TM Forum Introductory Guide

Autonomous Networks Case Studies

IG1218A

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Notice

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Introduction

This document provides use case examples of Autonomous Networks, covering the usages of AN on the operational efficiency improvement and business revenue growth. The case studies illustrate the key operations and related Autonomous Networks Levels, which could be based on specific network operations issues e.g., network planning & deployment, maintenance & assurance, or could be more comprehensive scenarios e.g., enabling digital business.

This document serves as the inputs for distilling general user stories, business requirements, framework, key capabilities and E2E lifecycle of AN operations, as well as for technical reference solutions.

Intended Audience

This document is targeted at business decision makers and operations owners across all industries undergoing digital transformations, as well as being of particular relevance to CIO's, CTO's together with their architects and designers from both IT and networks backgrounds as we are seeing the consolidation of software thinking across the worlds of IT systems and networks.

This document will also position the TM Forums work on business requirements and framework of Autonomous Networks in relation to other standards organizations so that it is unambiguous as to the role that each organization will play in the development of the solutions going forward.

1. Overview

This clause describes the overall development method of Autonomous Networks case studies.

As described in Clause 1 of IG1218 [1], the basic method of defining AN is to use a user centric, top-to-down, business driven and quick-reiterative approach to develop all contents of Autonomous Networks, which case studies serve as the inputs to generalize the common business requirements, framework, key capabilities and lifecycle of operations.

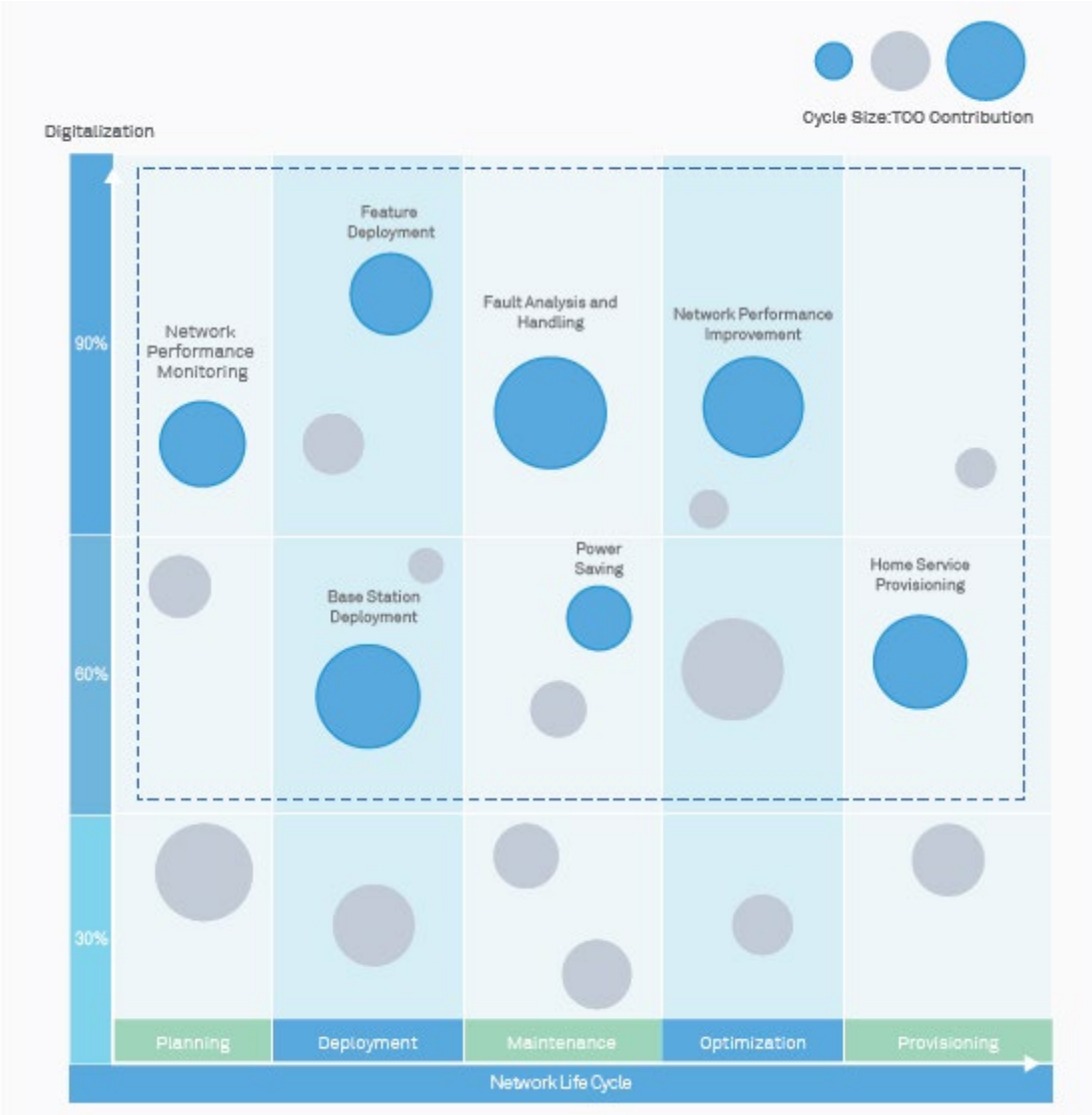
The case studies are categorized as follows:

- Operations efficiency improvement. Mainly focuses on the automation and intelligence of existing network services and operations, e.g., network planning & design, deployment, maintenance and optimization, which could be based on specific issues or E2E processes of telecom infrastructure.
- Business revenue enablement. Mainly focuses on the enablement of innovative services and agile operations of business growth, e.g., Autonomous ICT services/infrastructure and operations for verticals.

The case studies highlight the key issues that are related to AN, i.e., the automation and intelligence of operations, in particular, depicts the key capabilities per different levels of Autonomous Networks.

2. Case Studies of operations efficiency improvement

2.1 Wireless network operations automation



Cases of the lifecycle of wireless network operations: planning, deployment, maintenance, optimization, provisioning

Case 1: Base Station Deployment

1) Definition and Description of Scenario

The base station deployment scenario refers to the entire process after site survey, including network planning and design, site design, configuration data preparation, site installation, site commissioning and site acceptance.

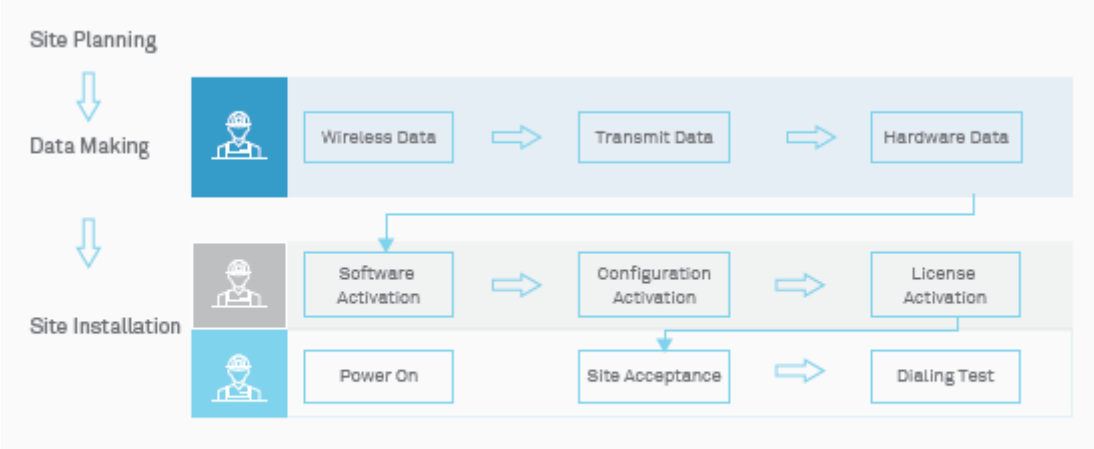


Figure 9. Flow of Base Station Deployment

2) Autonomous level:

Level 1: The O&M tool helps some elements of the process to be automated, but configuration and site acceptance have to be done manually.

Level 2: Some hardware can be detected and configured automatically, and configuration data is simplified based on rules.

Level 3: E2E automation: radio parameter self-planning, hardware self-detection and self-configuration, self-acceptance without dialing test.

Case 2: Network Performance Monitoring

1) Definition and Description of Scenario

The mobile network has entered the stage of very precise planning sites and resources: on the one hand, to identify and forecast high traffic areas, and allocate resources precisely to support business goals; on the other hand, to identify and forecast high-frequency temporary traffic, scheduling resources to meet business objectives.

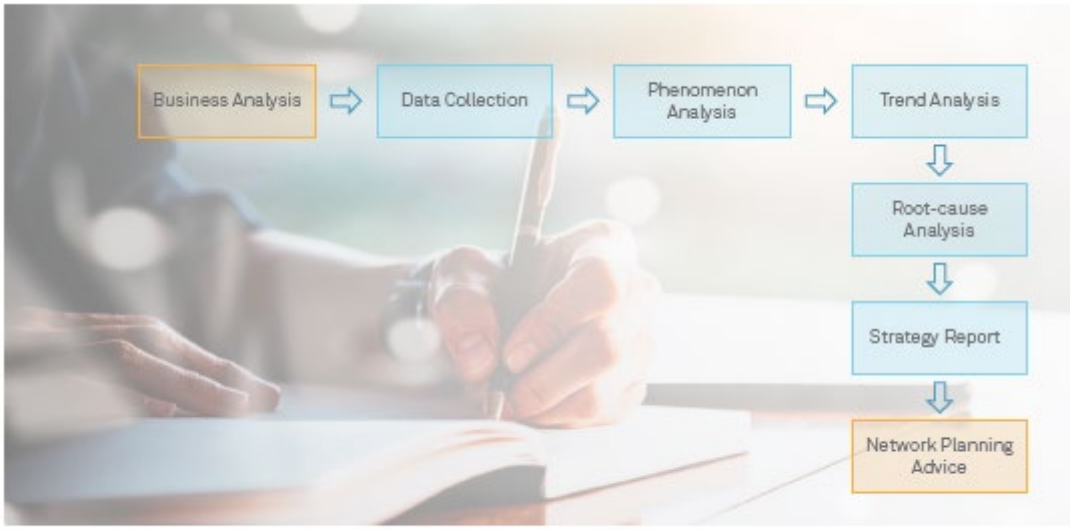


Figure 11. Flow of Network Performance Monitoring

2) Autonomous level

Level 1: Network quality is consistent, and network anomalies can be discovered by tools.

Level 2: 3D presentation of network quality and anomalies, and network planning is self-generated.

Level 3: E2E closed-loop monitoring and planning: predicting network development according to historical network information, finding value areas and hidden problems, recommending the best network planning and estimating the gain automatically.

Case 3: Fault Analysis and Handling

1) Definition and Description of Scenario

The security and reliability is the most important mission of the network, so quick alarm detection and quick fault healing are important. The fault analysis and handling scenario comprises several steps, including alarm monitoring, root cause analysis, and fault remediation.

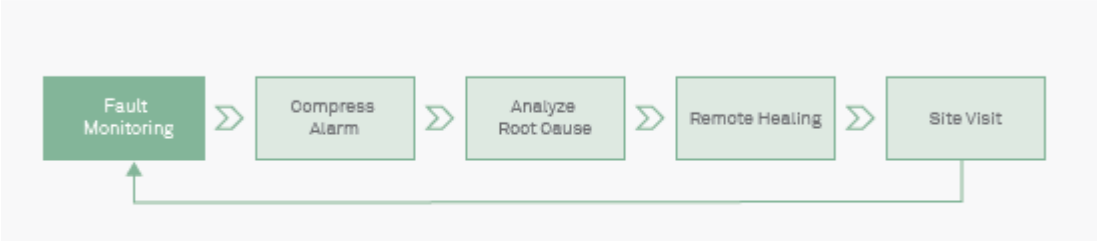


Figure 12. Flow of Fault Analysis and Handling

Monitoring: Real-time monitoring of network alarm, performance, configuration, user experience, and other information.

Analysis: By analyzing the correlation between alarms and other dimensions data, root cause of fault and fault repairing can be achieved quickly.

Healing: Repair fault remotely or by site visiting based on the repairing suggestions.

2) Autonomous level

Level 1: Some tools are used to simplify alarm processing, but thresholds and alarm correlation rules are set manually based on expert experience.

Level 2: Automatic alarm correlation and root cause analysis.

Level 3: Closed loop control of alarms analysis and handling process: Based on the intelligent correlation analysis of multi-dimensional data, accurate location of alarm root cause, precise fault ticket dispatching, and fault self-healing could be reached successfully.

Level 4: Proactive troubleshooting: Based on the trend analysis of alarms, performance, and network data, alarms and faults could be predicted and rectified in advance.

Case 4: Network Performance Improvement

1) Definition and Description of Scenario

Wireless networks are geographically very distributed, and activity varies significantly in different places and at different times of day. This makes the network very dynamic and complex. That complexity is further increased by the diversity of services and of terminal performance, and by

the mobility of users. If the network cannot achieve the benchmark KPIs or SLAs (service level agreements), or enable good user experience, it must be adjusted to meet or exceed those requirements.

This is the function of network performance improvement or optimization.

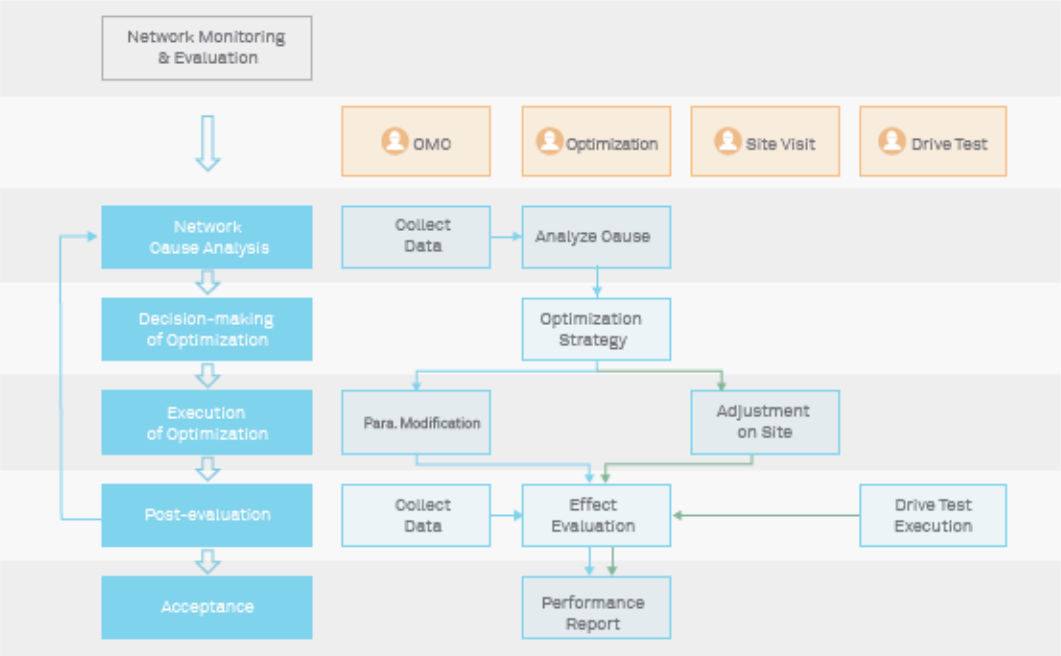


Figure 13. Flow of Network Performance Improvement

The complete process of network performance improvement or optimization includes several stages:

- network monitoring and evaluation
- root cause analysis of performance problems
- optimization analysis and optimization decision-making
- optimization implementation
- post- evaluation and verification

2) Autonomous level

Level 2: Drive test evaluation is not required for coverage optimization. Adjustment suggestions are provided automatically.

Level 3: Closed loop control of network performance improvement:

Automatic identification of network coverage and quality problems, automatic configuration of performance parameters, and automatic evaluation.

Level 4: Dynamic adjustment is implemented based on the scenario awareness and prediction to achieve the optimal network performance. Network prediction capability is available: scenario change trends could be perceived, and network configuration could adjust real-time to achieve optimal performance.

Case 5: Site Power Saving

1) Definition and Description of Scenario

Site power consumption cost accounts for more than 20% of network OPEX. Although network traffic declines greatly during idle hours, equipment continues to operate, and power consumption does not dynamically adjust to the traffic level, resulting in waste. It is necessary to build the "Zero Bit, Zero Watt" capability.

Figure 15. Flow of Power Saving

2) Autonomous level

Level 2: Tool aided execution.

Level 3: Power-saving closed loop: Based on the analysis of traffic trends, self-adaptive generation of power-saving strategies, effect and closed-loop KPI feedback.

Level 4: Real-time adjustment of power-saving strategies based on traffic prediction. Through integration with third-party space-time platforms, the operator can also add predictive perception of traffic changes, smooth out the user experience, and maximize power-saving.

Case 6: Wireless Broadband Service Provisioning

1) Definition and Description of Scenario

WTTx has become a foundational service for mobile operators because of its convenient installation and low cost of single bit. Rapid launch of WTTx service, accurate evaluation after launch, and network development planning have become important supports for new business development.

Figure 14. Flow of Home Service Provisioning

2) Autonomous level

Level 1: Blind launch.

Level 2: Automation tools to assist the launch, check the coverage and capacity of the user's location before the business hall, and experience evaluation.

Level 3: Closed loop for business launch: Integrated with BOSS system to achieve one-step precise launch, remote account launching, CPE installation, fault self-diagnosis and complaint analysis.

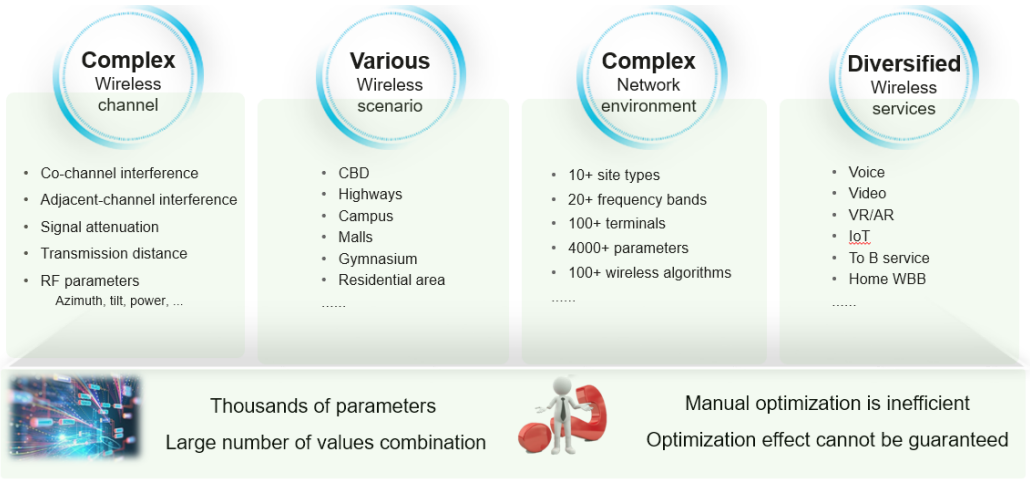
Level 4: Auto-balancing of multi-service, automatic value areas identification and network planning recommendation based on network problems forecasting.

2.2 Network operations assurance & optimization

This section illustrates multiple case studies of operations that are implemented in the TM Forum Catalyst projects – AI Empowered 5G Intelligent Operations [2] and AI for AN: Accelerating digital transformation in 5G era [3] respectively.

Case 1: Autonomous Networks supporting 5G Wireless Optimization

Wireless networks are geographically distributed, and mobile user activity varies significantly in different places and at different times of day. This makes the network very dynamic and complex. That complexity is further increased by the diversity of services and of terminal performance, and by the mobility of users. There are thousands of radio feature parameters (e.g., Massive MIMO pattern) with broad value ranges affect each other and combination reaches millions. In addition, the configuration of radio feature parameters values depend on various wireless scenario and diversified wireless services, the initial radio network feature parameters may not always meet the requirement and the adjustment effort needs to take consideration of interference control, huge parameters combination and frequent traffic change under diverse scenarios. So, it is beneficial to use AI technology to achieve the optimal radio features parameters combination automatically to deliver the best coverage and capacity for the complex wireless environment. The Multi-vendor area based wireless network deployment scenarios is the typical 5G network deployment scenario, where the operator's network is composed of several subnetworks and each subnetwork contains multiple NG-RAN Nodes from same vendor which cover different certain areas. The coordination of wireless network optimization for different areas also is the key challenge to achieve the optimal performance for the whole wireless network.



Complexity of wireless network

The multi-vendor OSS and different RAN Domain Managers work together with each other for the wireless network optimization to achieve the optimal coverage and capacity for the whole

wireless network in a coordinated manner. The multi-vendor OSS is responsible for generating and dynamically adjusting the wireless network requirements and coordination policies for different RAN Domain managers by predicting the trend of service performance (e.g., traffic) change. RAN Domain manager is responsible for the wireless network optimization for the NG-RAN nodes in certain area, which includes automatically identifying network issue and selecting the best radio feature parameters pattern based on online iteration optimization. In addition, the optimal radio feature parameters pattern combination is generated by fast predicting the gain value to achieve the scenario-adaptive and traffic-adaptive wireless network optimization.

AN capabilities of Wireless Network Optimization can be evolved into five levels:

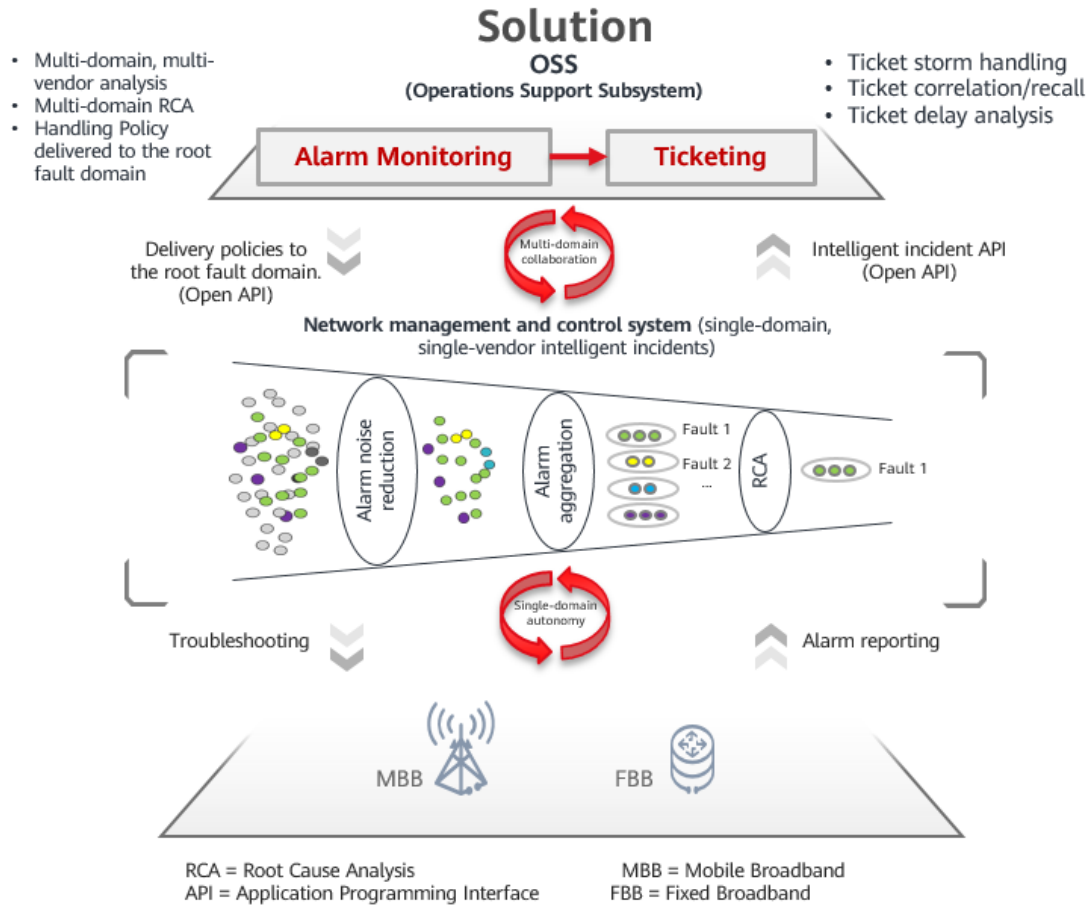
- L1: system assist human to improve the efficiency for wireless network optimization action execution and wireless network performance awareness.
- L2: system additionally analyses the wireless network performance and identify the network issue based on the network issue rules specified by human.
- L3: system additionally analyses the optimization solution and determine the adjustment actions to be executed based on wireless network requirements and optimization policies specified by human
- L4: system additionally determine and update wireless network optimization policies and requirements dynamically based on service assurance intent.
- L5: system achieve the full autonomy for wireless network optimization for full scenarios and services

Case 2: AI based 4G/5G intelligent assurance management

With the acceleration of 5G, 4G/5G collaborative networks are becoming more complex. On average, more than 500,000 transmission alarms are generated from the entire network of a province every day, it is inefficient to handle them based on specialists ‘experience. Trouble tickets are dispatched based on alarms, redundant and inaccurate trouble tickets may be dispatched; the root cause information of faults is not accurate, and the root causes of numerous faults are not provided. This affects onsite troubleshooting efficiency and prolongs the fault recovery time.

Automatically analyzes faults from the massive chaotic transmission alarms, recommends fault handling priority according to the network layer of the faults which affects the service. Automatically inferences failure unit according to “failure scene snapshot” and AIOps algorithm, then distributes incident tickets by OSS.

"AI, Big data and Fault domain algorithm" can be used to transform traditional alarm monitoring to intelligent fault O&M. Automatically analyzes 500,000 alarms per day and provides accurate fault location. The number of tickets decreases by 35% as tickets are dispatched based on incidents instead of alarms.



4G/5G intelligent assurance management

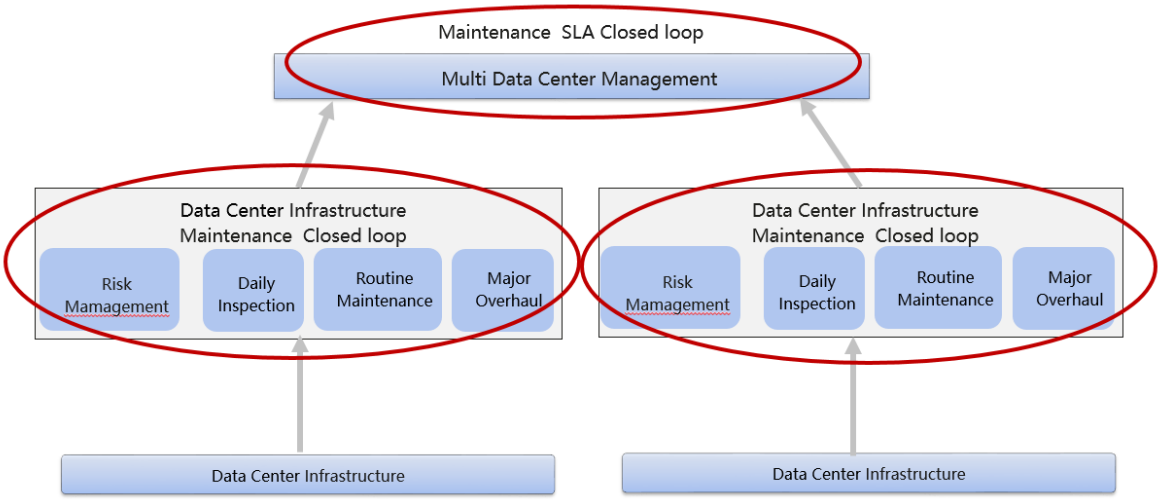
AN capabilities of the 4G/5G intelligent assurance management can be evolved into five levels:

- **L1：** Manually monitored tool-assisted network alarms. Manually analyze the root cause and recover network.
- **L2：** The monitoring rules are manually designed and automatically monitored. Manual operation + system analyze the root cause and recover network.
- **L3：** Manually designs monitoring rules, automatically monitors the network, manual and the system predict network deterioration, automatically analyzes root causes, automatically generates recovery solutions, and manually recovers network.
- **L4：** Manual input of intents, automatic intent conversion to monitoring rules, automatic monitoring, automatic network deterioration prediction, automatic root cause analysis, automatic generation of recovery solutions, automatic decision-making, and automatic recovery execution.

Case 3: Intelligent energy O&M of Data center

With the rapid growth of data volume, data centres tend to be large or super-large. A large number of dumb devices or components are not digitalized, require a large amount of manpower for onsite meter reading and collection. Manual Inspection， 7*24hours attendance， 6 to 12 onsite inspections per day, the proportion of manpower cost continues to rise. As a result, Outdated O&M methods result in low efficiency and high O&M costs. Reliability is facing increasing challenges and risks, potential system risks cannot be identified in advance, and the SLA cannot be guaranteed.

The automatic inspection technology automatically collects device data and device status information that is not digitized through image recognition and voice recognition. The full digitization of devices is automatically detected in the following modes: Data collected by the traditional monitor system; Device panel status identification. Identify potential device faults: Identifies and analyses abnormal audio features of devices, Real-time noise reduction, feature extraction, and exception identification. Automatic inspection is implemented to greatly improve inspection efficiency, and further improve the reliability and availability of data centre infrastructure and reducing O&M costs.



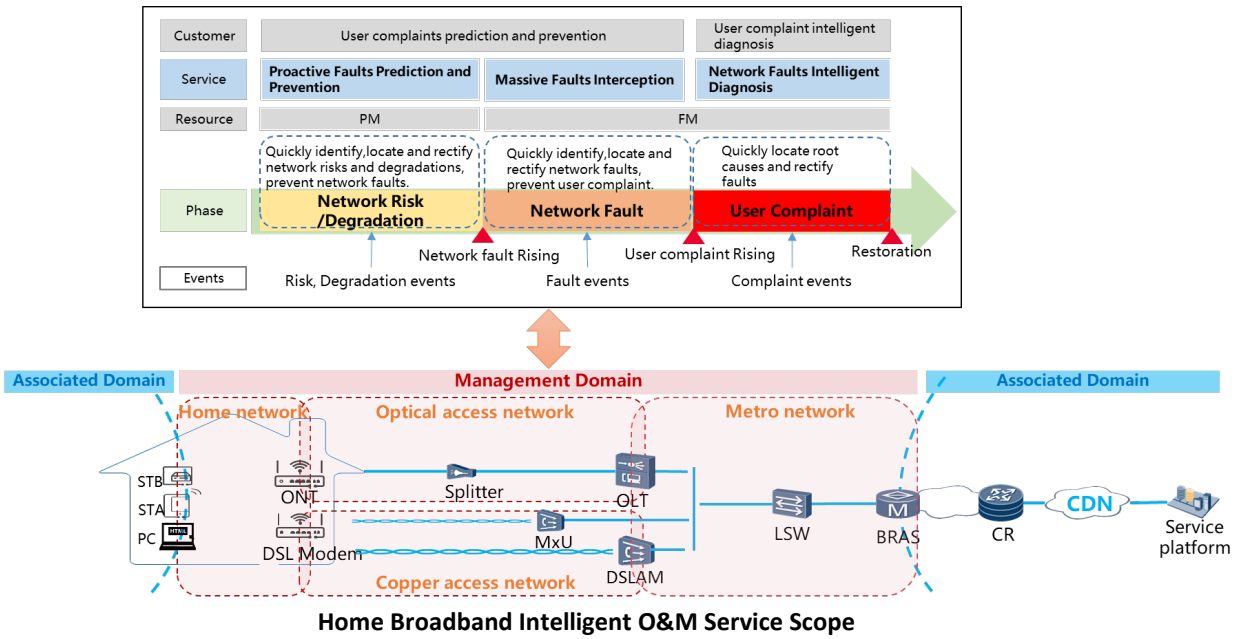
Automatic Maintenance for Data center Facility

AN capabilities of Intelligent energy O&M of Data center can be evolved into five levels:

- L1 (Tool-assisted operation): Tool-assisted monitor network status, operator can handle the network fault manually.
- L2 (Partial Autonomous Networks): system automatic executes system faults recovery action, basically eliminating the need for recovery manually.
- L3 (Conditional Autonomous Networks): system automatic intelligently identify problems that occur during device running and predict the health status of devices and detect problems, basically eliminating the need for manual awareness
- L4 (High Autonomous Networks): system automatic root cause analysis, automatic generation of recovery solutions, automatic decision-making, basically eliminating the need for manual analysis and determine
- L5 (Full Autonomous Networks): All-scenario automation, completely autonomous operation and automatic recovery of system faults

Case 4: Provide intelligent maintenance to reduce complaints for HBB domain

The HBB Maintenance faces many problems, such as a large number of user complaints and many site visits for fault rectification. As a result, the O&M cost remains high. A CSP with about 2 million users handles about 15,000 user complaints every month. Most faults are handled manually and about 70% faults need to be handled on site. HBB Intelligence Maintenance can reduce user complaints and site visits effectively.



Home Broadband Intelligent O&M Service Scope

Network-based complaints rising generally go through 3 phases as above. Based on the service layer, HBB O&M is divided into three case studies: Proactive Faults Prediction and Prevention, Massive fault interception, and Network fault intelligent diagnosis.

AN capabilities of the HBB intelligent O&M can be evolved into five levels:

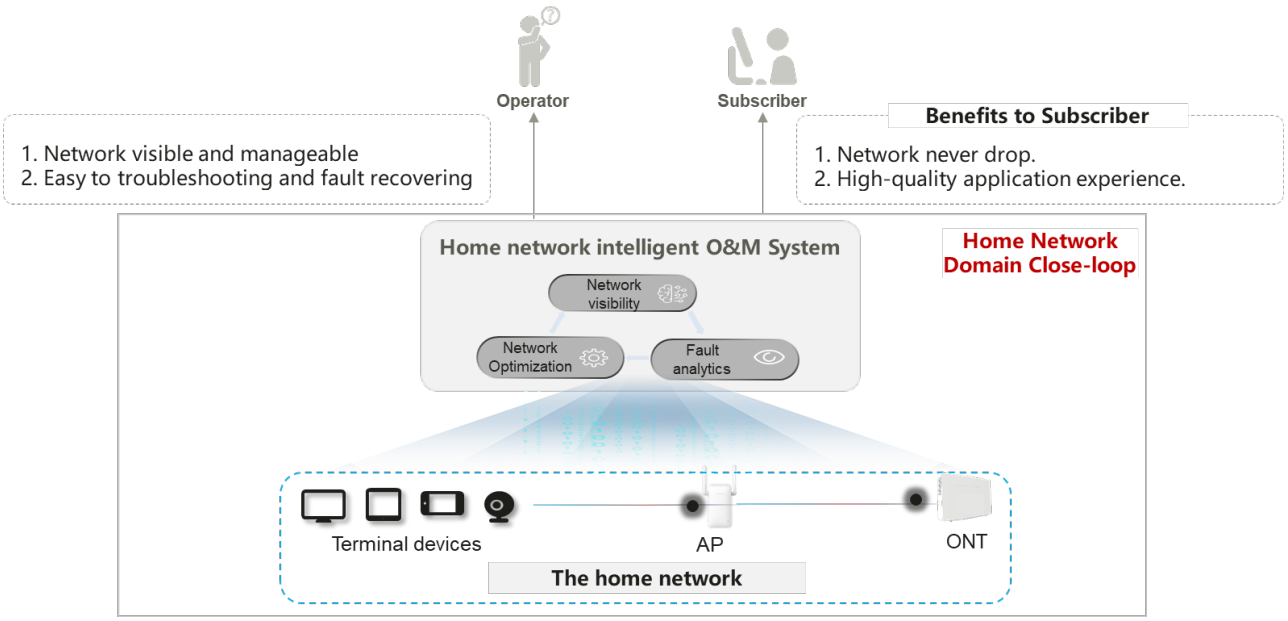
- L1 : Tool-assisted monitor network status, and troubleshooting, recovery. Events process automation rate is low.
- L2 : The system automatically detects port-level exception events, the system assists in root cause location, and automatically dispatches FMEs to rectify hardware faults onsite. Events process automation rate is medium.
- L3 : The system automatically detects service-level exception events. Automatically locates root causes, and recovery the software/configuration faults. The system automatically forecasts user compliant risks. Events process automation rate is high.
- L4 : The system automatically detects exception events in real time. The system automatically identifies root cause location, forecasts user compliant risks and makes decisions. Events process automation rate is very high.
- L5 : All-scenario automation(Events process automation rate is 100%.), with the same capability requirements as L4.

Case 5： Intelligent home network management to meet Bandwidth Experience Commitments

Majority of users' complaints are caused by the issues of home networking and home network equipment. As the traditional home network is unmanageable, resulting in long failure recovery cycle, high OPEX, and low user satisfaction. Therefore, operators need a more intelligent management system to create better broadband experience, reduce OPEX, analyze new requirements for the home intelligence networking and introduce new services opportunity.

The home network intelligent O&M solution can meet the requirements: Make the home network more visible, CSP easily monitor the status and indicators of the network continuously, and can determine whether the network is fault; Automatically identify the relationship of the user experience and indicators, find out the root cause of the network fault or poor experience, provide recommended solutions, and help operators to quickly and remotely troubleshooting; Automatically configure the device when root cause is related to some configuration, and

recoveries network failure or improve user experience before subscribers can perceive, so as to reduce complaints and improve subscribe satisfaction.



Home network domain close-loop

AN capabilities of the Intelligent home network management can be evolved into five levels:

- L1: Tool-assisted monitor network Topo and network status, operator can handle the network fault manually.
- L2: Continuously monitoring the home network, CSP can analyze the root cause manually and automatic recovery execution.
- L3: Automatic perception of abnormal status of home network, automatic identification of issues, and CSP can analyze the root cause manually.
- L4: Automatic root cause analysis, automatic generation of recovery solutions, automatic decision-making, and automatic recovery execution
- L5: All-scenario automation, with the same capability requirements as L4

Case 6: 5G Core Network Intelligent Operation and Maintenance

The core network plays an important role in the carrier network. A small potential risk or fault may cause service interruption or service quality deterioration on the entire network. After virtualized infrastructure and software-based network elements (NEs) are introduced to the 5G core network (5GC), network assurance involves the cooperation of multiple systems, such as virtual network functions (VNFs), physical devices, and virtualization software. This further increases the difficulty in predicting and preventing network risks and demarcating and locating faults. How to detect and prevent network risks, quickly demarcate and locate root causes of faults, and resolve problems before customer complaints without increasing O&M personnel and O&M costs is an urgent issue for telecom operators before large-scale 5G commercial use.

The Huawei 5GC intelligent O&M solution combines rich communication technology (CT) and information technology (IT) O&M analysis experience with artificial intelligence (AI), big data, and automation technologies. AI is used for model training, AI inference, intent insight, and intelligent analysis to mine log data, detect abnormal key performance indicators (KPIs), implement machine-assisted network change detection, and diagnose Network Functions Virtualization (NFV) cross-layer faults. In this way, core network faults and potential risks can be detected in advance and quickly demarcated and located. Moreover, performance monitoring, fault detection, and fault prevention can be implemented in routine maintenance and change scenarios of the core network, helping ensure normal running of the network and services.

- **Log analysis**: Based on O&M analysis experience, the AI and big data technologies are used to explore potential device risks in logs as a supplement to alarm events. In addition, multiple data sources such as logs and alarms are associated for intelligent analysis to detect network cloud faults and potential risks in advance and quickly demarcate and locate the faults.

- **KPI anomaly prevention and prediction and machine-assisted network change detection**: AI modeling and online detection are used to monitor NE KPIs in real time in various scenarios such as routine maintenance, key event assurance, and network change. In the early phase of a fault, exceptions are identified and reported in a timely manner, shortening the fault detection time. The accuracy of exception identification reaches 85%.

- **NFV cross-layer fault diagnosis**: The system comprehensively analyzes fault information, such as NE alarms, configurations, KPIs, and logs, in the space and time dimensions in the cross-layer topology to form a rule workflow for diagnosing faults. This helps automatically analyze and demarcate NFV cross-layer problems and shortens the cross-layer problem handling duration.

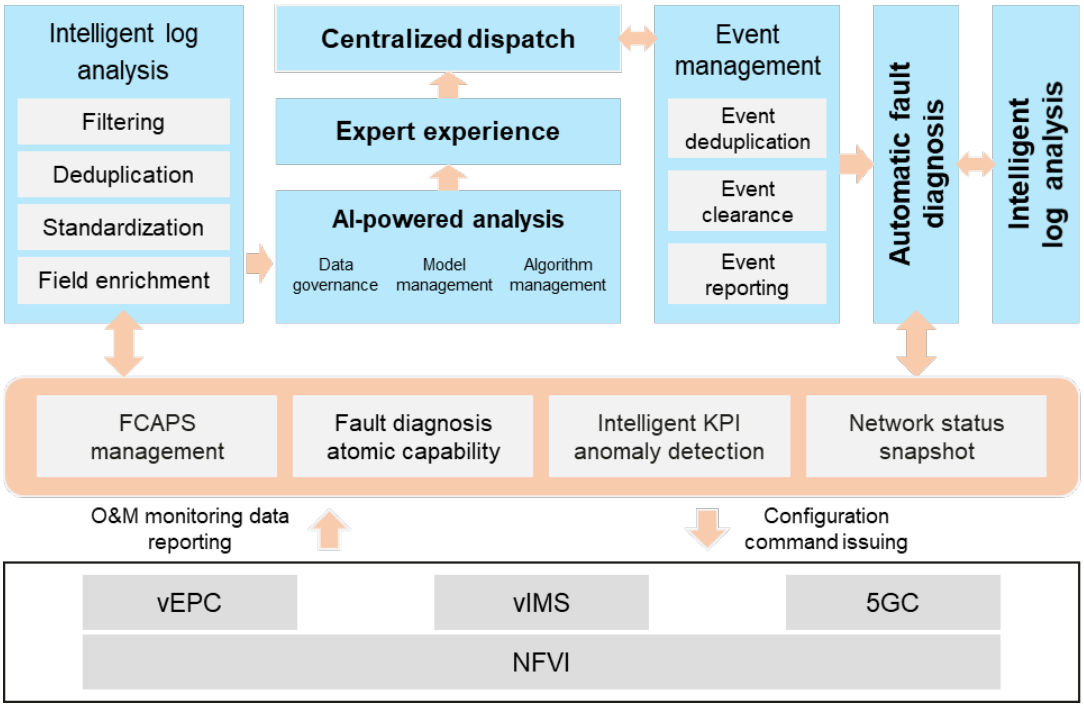


Figure: 5GC intelligent O&M system

The Autonomous Network Levels of the 5GC intelligent O&M are described as below.

- L1: assisted management . The system monitors the network running status in real time, reports alarms in a timely manner, and helps demarcate and locate faults, rectify faults, and restore services based on expert experience.
- L2: partially autonomous network. Static rule/policy based, Execution automation. In some fault scenarios, single-layer faults of a single NE are visualized, and exceptions of KPIs based on static thresholds are visualized and alarms are reported. Users use tools or the system to locate faults, and the system provides recovery suggestions to help users formulate recovery solutions.
- L3: conditionally autonomous network. Dynamic rule/policy based, Analysis automation. AI is preliminarily involved. The preset model of the system automatically identifies faults and report's fault events based on multidimensional data (alarms, KPIs, logs, and user records) in the space and time dimensions, and automatically demarcates faults based on preset fault scenarios to help formulate recovery solutions.
- L4: highly autonomous network. Intent driver, Closed-loop control, Decision automation. On the basis of L3, expert experience and AI are efficiently collaborated. The system automatically identifies service impacts and fault severity and reports them. The system presets repair templates or rules to implement fault self-healing in limited scenarios.
- L5: fully autonomous network. 5GC-related network risks and faults are automatically predicted, prevented, and rectified.

Benefits of 5GC Intelligent O&M

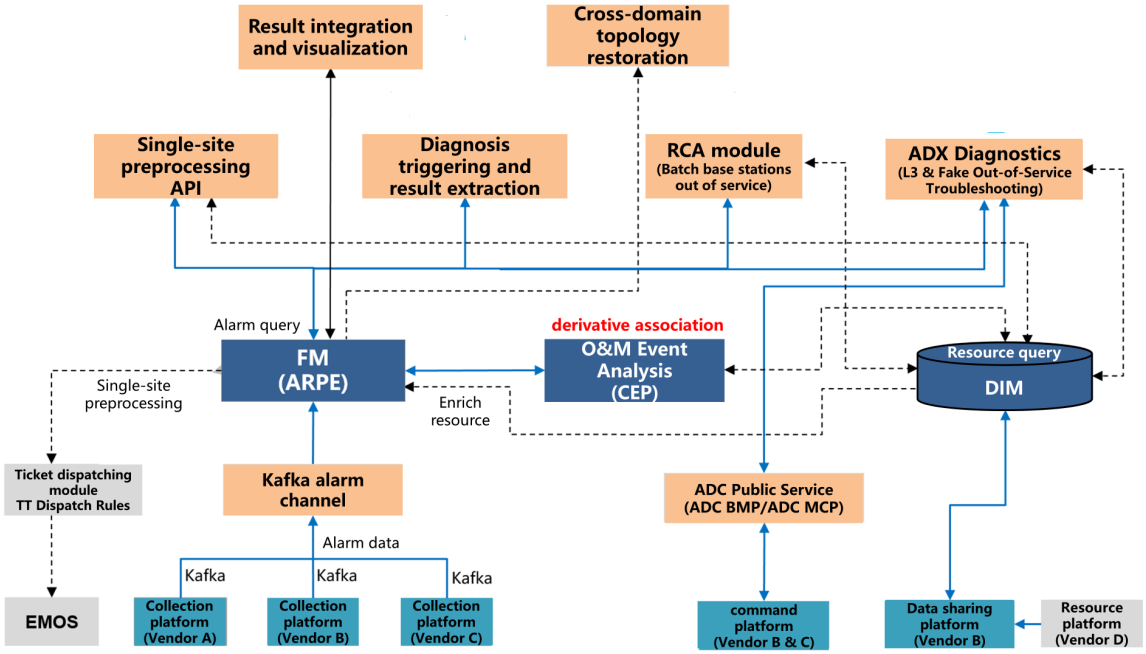
- Intelligent identification of potential risks: NFV logs are used to analyze network risks 15 minutes in advance, reducing the fault rate by 5%. Compared with the traditional method, KPI anomaly prevention and detection can identify 30% of core network service faults and network exceptions caused by NE configuration changes in advance and help quickly demarcate faults.
- Quick fault rectification: Typical faults are automatically diagnosed within 15 minutes. The time for locating the root cause of a network fault is reduced by 30%, and the Mean Time to Repair (MTTR) of major interruption faults is shortened by 35%.

Case 7: Intelligent batch 5G base station out of service detection and isolation

With the further expansion of the 4G/5G hybrid network scale, manual fault locating is often required when a sudden fault occurs. Because multiple technologies can be involved (e.g., IP, fiber, microwave, etc.), fault locating is difficult and time-consuming. Therefore, the intelligent root cause locating function needs to be added to help the monitoring front office to analyze and locate the fault root causes. This feature implements refined management of out-of-service faults of wireless base stations, distinguishes different fault causes, effectively detects unexpected faults, and enhances the management of out-of-service faults and incidents of wireless base stations.

To address existing challenges, the intelligent preprocessing of 5G base stations out of service in batches solution constructs autonomous capabilities in three scenarios:

- Intelligently mine alarm correlations with AI to implement intelligent identification of multi-vendor cross-domain faults and incidents.
- Automatic diagnosis of multi-vendor faults and incidents based on expert experience
- In-depth analysis of batch out-of-service faults and incidents through all-domain lossless information collection and association analysis



Business Value:

The intelligent preprocessing solution provided to the customer for 5G base station out-of-service in batches improves network autonomy, greatly improves maintenance efficiency, reduces a large number of invalid work orders, and improves the overall network quality. For example, in a project of a carrier in China:

- The customer's AN level score is improved from 1.5 to 2.8 according to the AN level methodology outlined in [1].
- The MTTR is reduced by 10% to 20%.
- Invalid work orders are reduced by more than 20%.
- The troubleshooting efficiency of maintenance personnel is improved in both front office (by 80%) and back office (by 25%)

Classification characteristics of L1-L5

The 5G batch base station out-of-service autonomous capability can be classified into the following five levels:

- Level 1: Assisted management: EMS assist to monitor 5G base station out-of-service alarms based on pre-configured monitoring rules, identify batch 5G base station out-of-service fault and incident, demarcate and locate root causes based on expert experience such as connectivity tests, and restore services manually.
- Level 2: Partially autonomous networks: Based on static rules, the system automatically enriches and standardizes alarms from different vendors, correlates cross-domain faults, locates faults and incidents via analyzing alarms and executing commands, and the system can automatically dispatch trouble tickets when 5G base station status are abnormal base on pre-configured trouble ticket dispatching rules.
- Level 3: Conditional autonomous network: The system support dynamic extension/adjustment on rules via self-learning 5G base station fault model. Based on that, the system provide 5G base station out-of-service faults and incidents identification. The system providing automatic decision-making based on pre-configured recovery policies.
- Level 4: Highly Autonomous Networks - intent/experience driven closed-loop control can be accomplished for cross-domain 5G base station faults and incidents under human

monitoring or intervention in emergency situations. The system can accurately identify and predict 5G base station faults in advance, predict and analyze massive faults and incidents automatically. In addition, the man-machine coordination mode is provided to assist decision-making for unsupported scenarios.

- Level 5 - Full autonomous network: This level is the end-goal for telecom network evolution. The system possesses closed loop automation capabilities across multiple services, multiple domains, and the entire lifecycle, achieving autonomous networks.

Rating and Actions Implemented at Current Achievement Levels

With the following functions in the intelligent preprocessing of 5G base stations out of service in batches solution, the AN level score of a carrier in China increases from 1.5 to 2.8.

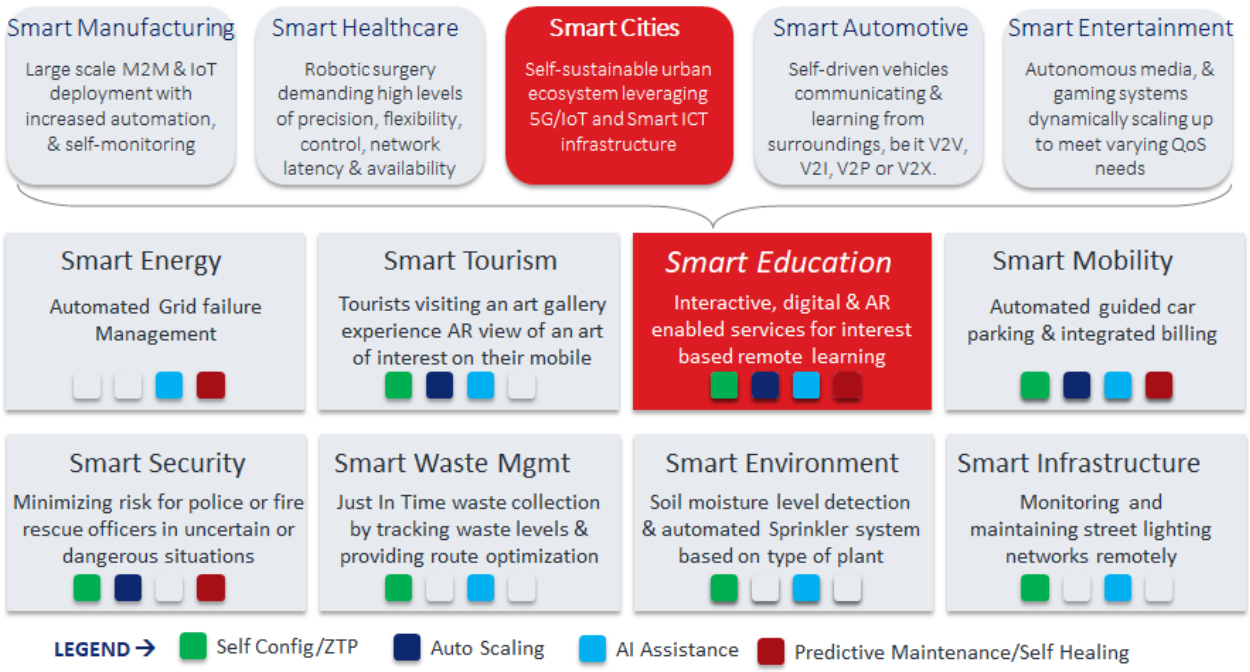
1. 5G network topology restoration
2. Single 5G base station out-of-service fault and incident demarcation and locating.
3. Wireless, transmission, and power cross-domain fault demarcation and engineering information check
4. Automatic diagnosis based on expert experience for fault and incident, such as backbone transmission fault and incident, batch 5G base station out-of-service fault and incident.

3. Case studies of business revenue enablement

3.1 Autonomous Networks hyperloops for enabling Smart-X industries

The advent of 5G is pushing CSPs to rethink their business models and to come up with new designs and deployment strategies to cater for vertical specific enterprise case studies. 5G adds the capacity and latency to support a wider range of case studies, device types and network architectures (edge, virtualization, network slicing, SD/NFV, SD-WAN, AI/ML), but it also comes with its own set of challenges such as increased network complexities and management issues. To address these challenges, CSPs need to rapidly adopt a new end-to-end architecture which is controlled and managed autonomously.

Autonomous Networks with zero wait, zero touch and zero trouble capabilities are needed to support the diverse set of vertical use case requirements. Once Autonomous Networks are in place, B2B companies like smart cities and service providers, B2C customers, digital service providers and telecom service providers will benefit from enhanced quality of seamless experience and improved operational efficiency. In addition, the end-to-end life cycle complexity will be hidden behind the scenes and experience assurance will in inbuilt. The new Autonomous Networks framework enables greater agility and provides best practices for much faster launch of new services and solutions.

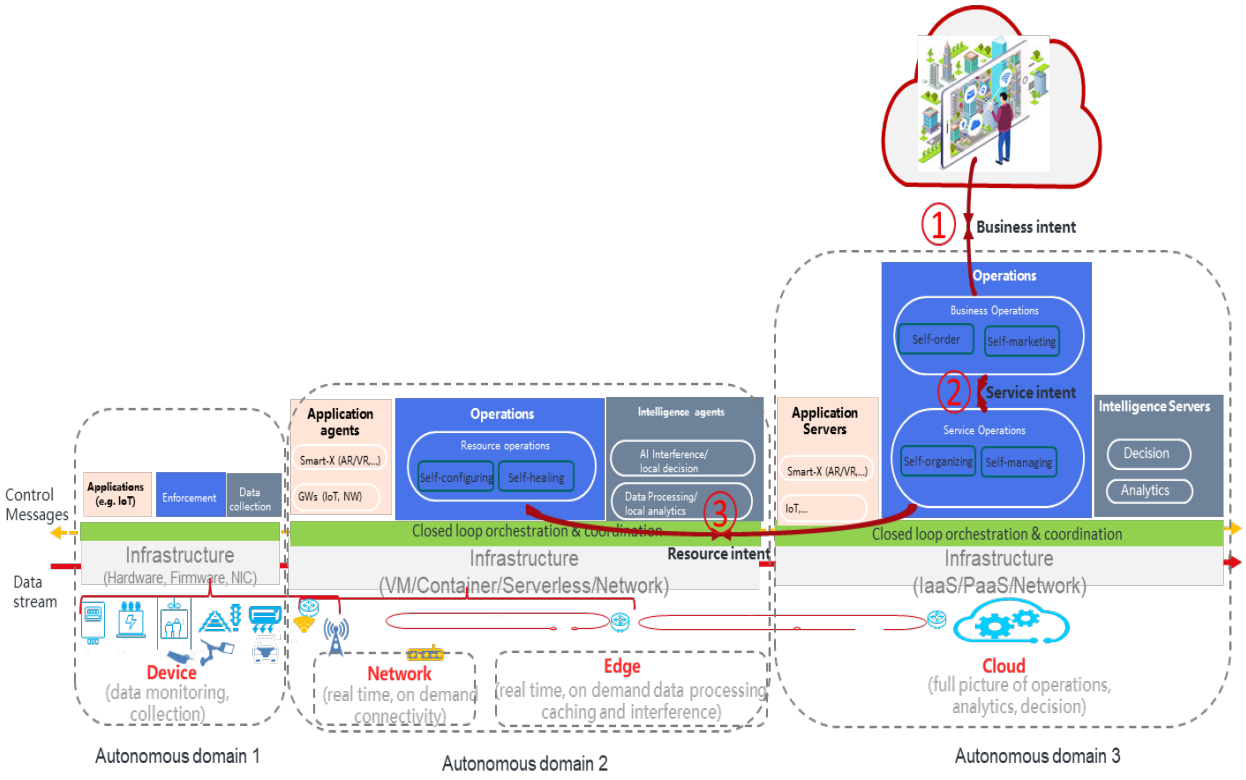


showing Smart-X industries' specific use case examples

The TM Forum catalyst project Autonomous Networks Hyperloops [4] demonstrates an E2E solution based on Autonomous Networks framework and capabilities as defined in chapter 4, to enable Zero-X customer experience and improved operational efficiency for B2B companies and DSPs in key Smart-X industries: City, Entertainment, Manufacturing, Healthcare, Agriculture and smart education (as demonstrated in the phase one use case).

The high-level solution architecture is illustrated in figure 16, which provides the key capabilities of Business Operations (BO), Service Operations (SO) and Resource Operations (RO) across three autonomous domains:

- Autonomous domain 1 (AD1) – Device. This AD supports different types of devices (e.g., IoT, AR/VR, AP/STB/mobile)
- Autonomous domain 2 (AD2) – Edge/access network. This AD supports the RO with real time processing and localization required for agents of connectivity, resource control, orchestration, data analytics and applications
- Autonomous domain 3 (AD3) – Cloud. This AD supports BO and SO for management and control, Intelligence & governance, as well as applications.



showing the high-level solution architecture for Autonomous Networks

The project illustrates a full life cycle of Autonomous Networks solutions and its requirements for dynamic business processes and models by leveraging cutting edge technologies like 5G, edge, AI, and virtualization.

The project aims to implement, verify and illustrates the key capabilities of Self-X (e.g., self-ordering, self-fulfilling and self-serving) in a full lifecycle of user/business/service/resource closed loops of Autonomous Networks solutions. It is based on business intent to resource intent interaction, which is a requirement for dynamic business processes and models. It is achieved by leveraging cutting edge technologies like 5G, Edge Computing, AI, and virtualization. The detailed information of the solution can be found in the Catalyst Project Whitepaper – ANHL [4][i].

The interacting closed loops to ensure full end-to-end lifecycle operation and management, as follows:

1. Business Closed Loop:

1a) Business Request: the user described their "Business Intent" (application attributes, SLA and key characteristics of AN services) to the “Business Operations (BO)” system in AD3 that requests AN services (e.g., xxx) for smart education.

1b) Business Fulfillment: the BO translates the business intent into Service Intention (e.g., connectivity, availability, security, and quality of experience) and send as Service Intent requests.

1c) Business Close Loop lifecycle management: The BO continuously guarantees that the Business intent is delivered and takes care of changes, if allowed, down to the termination.

2. Service Closed Loop:

2a) Service Request: the SO in AD3 translates the Service Intent into Resource Intent (Resource (bandwidth, computing/storage) and QoS (latency, jitter, packet loss)) according to the requirements of each RO.

2b) Service Fulfillment: the SO will interact and instruct "Resource Operation (RO)" in AD2 to deploy all required applications and orchestrate, manage, and monitor their resources.

2c) Service Close Loop lifecycle management: The SO continuously guarantees that the Service intent is delivered end to end by the different RO and takes care of the service changes, if allowed, down to service termination.

3. Resource Closed Loop:

3a) Resource Request/fulfillment: The RO of AD2 manages its resources to meet the needs of each service.

3b) Resource Fulfillment: The AD2 also transfers and processes applicable data flow in the edge node in real time.

3c) Resource Close Loop lifecycle management: Each RO continuously guarantees that the Resource intents are delivered by each AD and takes care of automatic reconfiguration of the network and IT resources (self-healing, self-optimizing) down to the releasing of the resources.

4. User closed loop with assurance:

4a) User closed loop is supported through streamlining the above 3 closed loops, not only for service delivery but for service assurance as follow.

4b) Each Autonomous Domain monitors abnormal events (e.g., performance and fault events, or security attacks), and alerts other affected Autonomous Domains. Each affected Autonomous Domain collaborates to figure out the solution and informs the BO and SO in AD3 when the solution is implemented, and the problem is resolved. The SO may be involved in managing and orchestrating cross-autonomous domain events in real time.

3c) User Close Loop lifecycle management. The BO, SO and RO are also in charge of the monitoring of the activity of the close loops (evaluation of the results of execution)

The mapping of Autonomous Levels:

- Level 2: one or multiple Self-X capabilities supported in one of the steps of one lifecycle of business, service or resource closed loops e.g., self-ordering, self-organizing or self-healing.
- Level 3: one or multiple Self-X capabilities supported in one or multiple full lifecycles of business, service or resource closed loops e.g., self-serving, self-fulfilling or self-assuring if applicable.
- Level 4: All Self-X capabilities supported in one or multiple full lifecycles of business, service or resource closed loops e.g., self-serving, self-fulfilling or self-assuring if applicable.
- Level 5: all Self-X capabilities supported in the full lifecycle of all closed loops

3.2 Autonomous Networks operations automation for vertical industries

Case 1: 5G slicing for enabling Smart Power Grid

The electric power industry raises requirements for high bandwidth, reliability, low latency, and large-capacity machine communication to communications networks. As a new-generation mobile communication technology, 5G features of high bandwidth, low latency, large

connections, and the network slicing can meet the virtual private network requirements of electric power grids. Four typical smart grid application scenarios for wireless communications networks include intelligent power distribution automation, information collection of low-voltage power consumption, and distributed power supply.

5G slicing can meet the requirements of Smart Power Grid automatically with Network resource evaluation, agile deployment of network slice and guarantee the SLA with closed loop assurance.

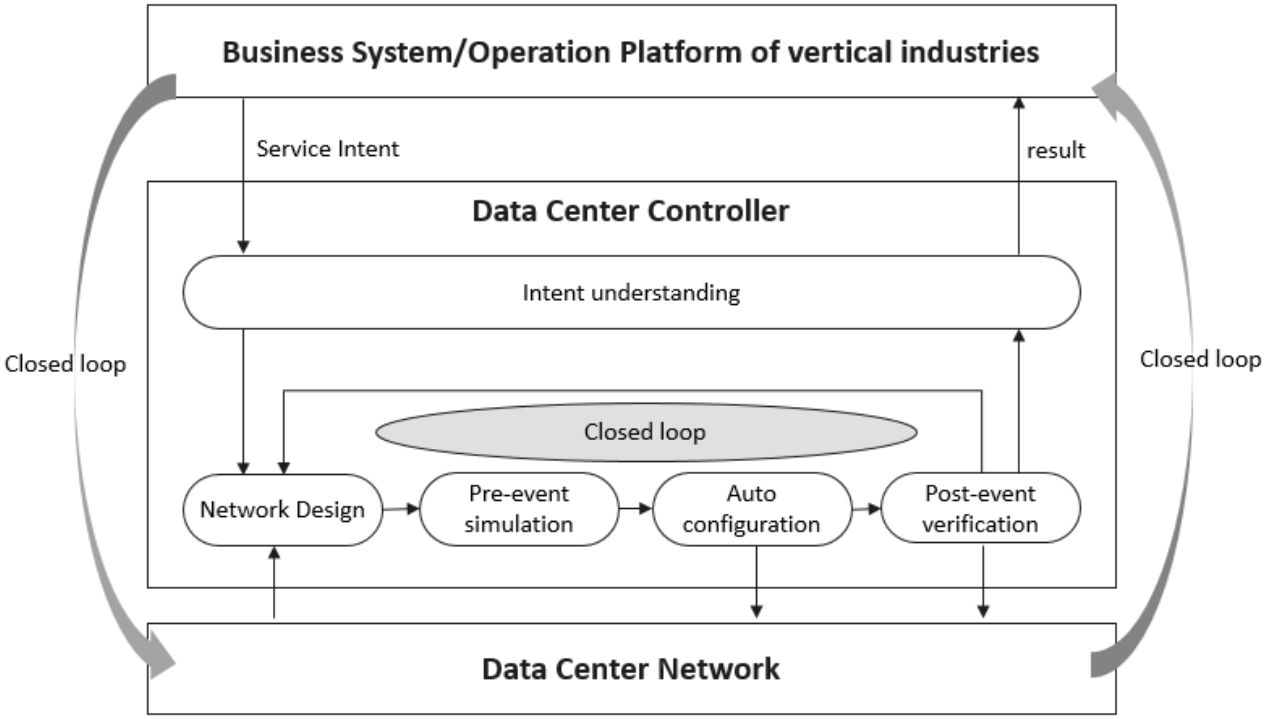
AN capabilities of 5G slicing for enabling Smart Power Grid can be evolved into five levels:

- L1： The system assists users in slice deployment adjustment and slice service verification, manually translate industry customers' service intents into network SLA requirements and manually design adjustment solution and manually determine.
- L2：The system can automatically execute deployment adjustment action , both human and system additionally design adjustment solution and determine, manually intent conversion
- L3： The system can additional automatically design adjustment solution based on the SLA requirements of industry slice tenants
- L4：automatic intent conversion ,automatic design adjustment solution ,automatic determine and deployment adjustment,automatic service verification
- L5：All-scenario automation, with the same capability requirements as L4

Case 2: Intelligent services fulfillment for enabling DC networks in vertical industries

Vertical industries, such as finance, Internet, government, CSP, transportation, and energy, are accelerating the upgrading of their business from offline to online to reduce CAPEX and OPEX. Therefore, the rapid development of online business requires that DC network services be quickly rolled out and quickly changed The DC network engineers must quickly design network and accurately configure networks based on fully understanding of vertical business.

With using service intent models for network design in various vertical industries, pre-event simulation mechanism, intelligent decision-making, automatic services configuration, post-event verification, E2E close-loop of network service fulfillment of DCN can be achieved.



E2E close-loop of service fulfillment for enabling DC networks in vertical industries

AN capabilities of Intelligent services fulfillment for enabling DC networks in vertical industries can be evolved into five levels:

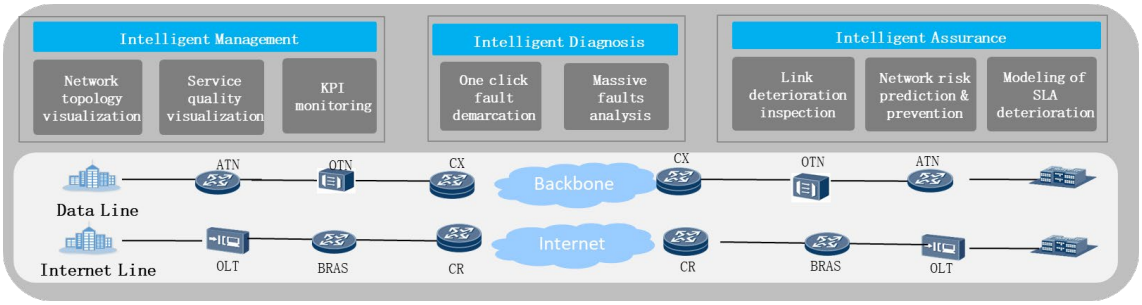
- L1: Manually convert service intent, manually define what resource to use, manually design network solution and make decision, manually deliver configurations, and verify service with offline tools.
- L2: System uses manual predefined rules to convert service intent, manually define what resource to use, system design network solution automatically, manually make decision based on the offline simulation result, system deliver configurations automatically, manually verify service with system tools and create verification report.
- L3: System convert build-in service intent automatically, system allocate resource and design network solution based on the real-time status of the Fabric network, manually make decision based on the online simulation result, system deliver configurations automatically, system verify service and create verification report automatically.
- L4: System convert customized service intent automatically, system allocate resource and design network solution based on the real-time status of the Fabric network, system make decision and deliver configurations automatically, system verify service and create verification report automatically.
- L5: All-scenario automation, with the same capability requirements as L4

Case 3: Intelligent Maintenance for Private Line Services provided to Vertical Industry enterprise

Private line services provide high quality and dedicated network line services for enterprises through OTN, PTN, PON, and IP networking. Private line service O&M faces many challenges such like various network types, complex application scenarios, and fault demarcation & locating across the multi network domains. The verticals like Bank, Hospital and Gaming have high expectation on Service Level Agreement (SLA). There are many complaints about private line services, among which 57% of complaints are caused by network interruption. Usually, fault

detection lags behind customer complaints. The enterprises are lack of the abilities on service quality awareness and quality monitoring, also fault diagnosis.

To address these challenges, intelligent O&M solution for private line services provide the capabilities through following three aspects, Intelligent management to enable service quality visualization, Intelligent diagnosis to enable high efficiency O&M; Intelligent assurance to enable fault prediction and prevention.



The Scope of Intelligent Maintenance for Private Line Services

With the adoption of intelligent O&M solution for private line services, enterprises can improve their network autonomy level, maintenance efficiency. Meantime, the private line service user's satisfaction is also improved. Take one project in China area for example, the network autonomy level was increased from 1.0 to 2.3, Mean Time to Resolution (MTTR) was decreased by 10%, the number of customer complaints was reduced by 10%, SLA violation rate was reduced by 10%.

The Autonomous Network Levels of the intelligent maintenance of private lines are described as below.

- Level 1 - Assisted Operation & Maintenance. EMS assist to monitor NE alarms and KPIs based on pre-configured monitoring rules. Demarcate and locate single-domain faults based on expert experience and restore services manually.
- Level 2 - Partial autonomous networks. The system provides visualized KPIs & SLA report based on static configured rules. The system can automatically prioritize the SLA assurance for verticals based on promised service rules. And the system can automatically dispatch trouble ticket when private line service status are abnormal base on pre-configured trouble ticket dispatching rules. The system support one-click fault demarcation and location function in single-domain.
- Level 3 - Conditional autonomous networks. The system support dynamic extension/adjustment on Root Cause Analysis (RCA) rules and Service Impact Analysis (SIA) rules based on the service status of private line. Based on that, the system provide service degradation analysis, service prediction and prevention function automatically.
- Level 4 - High autonomous networks. Intent/experience driven closed-loop control can be accomplished for cross-domain private line faults under human monitoring or intervention in emergency situations. The system can accurately identify and predict private line faults in advance, predict and analyze massive faults and incidents automatically. The automation rate of incident management of private line services can reach 90%.
- Level 5: Full autonomous networks. The system possesses closed loop automation capabilities across multiple services, multiple domains, and the entire lifecycle, achieving autonomous networks.

As introduced in the last paragraph, one of our private line customer's network autonomy level was improved from 1.0 to 2.3. To achieve this, we use several methods as described here.

1. System provides SIA visualization function to quickly detect private line faults. Identify problems before subscribers.

2. System provides SLA visibility function, ensures the availability of private line services. Ensure SLA for high-priority services and reduce the service violation rate.

3. System provides AI algorithms to automatically extending private line RCA rules, help operator locate more accurate fault root cause location.

4. System provides private line KPI curves and service trend analysis function, help operator locate fault and forecasting service.

5. System provides Expert diagnosis function which based on rules and expert experience. It greatly improves the troubleshooting efficiency.

6. System provide quality impact analysis when service network changes, help operator forecasting service impact.

Case 4: Intelligent and Automated O&M of 5G Customized Network Services for verticals

The large-scale commercialization of 5G is accelerating globally. With network capabilities such as "ultra-low latency, ultra-high reliability, and ultra-high mobility", it has empowered hundreds of industries to accelerate their digital transformation. 5G customized network refers to customized 5G network services provided to customers in vertical industries, especially for government and enterprise customers with “wide area priority, delay-sensitive, and security-sensitive”.

The intelligent and automated operation and maintenance of 5G customized networks should to meet: 1) needs of network capability customization and adaptation, according to different needs, based on user intention and service intention, the network capability and performance are intelligently identified and adapted; 2) needs of lower latency and higher stability, establish end-to-end service perception and intelligent guarantee solutions to meet the SLA requirements of users for different service; 3) needs of complex and diverse scenarios for enhancing AI capabilities, and give full play to the advantages of cloud computing power, the ability of enhancing AI model training, and AI analysis application.

In order to meet the above requirements and the needs of government and enterprise customers for 5G customized network, such as "personalized customization, end-to-end intelligence, cross domain collaboration, and Application on demand", China Telecom focuses on the three value scenarios of "network intelligent management, service intelligent operation, and Intelligent performance tuning", and builds a service support application platform for intelligent 5G customized network. The platform includes five capability centers and three intelligent engines, and realizes the functions of end-to-end intelligent perception analysis, high network performance prediction, and low-power scenario slice guarantee and so on. So, it realize full closed loop intelligent operation and maintenance of network. The platform architecture is shown in Figure 1.

The application platform has been deployed in 7 provinces and municipalities to effectively support the operation and maintenance of 5G customized networks for 7 government and enterprise customers.

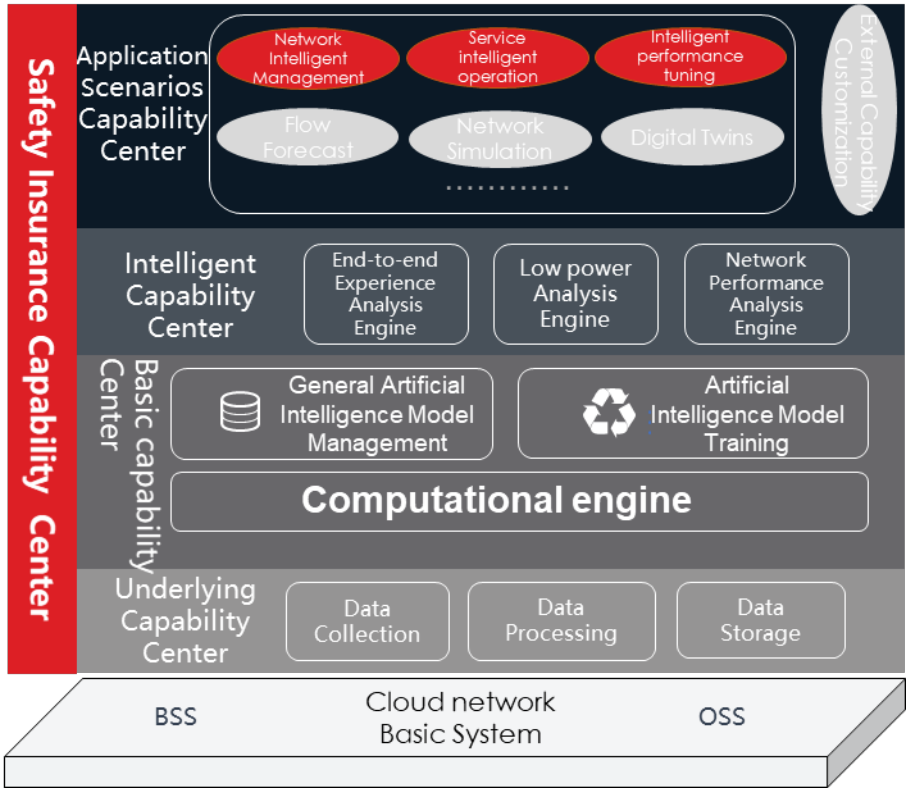


Figure: Architecture of 5G customized network service support application system

The L1-L5 classification characteristics of AN capabilities of 5G customized networks are as follows:

- L1: Assisted operation and maintenance. Engineers/experts formulate customized network optimization strategies to meet various network requirements, system-assisted execution, engineers/experts focus on problem analysis and decision-making.
- L2: Partial autonomy. The end-to-end experience analysis engine perceives the performance and hidden dangers of the customized network in real time, and for common network problems, the system automatically executes the adjustment and optimization strategies formulated by experts in advance.
- L3: Conditional autonomy. The system automatically perceives network problems in the customized network, the network performance analysis engine automatically performs root cause analysis, and provides network adjustment and optimization strategies, and sends them to the system to automatically execute the strategy. Under certain circumstances, the optimization strategy formulated by the engineers/experts.
- L4: High autonomy. The system perceives user experience and network operation issues based on user intent and service intent, and then the network performance analysis engine provides network adjustment and optimization strategy and sends it to the system to automatically execute the strategy, forming a closed-loop control from intent to decision. Engineers/experts focus on the management of intentional AI models and scenarios that the system cannot handle
- L5: Full autonomy. On the basis of L4, AI models and network optimization strategies for specific scenarios can be automatically updated, and engineers/experts only need to monitor the operating status of the network system.

The intelligent and automatic operation and maintenance of 5G customized network has been tried in many places, which greatly improves the maintenance efficiency and operation efficiency of the network. In the aspect of network intelligent management, the network autonomy and adaptive optimization ability have been expanded, and the accuracy rate of performance

prediction model has reached 93.8%, which is 30.4% higher than the early warning accuracy rate of artificial rules; In terms of service intelligent operation, it has created the end-to-end experience and analysis capability of the network. The running customized network of an enterprise intelligent park has 238 device connections and daily flow of 839.4 GB, realizing the end-to-end support capability of SLA; In the aspect of Intelligent performance tuning, the average daily power consumption of the pilot community is reduced by more than 20%, and the annual power saving is 5 million kWh, and the electricity cost is saved more than 1 million dollars.

4. References

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4. TM Forum Catalyst project, Autonomous Networks Hyperloops, 2020.

5. Administrative

5.1 Document History

5.1.1 Version History

Version Number	Date Modified	Modified by:	Description of changes
1.0.0 r1	05-May-2021	Dong Sun	Initial draft split from IG1218 v1.1.0 Appendices
1.0.0 r2	10-May-2021	Dong sun	Add a new use case, contributed by Huawei
1.0.0 r3	17-May-2021	Dong sun	Add new case studies, contributed by Huawei & China Telecom, China Mobile
1.0.0 r4	24-May-2021	Dong sun	Add new case studies, contributed by Huawei & China Telecom, China Mobile
1.0.0 r5	27-May-2021	Dong sun	Editorial changes per comments
1.0.0 r6	28-May-2021	Dong sun	Editorial changes per comments
1.0.0	28-May-2021	Alan Pope	Final edits prior to publication

5.1.2 Release History

Release Status	Date Modified	Modified by:	Description of changes
Pre-production	28-May-2021	Alan Pope	Initial release
Production	26-Jul-2021	Adrienne Walcott	Updated to reflect TM Forum Approved Status

5.2 Acknowledgments

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