Autonomous Network Technology Innovation in Digital and Intelligent Era

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Abstract: The issues of wireless communication network autonomy, the definition of capability level and the concept of AI-native solution based on the integration of the information communication data technology (ICDT) are first introduced in this paper. A series of innovative technologies proposed by ZTE Corporation, such as an autonomous evolution network and intelligent orchestration network, are then analyzed. These technologies are developed to realize the evolution of wireless networks to Level-4 and Level-5 intelligent networks. It is expected that the future AI-native intelligent network system will be built based on innovative technologies such as digital twins, intent-based networking, and the data plane and intelligent plane. These new technical paradigms will promote the development of intelligent B5G and 6G networks.

Keywords: autonomous network; digtal twin; AI-native

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Wireless communication networks are moving from the era of interconnection and cloud to the era of intelligence. The Telecom Management Forum (TMF) has proposed the concept of autonomous networks (AN), which aims to use automation and intelligence technologies to help operators simplify business deployment and enable network capabilities of self-configuration, self-optimization, self-healing and self-evolution. At present, with the emergence of intelligent application scenarios, AN is developing rapidly. The integration of the open network automation platform (ONAP), RAN intelligent controller (RIC) and AN is becoming a hierarchical closed loop and new technologies such as intent-based networks and digital twin networks (DTN) are also being introduced.

1 Concept and Progress of Autonomous Network

1.1 Definition of Autonomous Network

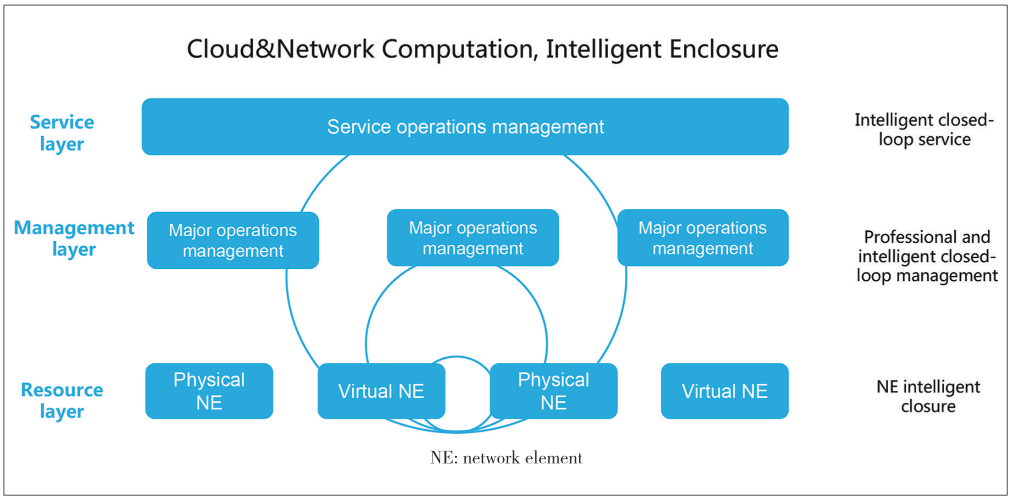
As an industry-recognized systematic method to promote network automation and intelligence, AN can not only help operators "realize network intelligence, enable intelligent services, and promote business intelligence", but also become the intersection of "network technology and digital technology"[1]. AN is expected to be a new driving force for a new round of technological innovation and industrial transformation, to be a new strategic fulcrum for leveraging the upgrading and evolution of the communication industry, to drive network services to open a new era of digitalization, intelligence and greening, and to enable the digitalization transformation of thousands of industries[2]. Fig. 1 shows a typical closed-loop architecture of AN[3].

AN aims to provide vertical industries and consumers with the ultimate experience of Zero-X (zero-wait, zero-contact and zero-fault) through fully automated networks and ICT infrastructure, agile operation, and full-scenario services. By using AI technologies, the AN leaves the complexity to the supplier and minimizes the complexity for the customer. AN helps the operators build and maintain the operation and maintenance (O&M) of Self-X (self-service, self-distribution and self-guarantee), and also enables the departments of network planning and construction, marketing service, and operation and maintenance to achieve the automation and intelligence of production, operation and management.

1.2 Application Scenarios of Autonomous Network

The AN application scenarios in a mobile communication system are divided into two types: intelligent network O&M and intelligent network elements (NE).

In the scenario of intelligent network O&M, AN can implement intelligent improvement of overall network O&M, improving the efficiency of the network and O&M. For example, intelligent energy saving is used to guarantee base station operation and dynamic energy saving. Intelligent MIMO is used to implement accurate scenario identification and ultra-fast op-



▲Figure 1. Closed-loop architecture of autonomous network

timization of antenna weights. Intelligent troubleshooting is used to implement accurate fault location and alarm work order reduction. Intelligent optical access is used to implement weak optical root cause analysis and poor video quality analysis. Intelligent edge technology is used to achieve intelligent coordination at the cloud edge and facilitate vertical industrial applications. Virtualized infrastructure intelligent O&M implements cross-layer management and location of virtualized system O&M problems and makes accurate predictions of cloud system faults. Intelligent slicing implements dynamic scheduling of slice resources and accurate guarantee of end-to-end (E2E) Service-Level Agreement (SLA). Intelligent operation can realize the management and analysis of all data in the whole domain and support the integrated operation of E2E's user perception guarantee and network life cycle.

AN uses AI capabilities to orchestrate network resources intelligently, in order to enable Intelligent NEs. Intelligent orchestration networks with adaptive scenario intentions are built based on user experience, following the capability vision of demand-based orchestration and the basic framework of endogenous intelligence. Through deep coordination between macro-level network orchestration and micro-level user orchestration, intent-driven joint optimization is achieved, which realizes NE-level intelligence.

1.3 Definition of Intelligent AN Model

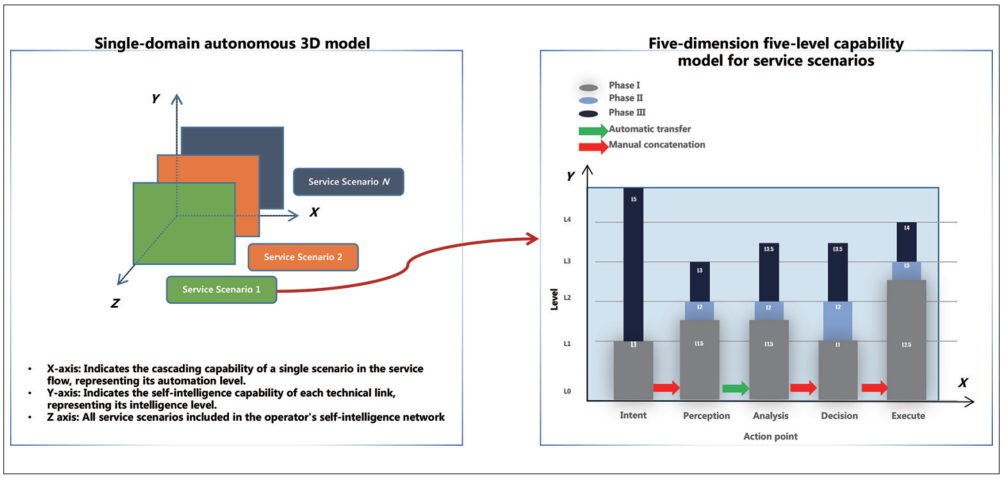
Based on the classification definition of autopilot networks in the industry[3], TMF has constructed a five-level capability classification system for communication network autonomy, and macroscopically defined the classification standard of autopilot networks with L0 – L5 levels. L0 refers to manual intervention with no automation ability, while L5 supports complete intelligence of the network with the ability of self-learning and self-evolution. Besides, L2 enables closed-loop O&M automation of a specific NE in a given external environment based on an AI model. L3 further perceives changes in the real-time environment and implements intention-based closed-loop automatic management in a specific network domain. Based on prediction, L4 realizes closed-loop automatic management driven by customer experience and business quality in a complex cross-domain environment.

In traditional system construction, we usually focus on the real problems that can be solved by a tool or a system, the available systems in different scenarios of network planning, maintenance and operation, and whether this discrete tool can evolve from manual to automatic and intelligent. However, neither a stable workflow nor the organic integration of scenarios, intelligent levels and other factors are considered. As a result, each system has its own way and plays its own role, which finally leads to the chimney effect that is amplified year by year. With the emphasis on single-domain self-governance and intelligent system construction, the existing capability level definition is no longer fully suitable for the continuous development of future industries and competitiveness. Therefore, we comprehensively consider the collaboration between humans and AI from the aspects of intention, perception, analysis, decision-making and execution, and refine the evaluation model of network intelligence capability in scenarios. Fig. 2 shows a reference model architecture defined according to the five-dimension and five-level capability model of business scenarios.

1.4 Standardization Progress of Autonomous Network

With the development of standards and industries, the concept of AN has reached a consensus in academia and industry. The leading operators and suppliers work around the four elements of "target architecture, grading standards, evaluation system and operation practice" to push the AN industry from the incubation period to the promotion period. Industrial and standardization organizations, such as Next Generation Mobile Networks Alliance (NGMN), TMF, ITU, 3GPP, ETSI and China Communications Standards Association (CCSA), have initiated related standardization and research programs and established a cross-organization AN collaboration platform M-SDO to accelerate the implementation of industry standards.

The three key study fields of NGMN in AN are E2E decoupling, green future networks and 6G. The TMF autonomous network project team (ANP) is divided into two lines: business architecture (BA) and technical architecture (TA). TMF has released several standards on multiple hot technologies such as the autonomous network architecture, hierarchy,



▲Figure 2. Reference capability model architecture of autonomous network

intention, closed loop and M-SDO. ITU SG13 focuses on future networks (including IMT-2020), cloud computing and trusted network infrastructure. ITU Focus Group on Autonomous Networks (FG-AN) was established in December 2020 to focus on the pre-research of autonomous network standards. It has released Y.317X series specifications of the requirements, architecture and levels related to the intelligence of autonomous networks. Moreover, the standardization of specific intentions, perceptions and sandboxes is under research. The 3GPP has defined the standards and specifications related to AN from R16. Its working group SA5 undertakes the most projects related to AN, including the standards and specifications of the autonomous network level (ANL), closed-loop control, intent-driven management service (IDMS) and enterprise management data analysis (eMDA). CCSA Network Management and Operation Support Committee (TC7) takes operation management intelligence as the core evolution content. Many meaningful specifications have been released, such as the definition of several functions including 3GPP Network Data Analytics Function (NWDAF) and Management Data Analytics Function (MDAF).

2 Technology Innovation of Autonomous Network

2.1 ZTE uSmartNet

ZTE Corporation has proposed a self-evolving network uSmartnet[4], which adopts the universal AI technology and can be deeply embedded in all levels of the communication network to realize a unified autonomous system. This solution promotes the continuous improvement of network intelligence capabilities by comprehensively introducing AI-enabling technologies into the network infrastructure layer, O&M layer and business operation layer, realizing the network voluntary, simple O&M, and random service.

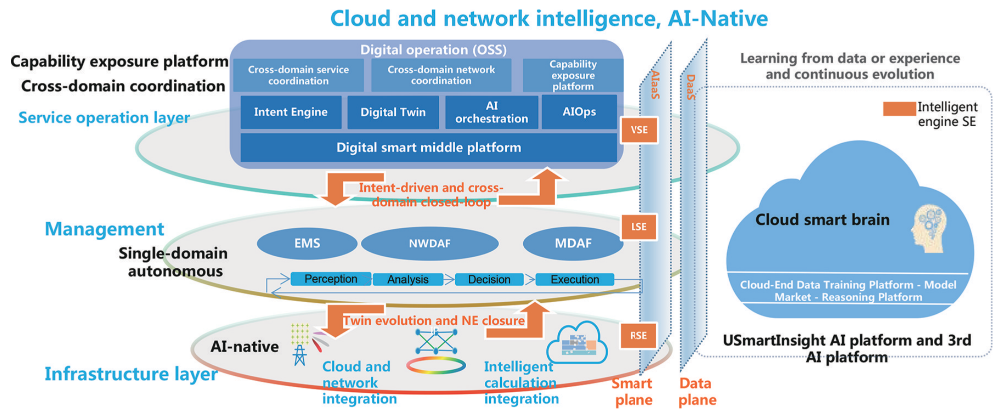
At the network infrastructure layer, AI engines are embedded in NEs to support AI-endogenous infrastructure. At the O&M management layer, single-domain autonomy is achieved through the introduction of an intelligent closed-loop mechanism of perception, analysis, decision making and execution. At the business operation layer, the openness of O&M capabilities and the cross-domain business and network collaboration are realized based on the construction and interconnection of the data middle platform and intelligence middle platform, with the introduction of technical capabilities such as intention engine, digital twins, intelligent orchestration and capability opening.

In terms of technical architecture evolution, Data as a Service (DaaS) and AI as a Service (AIaaS) will be implemented in future networks based on the logic functions of the AI-native data plane and intelligent plane. The cloud smart brain, composed of a cloud-based data lake, AI training platform, model market, and inference platform, provides AI model training and inference capabilities. Fig. 3 shows the technical architecture of the autonomous network uSmartNet.

2.2 Network Cross-Domain Collaboration Technology

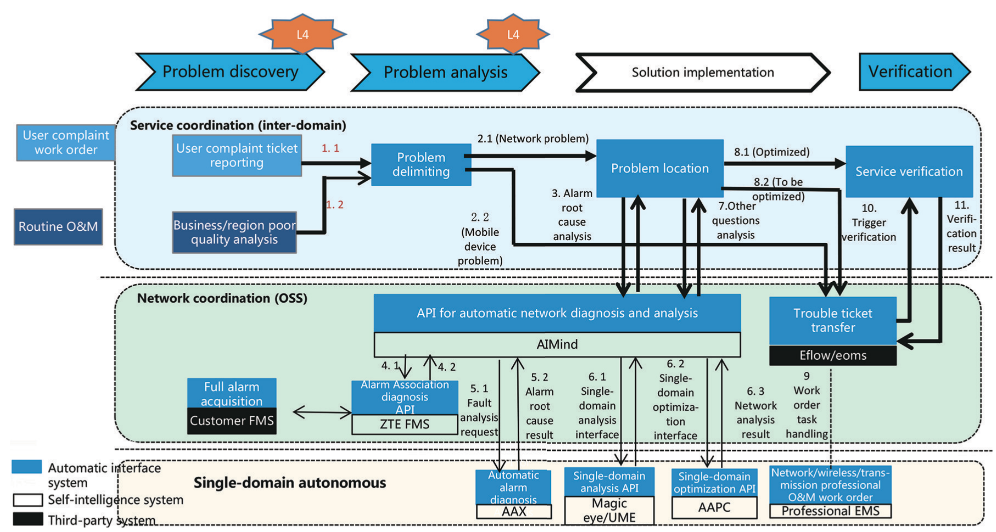
The cross-domain system is located in the upper layer of an O&M management network. The cross-domain collaboration includes cross-domain business collaboration and cross-domain network collaboration. The former mainly focuses on the service indicators oriented to improving user perception and on the guarantee and improvement of end-to-end service experience. The latter is the coordination of the upper-layer operators' quality centers and fault centers at the O&M layer and the underlying single-domain autonomous system, such as the radio access network (RAN), core network (CN) and transmission bearer system. It ensures the closed-loop processing of workflows, O&M and troubleshooting, as well as user experience in closed-loop O&M. Based on capability collaboration, it provides capability openness to operators and third-party customers through a unified capability opening platform and interface and facilitates low-code development services and network capability services.

We take the cross-domain deployment of an automatic quality optimization system based on business awareness as a use case to show cross-domain collaboration (Fig. 4), where the following two typical application scenarios are considered: 1) Troubleshooting of Voice over LTE (VoLTE), evolved packet system (EPS) fallback and Voice over 5G New Radio (VoNR) services, and cross-domain analysis and result verification from E2E terminals to wireless networks, to bearer networks,



AI: artificial intelligence
AIaaS: AI as a service
AIOps: artificial intelligence for IT operations
DaaS: Data as a Service
EMS: element management systems
LSE: light smart engine
MDAF: Management Data Analytics Function
NE: network element
NWDAF: Network Data Analytics Function
OSS: Operation Support Systems
RSE: real-time smart engine
SE: smart engine
VSE: VMAX smart engine

▲Figure 3. Technical architecture of ZTE uSmartNet



AAPC: artificial intelligence automatic parameter control
AAX: automatic alerting X–function
API: Application Program Interface
EMS: element management system
FMS: fault management system
O&M: operation and maintenance
OSS: operations support systems
UME: Unified Management Element

▲Figure 4. Cross-domain collaborative deployment framework

and to core networks; 2) Problem identification of web, video games and cloud virtual reality/augmented reality (VR/AR) services, and E2E network cross-domain analysis and result verification.

Building a complete O&M closed loop through service coordination and O&M systems can implement a loop from problem discovery, problem analysis and fault delimitation to subsequent closed-loop control and verification, as well as a loop from the operations support system (OSS) to the bottom single domain system. This cross-domain collaborative system can greatly improve the efficiency of E2E network O&M and effectiveness of work order flow.

For such cross-domain systems, AN has some new requirements for capability characteristics as follows:

- Enabling interconnection with the complaint work order system and improving complaint scenarios;
- Interfacing with the FMS system and improving the alarm diagnosis ability;
- Enabling interconnection with the network collaboration system to improve the capability of diagnosing and analyzing NEs, users and service problems in the system;
- Connecting professional platform capabilities of such single domains as the core, wireless and transmission to form complete analysis capabilities;
- Enabling interconnection with the work order transfer system of the customer;
- Enabling interconnection with the capability exposure system to implement automatic orchestration of processes.

2.3 Network Intelligent Orchestration Technology

With the gradual scale-up of 5G commercial networks and the fundamental proposition of improving the value and economic benefits of the 5G network, the contradiction between the increasing diversification of 2B+2C (to Business and to Consumer) services and the relatively fixed network resource strategy has become increasingly prominent. Within the limited network resources, we need to provide better services for users and business with more differentiated needs. The transformation from the network-centric resource allocation strategy to a user-centric precise resource service mode is necessary to achieve the best balance between user experience and network efficiency.

Wireless intelligent orchestration is a solution that is based on the computing engine of the IT BBU endogenous intelligence. It conducts multi-dimensional perception and learning of many factors in the network (such as terminal capability and service requirement). In a multi-layer network, user orchestration and network orchestration are the two wheels driving the flexible orchestration of network service capabilities to be realized. The flexible orchestration based on network service capabilities enables the precise empowerment of the network and brings the optimal resolution of user experience and network efficiency.

An intelligent orchestration solution[5] includes user orchestration and network orchestration. The former is to orchestrate the service combination capability of multiple frequency points in the network, with given network service capabilities (fixed spectrum configuration). When the user experience of a service is lower than its experience baseline, an optimal solution will be provided based on the service requirement and terminal capability, which will guide the user to another cell with better service experience. The latter is based on a given traffic distribution situation. If the current network configuration cannot meet user experience requirements, flexible orchestration of network service capabilities will be carried out based on spectrum, carrier, frame structure and beam. In this way, together with traffic trend prediction, self-adaptive network service capability sets based on the current traffic trend can be achieved, thus improving user experience.

Fig. 5 shows the evolution of the intelligent wireless orchestration capability. An intelligent orchestration network is intention-driven instead of experience-driven, aims at meeting differentiated value demands of different development stages and in different scenarios, and achieves accurate matching with the intention customization and orchestration capabilities of network service operation objectives. It changes single-domain orchestration driven by wireless domain experience to cross-domain orchestration based on knowledge plane empowerment, driving the evolution of diversified intelligent service capabilities from user experience to network values. It can also achieve the optimal joint orchestration driven by the intention through the deep coordination between the network orchestration at the macro level and the user orchestration at the micro level. In addition, the integrated orchestration architecture of 2B and 2C and the evolution of the multi-target intelligent resource management capability facilitate the best unity of service differentiation and capability consistency.

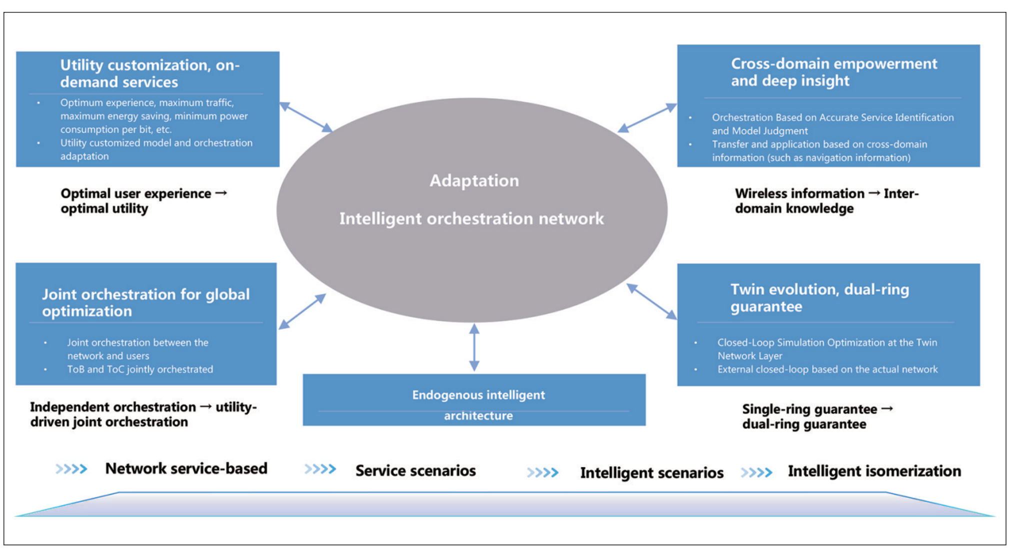
The single-layer closed loop is replaced by a dual-layer closed loop in an intelligent orchestration network. This relies on the high-precision digital modeling and simulation capabilities provided by the digital twin technology to implement efficient search, effect prediction and closed-loop optimization of the virtual network for optimal orchestration solutions in the virtual world. The optimal accurate orchestration capability is also available based on the optimal solutions provided by the digital twin technology and the closed-loop optimization of the physical network.

2.4 AIOps Technology and Algorithm

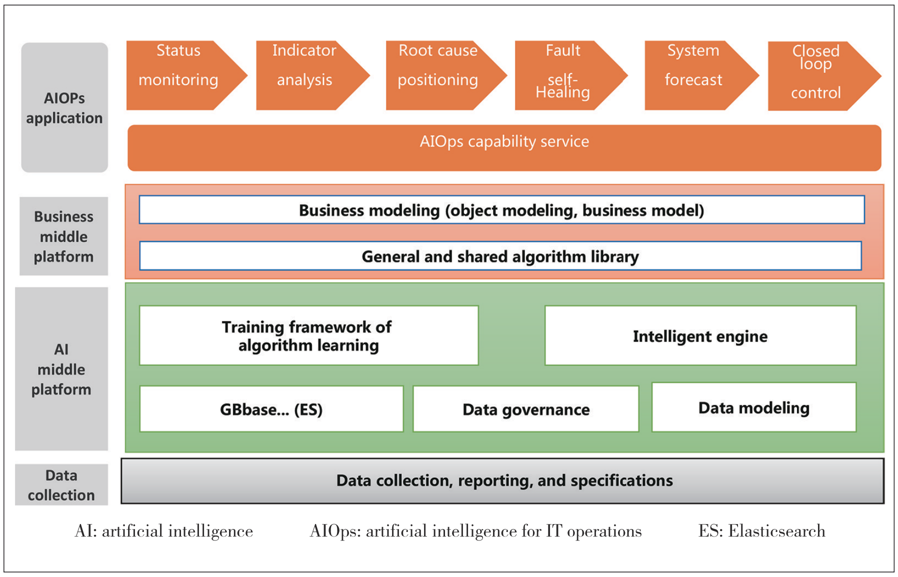
Artificial intelligence for IT operations (AIOps)[6] adopts some generalized AI technologies (rules, knowledge base, machine learning, deep learning, etc.) to implement intelligent operation and maintenance of the network. The application functions of AIOps mainly include status monitoring, index analysis, root cause location, fault self-healing and system prediction of network business operation and maintenance. These will transform the network operation and maintenance from passive to predictable.

The emergence of AIOps transforms the traditional human-machine O&M mode into a human-machine coordination O&M mode. Human-machine coordination uses artificial intelligence technologies such as machine learning (ML) and deep learning (DL) to transfer the algorithms used for network O&M scenarios to O&M tools and facilitates the operation and maintenance through actions such as perception, analysis, decision-making and execution. The AIOps mode gives network O&M management the algorithm and ML ability, makes operation and maintenance intelligent, sublimates data into knowledge, and further promotes the learning ability of machines to form a closed-loop operation and maintenance mode with self-decision-making and self-execution of machines.

AIOps has abundant and diversified use cases and algo-



▲Figure 5. Evolution of intelligent orchestration network



▲Figure 6. AIOps service platform framework

rithms. How to maximize sharing and algorithm optimization is the focus of AIOps. AIOps uses the middle platform to share and reuse components and functions and uses the algorithm library to optimize and generalize algorithms. A unified AIOps platform is composed of the service middle platform, data middle platform and AI middle platform. The service middle platform is responsible for the service capability and capability opening components of the service. The data middle platform is responsible for unified data collection, governance and service provision. The AI middle platform provides the model training and reasoning capabilities of intelligent applications. Fig. 6 shows the service platform framework of the wireless AIOps.

The AIOps-oriented algorithms and application scenarios are as follows:

1) Multi-index association mining: Multi-index association analysis determines whether multiple indexes fluctuate or increase frequently. This algorithm can be used to build fault propagation relationships for fault diagnosis. Common algorithms are Pearson correlation, Spearman correlation and Kendall correlation.

2) Indicator clustering: Multiple key performance indicators (KPIs) are clustered into multiple categories in accordance with the curve similarity. This algorithm can be used for large-scale indicator exception detection. It uses the same exception detection algorithm and parameters in the same indicator type, greatly reducing the training and detection costs. Common algorithms include Density-Based Spatial Clustering of Applications with Noise (DBSCAN), K-medoids and Clustering Algorithm Based on Random Selection (CLARANS).

3) Index and event association mining: The association between events and indicators in text data is automatically mined to establish fault propagation relationships and diagnose faults. Common algorithms are Pearson correlation, J-measure and the two-sample test.

4) KPI trend prediction: By analyzing historical KPI data, KPI trends and predicted values can be determined in the future and then used for abnormal detection, capacity prediction and capacity planning. Common algorithms include the Holt-Winters, time sequence data decomposition and Autoregressive Integrated Moving Average (ARIMA) model.

5) Event and event association mining: Analysis of the association relationship of abnormal events associates the events that occur frequently together in history. This algorithm can be used to build fault propagation relationships for fault diagnosis. Common algorithms include FP-Growth, Apriori and the random forest.

6) Fault propagation relation mining: It combines text data and index data. Based on the above-mentioned algorithms (such as the multi-index association mining, index-event association mining and event-event association mining), the module invocation relation diagram derived from tracing, the auxiliary server-network topology, and the fault propagation relation between components are established. This algorithm is applicable to fault diagnosis.

3 Development Trends of Autonomous Network Technologies

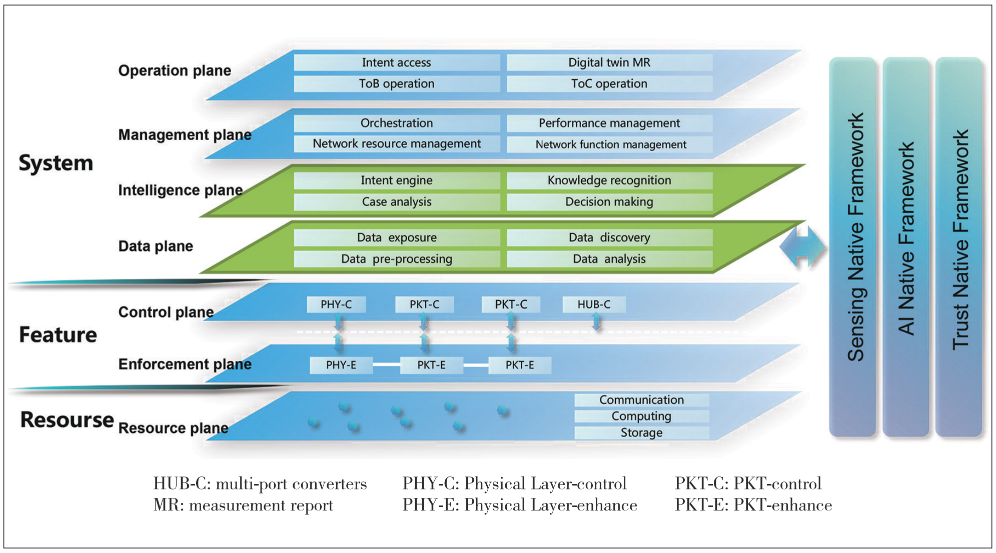
In the future, AN may evolve toward a "multi-service intelligent connection and digital-twin enabled" 6G system[7] and also to the L5-level intelligent capability. The evolution may encounter the problems of current network intelligent plugins and lack of standardization, more application generalization problems of ICDT technologies, and the problems caused by the limitations of the AI technology itself. These problems will be solved with the AI-native technology architecture and more emerging technologies, such as graph neural networks, digital twin networks and self-learning technology, which will direct the technological development trend of autonomous networks.

3.1 AI-Native Architecture

The technological development of AN is presenting a trend of scene intelligence and AI-native system.

Scene intelligence can achieve efficient and precise scenario-based services and continuous evolution through effective, scenario-sensible, policy-flexible and controllable closed-loop intelligence.

AI-native integrated network architecture (Fig. 7) is based on the deep integration of AI computing capabilities and the communication process. It can comprehensively improve the intelligent learning and scenario adaptation capabilities of different levels and support the continuous evolution of personal-



▲**Figure 7. Architecture of AI-native network system**

ized intelligent service ability. The intelligent plane and data plane are integrated into the network architecture design and implementation of NEs and interfaces, so that future intelligent networks will be self-adaptive, self-learning self-correcting and self-optimizing. The main features of an AI-native system are as follows:

1) It can provide complete AI capabilities in the communication network defined by 3GPP standards, including data, computing power and algorithm capabilities.

2) In terms of communication network architecture, it fully considers the application requirements of the future intelligent plane at the functional and logical levels.

3) In the future, the protocol stack design and interface design have to be changed to adapt to the deployment of AI applications.

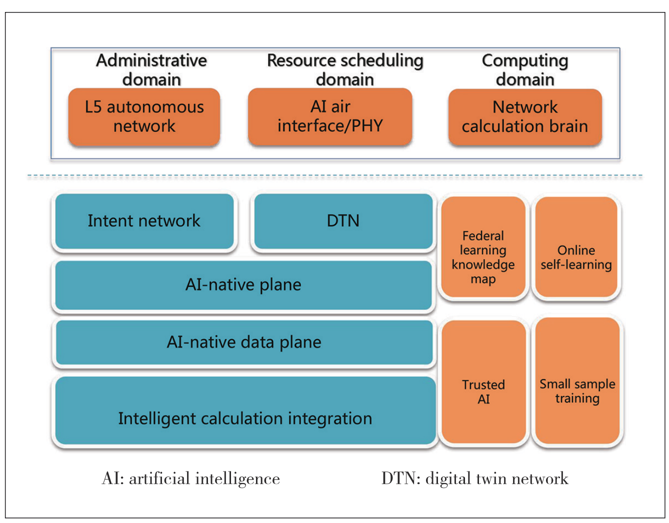
Considering the integration of the AI-native system architecture and the development of AI itself (such as automatic machine learning, trusted AI and model pre-training), the key technology map of AI-native networks in the future B5G system is shown in Fig. 8.

3.2 Intent-Based Network

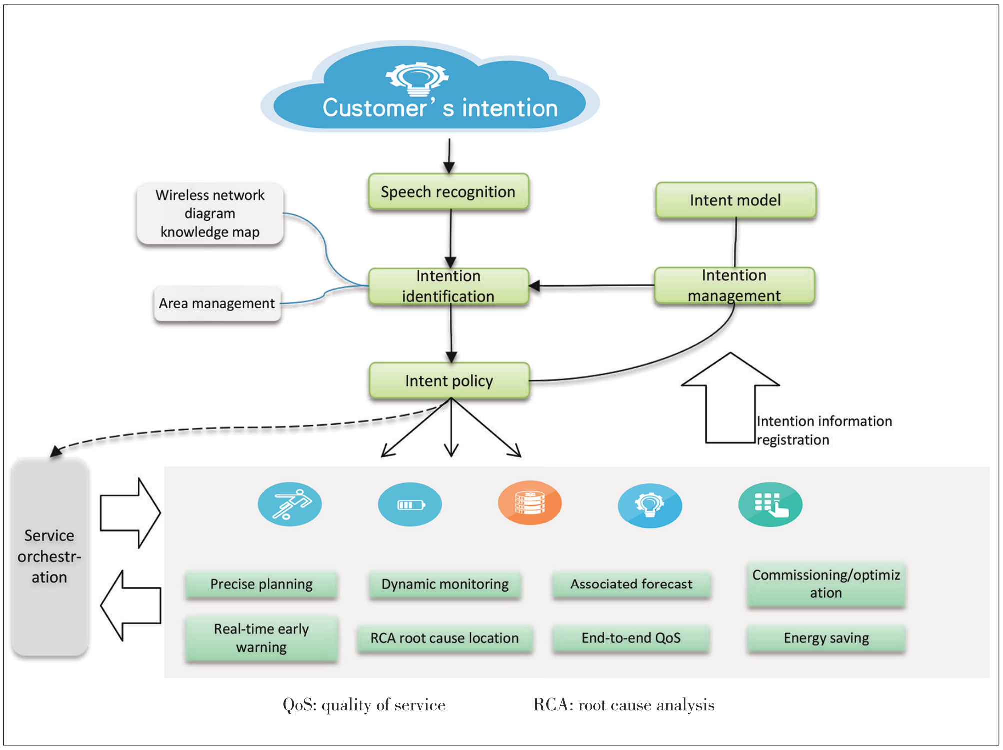
It can be seen from the autonomous classification standards that the L4/L5 high-level autonomy has the following two features: policy self-generation and intention-driven. The former requires that the system automatically generates/updates policies to achieve the operation or maintenance intention without manual intervention or guidance. The latter requires that the system automatically verify and optimize these self-generated policies to avoid system risks. That is to say, the latter requires the system has the capability of processing intention.

An intent-based network[8 – 10] takes the intention and strategy entered by the operator as guidance. Combined with the self-perception and prediction of environment, network resources and status, it can intelligently translate the demand for the network into network parameter configuration, network function configuration and network architecture configuration, and then realize the deployment and implementation of network function through automated configuration execution and test verification. Network self-configuration based on intelligent endogenesis is characterized by intention transformation ability and dynamic adaptability. Self-configuration can identify the intention of the operator and translate advanced and abstract intention into a clear and quantifiable configuration through intelligent analysis and calculation, so as to provide personalized and adaptive network services and realize the optimization of network performance, user experience and cost.

Fig. 9 shows the construction and processing workflow of an intent engine. In the figure, the intent model formulates the specifications of the intent and its requirements are universal, flexible, with sufficient expression ability, and easy to carry out. The identification of intention includes speech recognition and intent recognition. Specific intentions will be identified in accordance with the texts obtained through speech recognition. Intent recognition needs to know the intentions that the system supports and also a series of label data for each intention (input of supervision learning). The intent policy defines intent implementation that translates received intentions into execution strategies and implements and feeds back the strategies, the intention maintenance that enables real-time



▲**Figure 8. Key technologies of AI-native networks**



▲ **Figure 9. Intent-based network and intent engine workflow**

perception, prediction and automatic adjustment, and the intent conflict that detects and resolves conflicts.

3.3 Digital Twin Network Technology

With the vision of "ubiquitous intelligence and digital twins" becoming the consensus of the industry, the digital twin technology is playing an important role in the network evolution. A digital twin network (DTN) is a system with physical network entities and virtual digital twins that can perform real-time interactive mapping and interoperation.

DTN[11–13] uses the digital twin technology to create virtual mirroring images of the physical network facilities, that is, to build a DTN platform that is consistent with the entity NE, with the physical topology and with real data. It provides the test bed for verifying the correctness of network configuration and the effect of new technologies, which greatly reduces the risk of the existing network and eliminates the possibility of network faults caused by incorrect configuration. DTN is expected to change the working mode of network planning, network establishment, maintenance, optimization and operation in the future and help the network achieve low-cost trial, intelligent decisions and efficient innovation through real-time interaction of the physical network and the twin network.

The relationship between the DNT and the intelligent network is complementary. Fig. 10 shows the collaborative architecture of the twin network and AN. A closed loop is formed between the twin network and the knowledge agent. Before any algorithm application, parameter adjustment and major operations, verification and iteration are carried out in the twin network to ensure a controllable impact and effect on the physical network.

In a digital twin network based on the core data model, simulation model layer and twin management, the data domain collects and stores basic data and is also responsible for data governance; the data model layer mainly processes the model representation of the data layer without the mechanism model; the simulation model layer mainly constructs the service model, such as the channel model, air interface model, network model, terminal model and service model. Building a full-cycle and end-to-end digital twin platform can help implement new technology innovation verification and rapid iteration of intelligent algorithms, and enhance the level of intelligence in collaboration with self-intelligent networks. The digital twin technology will be an important supporting platform technology for intelligent networks in the future. A reference architecture of the digital twin platform is shown in Fig. 11.

4 Exploration and Practice of Autonomous Network Technology

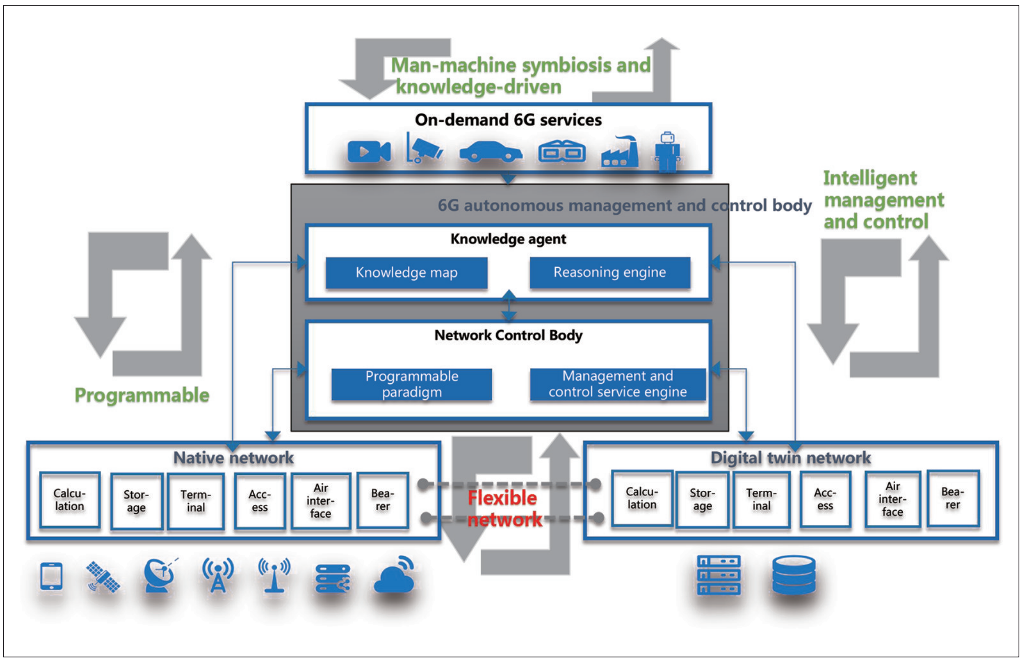
Use cases based on AN have been explored and researched, such as E2E root cause analysis based on closed-loop control, alarm compression based on a knowledge map, user experience assurance based on intention, and network dynamic planning based on digital twins. As follows, we will take the network planning of the Port of Rizhao, Shandong, China as an example to explain the practice of dynamic network planning based on DTN.

1) Characteristics of network planning for the Port

• Container stacking blocks the wireless signal. The stacking height can reach more than 20 m and the wireless signal cannot penetrate the metal box of the container.

• Container stacking dynamically changes. The height of container stacking often changes, the coverage area of wireless signals also changes, and the signal interference level changes constantly.

• The roads are narrow and densely distributed. The roads between the stacks can be up to more than 500 m long and the distance between the two adjacent roads is about 60 m.



▲Figure 10. Autonomous network system based on digital twin network

2) Disadvantages of the existing network planning solution to the Port

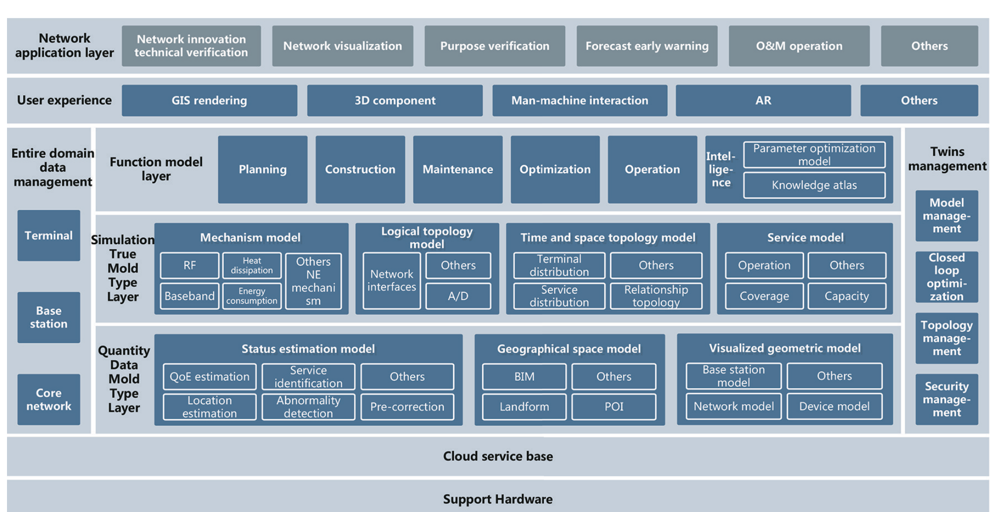
• The existing network planning only supports level network planning based on Reference Signal Receiving Power (RSRP)/Signal and Interference to Noise Ratio (SINR) and cannot match the clear QoS requirements of 2B scenarios.

• The network planning is based on static scenarios. For example, 2B scenarios at the Port of Rizhao may change dynamically, but the static network planning cannot match the scenarios.

• Multiple network optimization is relied on after network construction. For example, after the completion of a 2B scenario by Rizhao Port of Telecom, it usually takes several months of multiple network optimization, or even demolition and reconstruction, which greatly increases the cost.

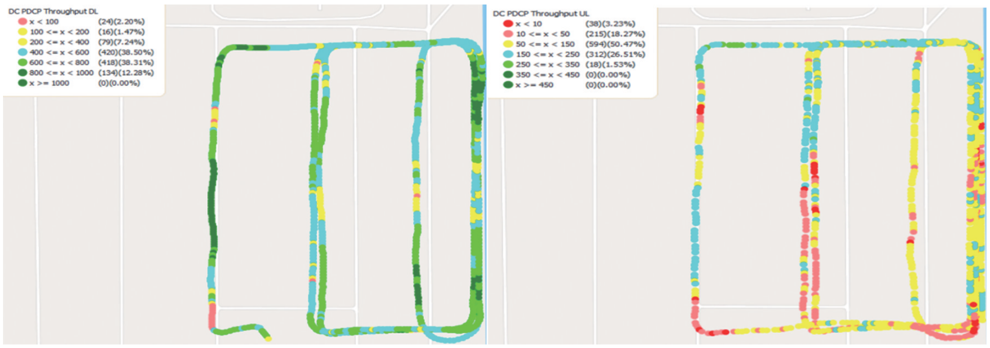
3) Benefits of dynamic planning schemes based on DTN for the Port

We use unmanned aerial vehicles to take photos of the Port of Rizhao first and obtain a digital twin network model of the port through 3D modeling. Through the digital twin network and ray tracing technology, we dynamically plan the network changes of the port. In this way, both the QoS level planning of the network and dynamic changes caused by container changes are supported. It can achieve "free network optimization" and support the design and version parameter planning of high-precision site hardware selection, site location selection, hanging height azimuth and so on, without manual network optimization. Fig. 12 shows the dynamic planning simulation results of this use case.



A/D: analog/digital
AR: augmented reality
BIM: building information modeling
GIS: geographic information system
NE: network element
O&M: operation and maintenance
POI: point of interest
QoE: quality of experience

▲Figure 11. Framework of digital twin network system



DC: dual-connectivity DL: downlink PDCP: Packet Data Convergence Protocol UL: uplink

▲**Figure 12. Dynamic network planning simulation based on digital twin network (DTN)**

5 Conclusions

At present, autonomous networks are booming and various autonomous systems are constantly emerging. Autonomous networks are moving from concept to reality. Looking forward to the future, we need to continuously promote the transformation of an intelligent ecosystem. In terms of standardization, academia and industry are expected to work together to promote the standardization of AI-native systems and also explore the standardization of data and intelligence. 3GPP AI-native endogenous data, algorithms and computing power may be supported. In terms of technological development, the integration of ICDT technology and the introduction of intention engine, digital twins, automatic learning and other technologies will enable the innovation and orderly evolution of intelligent networks in the future for new scenarios of intelligent communications, such as AI-AI (air interface based on AI), large-scale intelligent management and control, communication-sensing-computing integration and semantic communications.

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