subsidiaries exceed 10 million, involving multiple network domains, long collaborative chain and complex dependency relationships. With the development of 5G to Business services, enterprise customers have higher requirements for network fault detection and processing efficiency. They therefore urgently need to transform to the predictive and preventive maintenance mode that integrates human-machine and data-driven services to improve fault self-guaranteed and self-healing capabilities.

The Zero-touch Reliability guarantee of 5G network business solution uses single-domain autonomy and cross-domain collaboration as the core principle to build a fault management framework with comprehensive real-time sensing, automatic anomaly diagnosis, and intelligent decision-making.

- **Single-domain autonomy:** The resource operation layer improves the self-guarantee capabilities of wireless, transmission, and core network domains, including the large-capacity alarm processing capability of 2000 alarms per second, the 1000:1 alarm compression capability, and the network configuration capability of 800 atomic networks for the service operation layer to support fault self-healing.
- **Cross-domain collaborative autonomy:** The service operation layer implements visualized network quality monitoring through network topology restoration. Through centralized cross-domain big data analysis and flexible orchestration of atomized configuration capabilities at the resource layer, automatic diagnosis and automatic decision-making for 300 types of fault scenarios are implemented.

This solution has been deployed in multiple provincial and municipal subnets of China Mobile. After applying in the network, main faults such as batch base station out of service can be cleared within 30 minutes, with average processing efficiency increased by 40%. The number of invalid work orders is reduced by more than 20%. The fault handling efficiency of frontline maintenance personnel is improved by 80%, and that of second-line maintenance personnel is improved by 25%. The autonomous network level has increased from L2 to L3.

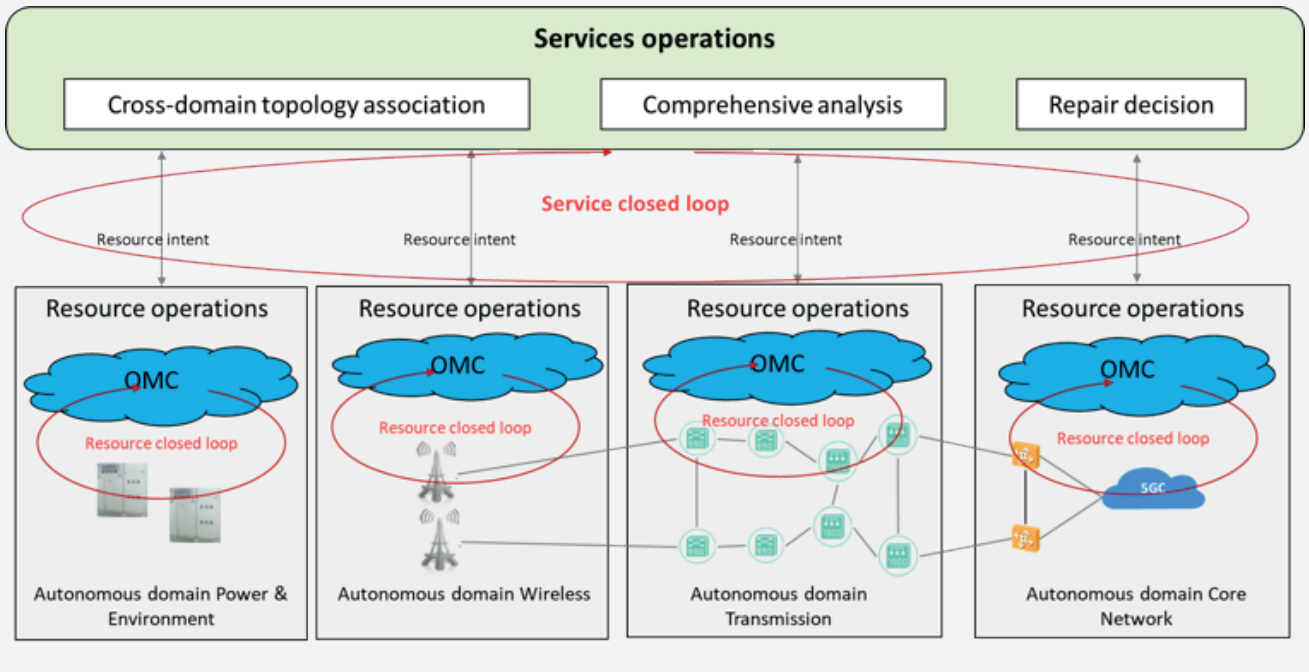


Figure 20: "Zero-touch" Reliability guarantee of 5G network

5. Industry activities and collaboration

5.1 CSP PRACTICES

China Mobile

China Mobile is exploring the path to achieve Level 4 automation by 2025[26]. A "234" implementation architecture has been developed with the dual goals of business expansion and increasing efficiency. It will also introduce autonomous capabilities at 4 levels to form 3 close-loops, and leverage capability evaluation 1-2 times annually to trigger iterative evolution. An **autonomous capability evaluation model**[27] has been developed and is used in the preliminary evaluation for all 31 branches, and 1,100 capability shortcomings were identified.

The new **"25N" OSS blueprint** is formulated with 8 technical specifications to guide 31 branches' practice in introducing over 3,000 autonomous capabilities. AI-driven OAM applications are promoted nation-wide based on over 100 AI capabilities hosted on the **"Jiutian" AI platform**[28], with over 100 million API calls annually. As a result, the OAM efficiency is increased by 10-20%; service opening time shortened by 30-50%; IDC/base station energy consumption reduced by 3-5%; and AI innovation vitality activated by 100%.

China Telecom

Based on the new-generation cloud-network operation system architecture and TM Forum autonomous network architecture, China Telecom integrates B, M, and O domain data, injects AI into network governance and builds China Telecom's autonomous network which realizes the intelligent operation and maintenance of the network as well as the digital management of the network and the rapid deployment of services. It can reach the minute-level discovery of hidden risks, the minute-level recovery of the service, and the hour-level processing of failures. At present, China Telecom has completed the construction of the L2 autonomous network and plans to reach the L3 autonomous network within two years. China Telecom aims to realize the L4 highly autonomous network between 2024-2025, and finally achieve L5 fully Autonomous Networks by 2030. In recent years, China Telecom has actively participated in projects in the areas of Autonomous Networks and AIOps in TM Forum. China Telecom expects to continue in-depth cooperation with TMF and other partners in the field of Autonomous Networks and AI smart operations in the future to achieve win-win results and create value for the telecommunications industry.

China Unicom

In March 2020, China Unicom formally proposed the vision of moving towards "Autonomous Networks" and released the "China Unicom Autonomous Network White Paper 1.0", which was the first to propose an AN level evaluation system in the industry. In 2021, China Unicom further defined the systematic AN implementation approach "Tri-in-one" to accelerate the AN evolution and deployed the digital management platform. Leveraging the systematic approach, China Unicom injected the capability of AI/IA into the full life cycle of network, planning, construction, maintenance and optimization, already applied to more than 1 million NEs. By promoting the solution to all subsidiaries, China Unicom achieved the outstanding outcome that the whole network O&M: value-based site selection increased 10 GB traffic per site, the number of secondary-visit to site decreased by 30%, the efficiency of BTS activation improved 40 times, trouble tickets reduced by 260,000+ per year, 4G/5G site intelligence power control saved of 100 million kWh per year.

HKT

HKT's business breath and scale ensures resilience and operational continuity.
The management remains constantly alert to rapidly changing market dynamics and are agile in responding to evolving customer needs. Customer 5G upgrades and the digitalization needs of our enterprise customers are a powerful catalyst for us to transform toward Autonomous Network for growth in the near term. As a whole, HKT will continue to unleash the potential within our digital infrastructure and digital businesses including our loyalty program, e-Commerce, Fintech and Health Tech to create value to stakeholders.

NTT

To resolve emerging various social problems around the world, it has become necessary in all circumstances to advance digital transformation utilizing ICT, as proposed under "Society 5.0." As "Your Value Partner", NTT Group aims to resolve social issues by means of advancing digital transformation through its business activities by utilizing its various management resources and capabilities, such as research and development, ICT infrastructure and personnel, while also collaborating with its partners. NTT Group believes that the resolution of social issues will contribute to achieving a smart society utilizing ICT and to SDGs proposed by U.N. As an initiative for technological development, we envision a future society and will promote the realization of the IOWN (Innovative Optical and Wireless Network) concept. We are actively working on AN Hyperloops catalyst which closely interacts with AN collaboration project in both the use of TMF assets and the contribution back to TMF standards.

Reference:
[26] *https://www.tmforum.org/resources/standard/ig1218b-china-mobiles-practice-on-autonomous-networks-v1-1-0/*
[27] *https://www.tmforum.org/resources/how-to-guide/ig1252-autonomous-network-levels-evaluation-methodology-v1-1-0/*
[28] *https://ecloud.10086.cn/home/product-introduction/jiutiandl*

MTN

In MTN, we have devised our "Autonomous Network Framework 2021." The framework includes the development of an AN blueprint, building an agile DevOps operational environment, constructing a high-performance network and implementing innovative high value Use Cases which are in line with MTN Ambitions 2025 strategy. Before the end of 2021 we plan to conclude the Proof of Concept (POC) of 10 Use Cases in Network and Services domains as per the AN framework. We plan with the support of our strategic partners to perform an AN Level evaluation of our Operational Processes based on TM Forum IG1252[29] recommendations. This year we have kicked off the deployment of digital quick ODN solution in Ghana and Nigeria, Cloud Private line solution in South Africa, and introduced DevOps for service agility, built automatic API and API matrix for Intelligent Service Operation, and implemented AI-driven Fault Management for O&M efficiency improvement, with AI and automation capabilities intrinsic to our network and operational platforms. We will continue to enrich these high value uses cases, analyze the gaps, iteratively optimize the solution, and implement the strategy to help us evolve to a higher level of network autonomy and target network service goals. In the coming years we plan to continue to invest in AI and Autonomous Network capabilities which are focused on key themes around network self-x capabilities, Zero-Touch experiences, and new business models around 5G and Edge.

Orange

Orange, as a major international global telecom operator, is working on inventing the future of networks and usages for both B2C and B2B markets. 5G is profoundly transforming the way networks are built, deployed and operated. At Orange we are exploring new approaches, new experimentations on how to get an autonomous network with end-to-end automation thanks to 5G features which allows greater openness and flexibility with automation closed loops, artificial intelligence triggers & fully edge cloud compatibility. These new-generation networks open up multiple possibilities for carriers, verticals (smart industry, smart agriculture, cities ...) and users. "Automation and closed-loop mechanisms mean the network is expected to develop the ability to adapt and repair itself. When a technical incident occurs, it is analyzed via AI, triggering an automated action. This results in improved user experience with greater fluidity." This means new visions for a huge scope of new business.

Robi Axiata

We see autonomous network as a new paradigm in attaining operational excellence. While rule-based engines were in place for many years yielding advantages in terms of network faults or problem monitoring they are not enough when it comes to adaptability with the ever-changing network landscape. We have identified different functions in the network management processes where a higher level of autonomy can be realized and embarked on a path toward implementing solutions in an iterative manner in complex multivendor heterogeneous networks. We see clear value, especially in processes related to network fault management and performance management. Multiple functions can be made fully autonomous which in turn would increase not only efficiency but also better customer experience.

5.2 MULTI SDO COLLABORATION

Since the release of the Autonomous Network White Paper 2.0 in October 2020, more and more standards organizations and industry organizations have shown strong interest and participated in the research and development of Autonomous Networks. This means that the industry direction of Autonomous Networks is becoming established and we will enter the rapid development phase of standards-driven and industrial collaboration.

3GPP SA WG5 has carried out a series of work items related to Autonomous Networks, covering the entire life cycle of mobile networks. The Rel-17 (planned to freeze in Q3 2022) work items include intent driven management for mobile networks, Levels of autonomous network, Management services for communication service assurance, and study items on Management data analytics service and Self-Organizing Networks (SON) for 5G networks.

ETSI OCG has set up an AN ad-hoc group to promote standard projects alignment internally and coordinate ISGs to participate in cross-organization cooperation. ETSI ZSM released closed-loop automation and initiated the intent interface and AI enablement in the layered and domain-based architecture; ETSI F5G Landscape v1 uses the TMF AN and ETSI ZSM architectures and concepts as the basis for F5G E2E management and control architecture design. The E2E control standardization has been started, basic design principles, including autonomous domain, intent, closed loop, simplification, etc., and the management and control architecture complying with the hierarchical domain-based approach of the AN.

In July 2021, CCSA TC7 held a joint meeting on Autonomous Networks, brought together three major carriers and multiple vendors in China, determined the outline of the "Intelligent Operation and Management of Information and Communication Network" series standards, and approved three generic work items: functional architecture, technical architecture, and autonomous levels of intelligent operation and management of information and communication network. CCSA TC7 WGs have initiated several research projects on intelligent management and operation levels in the mobile, IP, optical, and PTN/SPN domains. As an industry development promotion organization, TC610 announced that it would establish an autonomous network project, contents, objectives, ideas, and plans were defined.

The IETF OPS O&M management domain finished RFC8969, A Framework for Automating Service and Network Management with YANG. The NETMOD WG completed the MDT automatic labeling standard and ECA policy management automation model. The ANIMA WG finished the ACP and GRASP standards.

The IRTF NMRG Network Management Research Group released the definition of intent and initiate a digital twin architecture work item.

ITU-T Focus Group on Autonomous Networks was established by ITU-T Study Group 13 in December 2020. The Focus Group will draft technical reports and specifications for autonomous networks, including exploratory evolution in future networks, real-time responsive experimentation, dynamic adaptation to future environments, technologies, and use cases.

In 2021, the TM Forum organized seven AN Multi-SDO workshops, representatives from GSMA, NGMN, ETSI, 3GPP, IEEE, IETF, and CCSA agreed to collaborate on standardization of autonomous network.

Reference:

[29] *https://www.tmforum.org/resources/how-to-guide/ig1252-autonomous-network-levels-evaluation-methodology-v1-1-0*

5.3 INDUSTRY VIEWS

Network automation will drastically increase CSP efficiency and enable new digital services while transforming societies and industries through a wave of new service enablement (including industrial IoT, autonomous vehicles and smart cities). However, automation is not a choice; it is a necessity. In a survey of CSPs, ACG Research[30] found that CSPs are committed to automation in their business and network operations with a 30% growth in annual spending for automation projects. They have committed to these projects because of market demand for higher customer satisfaction and revenue growth with requirements for:

FASTER time to market and time to revenue **(25%)**

IMPROVED customer satisfaction and NPS **(24%)**

FASTER and more frequent new services **(18%)**

According to Analysys Mason[31] interviews, most CSPs are at Level 2 in TM Forum's classification system, and more advanced CSPs operate some domains at Level 3. Most CSPs are preparing to take their whole network to Level 3 and will continue to expand autonomous functionality through their networks incrementally to progress to the higher levels. The journey to the fully autonomous network is expected to take at least a decade.

Achieving this automation framework will require a series of steps, including:

- The adoption of new network technologies (such as cloud-native functions, SDN, orchestration, AI/ML, telemetry and open APIs).
- Simplified network architecture.
- Redesigned operational processes with a long-term vision and platform thinking.

An organizational and cultural transformation will be critical in this journey. Organizational transformation is much harder to achieve than technological transformation, but it is critical for success. CSPs should reskill their existing workforces and hire new talent with the requisite DevOps and software engineering skills. CSPs should also consider seeking support and adopting best practices from external vendors to ease and accelerate the journey of organizational change.

Efficiency and cost savings are important benefits of automation. A 2021 report from the GSMA[32] stated that three of five of the most favored technologies for OPEX reduction utilize automation with:

52% of mobile network operators (MNOs) considering service operations automation (billing, customer support, service setup).

39% of MNOs considering network operations automation.

32% of MNOs considering network deployment and planning automation.

The ascendance of service operations automation is aligned to an increasing focus on services beyond connectivity with an emphasis on enterprise verticals. 83% of telecom CEOs felt[33] that the enterprise and public sectors will represent 5G's greatest revenue opportunities. CSPs remain optimistic about the operational efficiencies of automation. More than 65% of operators surveyed by GSMA Intelligence believe that the automation of business and network functions is "extremely" or "very" important.

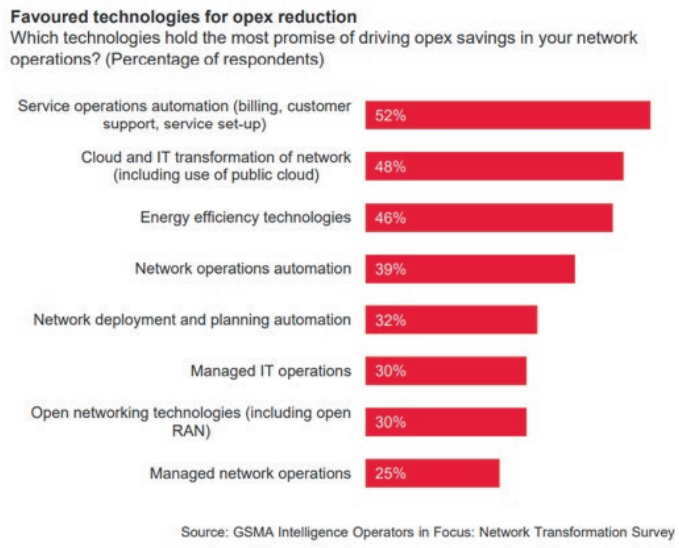


Figure 21: Favored technologies for OPEX reduction (source GSMA)

New enterprise use cases place new performance, agility and latency requirements on the network. ABI Research[34] has found that these requirements and the ongoing drive for new growth are compelling the industry to shed labor-intensive networks for an intelligence-driven ecosystem.

We are in an era of autonomous systems (AN Autonomous Decade), various autonomous systems and even autonomous enterprises are emerging. The network is the vital infrastructure for society's digital transformation and service providers urgently need to prioritize development and investment in Autonomous Networks to meet today and tomorrow's digital needs. Currently, AN is at the critical stage from concept to implementation and we call for broader collaboration among CSPs, SDOs, suppliers, analysts, and academia to collaborate in the AN journey to develop standardized approaches and use cases. The industry must work together if we are to be successful in accelerating AN development and deployment.

Reference:

[30] *https://www.cisco.com/cloud-systems-management/acg-economic-benefits-of-network-automation.pdf*
[31] *https://www.analysysmason.com/contentassets/analysys_mason_5g_autonomous_networks_oct2020.pdf*
[32] *https://data.gsmaintelligence.com/api-web/v2/Network-Transformation-2021.pdf*
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[34] *https://www.abiresearch.com/press/bid-capture-new-growth-telcos-turn-ai-and-operations-automation-5g-networks/*