4G/5G Shared Network Smart Co-Governance White Paper

GSMA Foundry

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Overview

This white paper is a collaborative work between China Telecom, China Unicom, Datang Mobile, Ericsson, Huawei, Nokia and ZTE based on experience in China of 4G/5G Shared Network Smart Co-Governance in GSMA Foundry.

This document describes the successful practices of China Telecom and China Unicom in the lifecycle management of the shared network, including the basis for co-dimensional and co-optimization by unified network coding and key configuration, unified frequency strategy, and network evaluation indicators.

Project Team

Since the initiation of 5G network co-construction and sharing, the project team has been working on the development of related standards, technical research, and business deployment. Our sincere gratitude goes to the team members from the following organizations for their contributions to this whitepaper in alphabetical order:

- **China Telecom**
- **China Unicom**
- **Datang Mobile**
- **Ericsson**
- **Huawei**
- **Nokia**
- **ZTE**

Contents

Contents

About This Document

In 2019, China Telecom and China Unicom embarked on an innovative partnership known as "5G co-construction and sharing". Essentially, the two operators agreed to jointly build one physical 5G network upon which they can deploy their own logical network and customized private networks. With this initiative, China now has the world's first and largest shared 5G SA network, laying the groundwork for scaled 5G deployments in the industry. The two operators followed up by extending this sharing approach to their installed 4G networks. In the wake of this extensive cooperation, challenges began to emerge that slowed down projects. Typically, there was a lack of robust technologies to streamline shared data exchange and trust, a lack of efficient mechanisms for alignment of configuration and operation, and big data support for bi-lateral joint optimization.

This document describes the successful practices of China Telecom and China Unicom in the lifecycle management of shared networks. Such practices include defining a unified set of network coding and key configurations, frequency policies, and network evaluation indicators for use as the yardsticks for joint maintenance and optimization, leveraging blockchain technology to ensure the storage and consistency of essential key shared parameters, confirm work order priorities bilaterally, and exchange essential parameters based on smart contracts; and the application of digital twins technology to facilitate joint network optimization.

With this document, global partners in the communications industry are provided with insights to better understand meaningful subjects such as the concerted operation, optimization, management, in the context of shared 4G/5G networks. China Telecom and China Unicom have successfully deployed effective technologies and successful practices for multi-party construction and sharing of 4G/5G networks and wish to share insights and lessons learned with the wider industry. Hence this white paper on shared 4G/5G network smart co-governance is released by the GSMA to the industry to facilitate future industry initiatives in network sharing.

1 Operation Challenges in Shared 4G/5G Networks

1.1 Network Co-construction and Sharing by China Telecom and China Unicom

The two operators have been steadily building and launching their shared networks across China in accordance with the cooperative framework agreement on network co-construction and sharing they signed in 2019.

Regarding 5G networks, the two operators have made tangible breakthroughs in terms of product, technology, Operations & Maintenance (O&M), and management innovations in collaboration with other partners. It is thanks to their meaningful contributions to the scaled deployment of 5G networks that China has the world's first, largest, and fastest shared 5G SA network. These cases can otherwise inspire similar or even better practices around the world.

In terms of 4G networks, the two operators have been engaged in reconstructing their installed 4G networks from 2022 to 2023 to make them shareable with the aim of improving quality and efficiency at reduced costs. Unlike building 5G networks, reconstructing 4G networks must factor in any potential negative impact on network quality and user experience. Set to minimize the total cost of ownership (TCO), the two operators designed plans for removing and then redeploying their 4G networks with careful consideration of elements such as coverage, load, complaints, antenna resources, equipment capabilities, and local conditions.

By the end of October 2023, the two operators had deployed 1.22 million shared 5G base stations and reconstructed over 2 million shared 4G base stations. This joint effort of building, optimizing, and operating networks has paid off with network quality and user experience having steadily improved, while investments and costs have been greatly reduced.

1.2 Challenges

With increasing co-construction and sharing, network operation becomes more complex, placing restrictions on network performance.

Several problems stand out:

3. Key network policies and essential parameter settings are inconsistent;
3. Network service experience is inconsistent;
3. Network Key Performance Indicators (KPIs) and service Key Quality Indicators (KQIs) are inconsistent;
3. There is a general lack of data sharing and trust in network planning, construction, maintenance, and optimization;
3. Lack of supervision on network configuration changes and inconsistency of network quality perception;
3. Networks are increasingly complex and require greater collaboration for optimization.

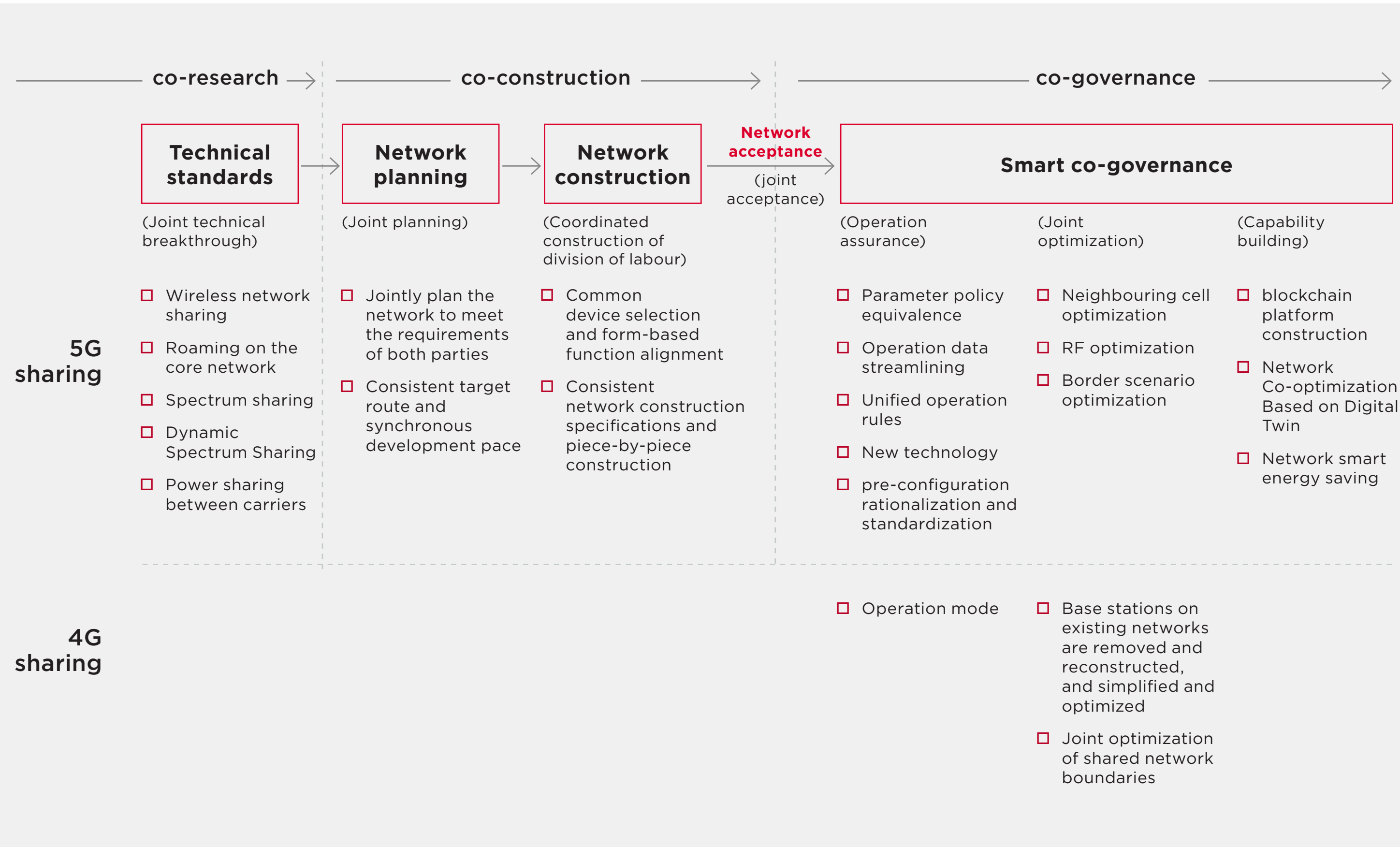
2 Full Lifecycle Smart Co-governance of Shared Networks

2.1
Network Co-construction and Sharing by China Telecom and China Unicom

The entire lifecycle of a shared network falls into three processes: co-research, co-construction, and co-governance.

Co-research solves the technical, component, and algorithm problems of shared networks. Coconstruction is to build shared networks in large scale and lays the groundwork for their cogovernance and co-operation. Co-governance ensures the healthy operation of shared networks and optimizes network services and user experience. Figure 2-1 shows the lifecycle management view of a shared network

Figure 2-1
Lifecycle management view of shared network

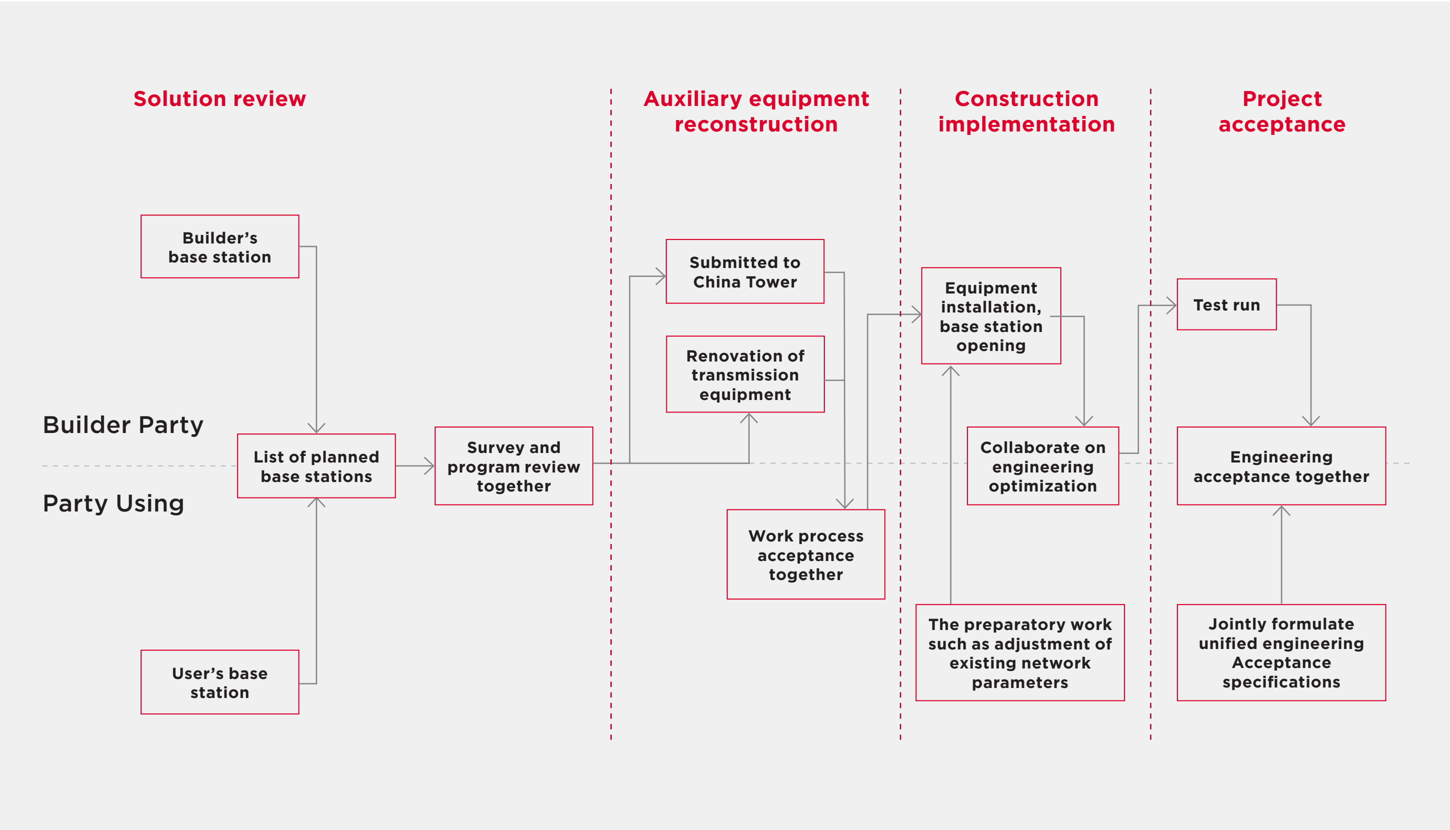


At MWC Barcelona 2023, GSMA Foundrypublished a white paper named 5G Network Coconstruction and Sharing Guide which shared the technological innovations of China Telecom and China Unicom in the evolution of shared networks and their experiences of sharing radio access and core networks to realize the world's first, largest, and fastest 5G Standalone (SA) shared network.

The network planning is underpinned by good co-ordination between the involved operators in terms of network resource status, as well as their planning and construction expectations, to ensure unified objectives and methodologies.

The network construction phase mainly covers solution review, auxiliary reconstruction, engineering implementation, and acceptance as shown in Figure 2-2.

Figure 2-2
Acceptance process example of joint construction



3. **Solution review:** A unified mechanism for site planning and review based on joint site surveys should be formulated to address the concerns of the involved operators at the optimal TCO and prioritize the construction of planned sites.

3. **Auxiliary reconstruction:** This helps adapt auxiliary equipment to shared networks. The main items include towers and transport equipment. Joint acceptance is needed as well.

3. **Engineering implementation:** Baseband Unit (BBU), Active Antenna Unit (AAU), and other site equipment are deployed and parameters are reconfigured to ensure good experience for the users of the involved operators. At this stage, joint optimization is important.

3. **Acceptance:** This helps ensure that the involved operators fulfill their respective responsibilities as scheduled, with the network constructing operator responsible for construction and the network sharing operator providing full coordination. It is crucial to apply unified standards and specifications and conduct joint acceptance to ensure project quality.

The smart co-governance phase focuses on maintenance and optimization tasks based on common operations rules and goals of dealing with network problems and pain points. Common policies are formulated to ensure the same service access and experiences for all users of the involved operators. Joint optimization is required to integrate network resources and reduce the OPEX of shared networks. To this end, emerging technologies such as big data, AI, and digital twins can be utilized to build an end-to-end shared smart operations system that can improve the operation efficiency of shared networks while ensuring the top-line quality and experience of the shared networks.

2.2

Network Co-construction and Sharing by China Telecom and China Unicom

2.2.1 Operation Assurance

Consistent criteria, Quality of Service (QoS), KPIs, parameters, and configurations enable the involved operators to secure the operations targets of maintaining one network and delivering good experience for all of their users. The operation assurance of shared networks focuses on:

3. **Aligning configurations and key service policies:** The unified configurations of service resources, mobility, essential Radio Access Network (RAN) parameters, and QoS are key to consistent, good experience on shared networks.

3. **Streamlining Network Management System (NMS) operation data:** With shared NMS interfaces and data formats, permissions and domains-based NMS capabilities, and the joint maintenance of operation data, the involved operators enhance the management and operation of shared networks.

3. **Unifying network operation rules:** The unified operation rules regarding capacity expansion as well as network and service evaluation facilitate network operation and optimization.

3. **Aligning and coordinating pre-configuration for new technologies:** Aligned, coordinated and unified pre-optimization and pre-configuration enable the involved operators to introduce and scale up the applications of new services, frequency bands, and features on shared networks.

2.2.2 Capability building

China Telecom's and China Unicom's smart network operations aim to use blockchain, digital twin, and Artificial Intelligence (AI) models to develop intelligent operations technologies for shared networks, taking into consideration the user experience requirements of both operators and focusing on typical concerns such as network coverage, capacity, and energy saving. This helps to quickly and accurately locate network problems and supports automatic and intelligent decision-making.

2.3

Smart Co-governance of 4G Networks

The following three operations solutions can be selected for shared 4G networks based on the advantages of both operators to improve operations efficiency and reduce operations costs:

1. Independent operations

In this mode, the operator who builds the network shall be responsible for maintaining the network. Both operators maintain their own equipment and assume different responsibilities depending on their role — network builder or sharer. As for border issues, solutions are formulated and implemented through negotiation. Both operators can optimize the networks through joint shift, joint optimization, and other flexible collaboration methods. This mode is applicable to the initial stage of a single 4G network.

2. Joint management and operations (by joint teams, virtual teams, or unified managed service teams)

The two operators jointly set up an operations team, which operates their 4G networks in a unified manner. The operations team is subject to the joint command and dispatch of China Telecom and China Unicom, and is responsible for handling routine maintenance and optimization tasks of the two operators as well as maintaining the unified configuration and sharing of premises, vehicles, diesel generators, and tools. This mode involves the maintenance of non-property equipment. For pilot purposes, a virtual unified operations team can be set up in each province to be in charge of unified maintenance, managed services, towers, optimization, and service requirements. This team also manages equipment and maintains resources in the specified area. Unified operations require collaboration between the transmission, power and environment, and resource departments of both operators.

2. Owner-led operations (including single-property operations)

Through negotiation, the two operators specify the 4G area of responsibility and determine the owner in charge of 4G operations in the area of responsibility ("the owner" for short). The owner is responsible for maintaining and optimizing its own and the other operator's equipment in the area of responsibility, while the other operator supervises and cooperates with the owner. This mode involves the maintenance of non-property equipment. China Telecom and China Unicom need to collaborate in every province, and can try to determine an owner for each province to optimize all equipment in the area of responsibility. The owner is responsible for fault monitoring and handling, which requires collaboration between the transmission, power and environment, and resource departments of both operators. Both operators shall manage equipment and maintain resources in the specified area.

2.3.1 Topology Optimization for Existing Shared 4G Networks

Unlike the native co-construction and sharing mode of 5G networks, 4G network sharing of China Telecom and China Unicom was carried out over their independent mature 4G networks. After these networks were integrated, they became a to-be-optimized shared 4G network with multiple carriers, mixed deployment of devices from various vendors, and disorganized site locations. This resulted in a series of problems such as signal overlap, disordered service bearing, and complex handovers, severely affecting user experience.

To achieve efficient integration and co-governance of the two operators' public 4G networks, strengthen the coordinated operations of 4G/5G on the shared networks, and slash operational costs, the existing shared 4G networks need to be comprehensively reconstructed by optimizing and adjusting the topology through device removal and redeployment.

Shared network reconstruction aims to optimize the topology and refine the capacity of to-be-optimized shared networks, so that TCO can be lowered without compromising network quality and user experience. It focuses on the following aspects:

3. **Resource integration and network simplification modes and principles:** Network simplification should be carried out by taking into account the load, user distribution, service development, device capability, and network capacity of both operators' networks in the sharing area. Inter-network interoperability policies should also be configured to guarantee network capacity and avoid impacting user experience during simplification. In addition, the area of responsibility should be determined to minimize mixed deployments of different vendors and operators and ensure good network quality.

3. **Reasonableness of device removal and redeployment for existing shared 4G networks:** After resource integration and network simplification, user and service experience in the area can be determined based on multi-source data, such as base station engineering parameters, network management indicators, Measurement Report (MR) counters, and Extended Detection and Responses (xDRs). This helps accurately evaluate the reasonableness of device removal and redeployment for existing shared 4G networks. In addition, digital platforms are used to implement iterative optimization of network simplification solutions and continuously improve the quality of the shared 4G networks.

2.3.2 Joint optimization of shared network borders

During shared network reconstruction, some network border issues will arise for various reasons such as inconsistent progress. These issues can manifest as shared and non-shared network borders and service provisioning area borders. When users move close to the borders, neighboring cells with some functions unavailable generate co-channel interference. Without refined optimization, users may experience deterioration of indicators such as handovers, user-perceived rates, and voice packet loss rates, severely affecting their network experience.

Therefore, it is necessary to perform joint optimization on the shared network borders, which mainly includes:

3. **Avoiding chaotic Radio Installation in the sharing areas and properly planning the shared borders:** Considering the impact of co-channel interference on the shared borders, chaotic radio installation in the sharing areas should be avoided and the shared borders should be limited to areas with a small number of users. RF optimization can also be used to reduce the overlapping coverage of border cells and minimize the impact of co-channel interference.

3. **Optimizing the inter-frequency handover policies and handover zones:** In the shared and non-shared border areas, one or two layers of handover zones can be deployed, so that users of both operators can switch to their own network as soon as possible, thereby reducing the impact of the shared borders on user experience. In addition, inter-frequency and inter-RAT measurement, control, or handovers can be triggered in advance based on the reference signal receiving quality (RSRQ), which significantly improves the inter-frequency or inter-RAT handover success rate.

3 Key Technologies for Smart Co-Governance in a Shared Network

3.1 Overall Policies for Smart Co-Governance

3.1.1 Unified Key Policies and Parameters

1. Unified Service Resource Policy

In the RAN sharing scenario, if operators independently define mapping relationships between 5QIs/QCIs and services and between 5QIs/QCIs and user levels, different operators' User Entities (UEs) in a cell will have different priorities to access the same service, causing inconsistent QoS values and uneven distribution of resources among operators.

To allocate resources evenly or in an agreed proportion, operators need to negotiate first to reach a consensus on services, users, resource scheduling, and slicing.

3. **Service policy coordination:** The mapping relationships between different types of services of each operator and 5QI/QCI should be the same as shown in Table 3-1.

3. **User policy coordination:** Operators have almost the same user levels, and configure mapping relationships between user levels and 5QIs/QCIs in their respective 5GCs.

3. **Resource scheduling policy coordination:** Operators coordinate QoS priorities based on the agreed 5QIs/QCIs, and use the priorities in their RAN hosting areas, ensuring that UEs en joy the same QoS in RAN sharing areas.

3. **Slicing policy coordination:** With correspondence between Service Level Agreement (SLA) profiles and slice IDs, operators manage slices in all areas in a unified way, enabling better user perception and service guarantee.

Table 3-1
5QI/QCI-Based Mapping Solution

OPERATOR	5QI1/QCI1	5QI2/QCI2	5QI3/QCI3	5QI3/QCI3	5QI3/QCI3	5QI3/QCI3	5QI3/QCI3	5QI3/QCI3	5QI3/QCI3
Operator A	Volte	Volte video	Real-time gaming	Video assurance	Ims signaling	Default bearer for low-level users	Disabled	Default bearer for high-level users	Disabled
Operator B	VoLTE	VoLTE video	Real-time gaming	Video assurance	IMS signaling	Disabled	Disabled	Disabled	Default bearer for all users
Unified Policy	VoLTE	VoLTE video	Real-time gaming	Video assurance	Ims signaling	Default bearer for high-level users	Disabled	Default bearer for medium-level users	Default bearer for low-level users

2. Unified Mobility Policy

A 5G network has a complex structure involving multiple frequency bands, RATs, and UE types. Therefore, it is necessary for operators to unify mobility management and coordinate inter-network interoperation policies to ensure good user perception of mobility. The following needs to be noted in a shared network:

3. Same inter-network interoperation policy and configuration for frequency priorities, intra-system and inter-system mobility, and thresholds.

3. Perception of mobility at boundaries, including the hosting operators' RANs, vendors' equipment, and RATs.

3. PLMN-based differentiated mobility policies, for example, the voice-data layering policy.

3. Unified Essential Parameters of the RAN

The key configurations of the shared RAN need to be aligned to ensure equal and good user perception of mobility and services for UEs of different operators in the shared network or between the shared and non-shared networks. In addition to the QoS parameters and mobility parameters mentioned in the above sections, the essential parameters of basic configuration, shared resource configuration, access and power control, scheduling, timer, and Bandwdith Part (BWP) are also included. For details, refer to Table 3-2.

Table 3-2
Essential Parameter Description of the RAN

TYPE	DESCRIPTION
Basic configuration	Configuration of absolute radio frequency channel numbers (arfcns), bandwidth, and synchronization signal blocks (ssbs). In the same area, the arfcns configured for the base stations of the operators should be the same to avoid inter-frequency handover, so the user perception of services and mobility can be improved.
Shared resource configuration	Configuration of the sharing function, sharing mode selection, and shared resources. Operators shall share network resource configurations, including radio resource control (rrc) connections, physical resource blocks (prbs), and res, ensuring that the available resources of each party are the same and are the maximum available resources of the network.
Access and power control	Configuration of user access as well as uplink and downlink power control, ensuring proper and orderly network access of ues with different capabilities and of different operators.
Scheduling	Configuration of the scheduling policy for base stations and ues when ues send uplink data or receive downlink data, ensuring optimal service perception of ues in different scenarios.
Timer	Configuration of twelve common timers, including t300, t304, t301, and t310, which are closely related to access, data, and voice services.
Bwp	Configuration of the initial bwp, dedicated bwp, and bwp switching policy and threshold.

4. Coordinated Numbering

In a shared 5G network, ID conflict between networks hosted by different operators and between shared and non-shared networks needs to be solved to avoid service or Call Data Record (CDR) errors. The solutions are as follows:

3. Coordinated Numbering in the RAN

Operators need to allocate Cell Global Identifiers (CGIs) (including E-UTRAN CGIs [ECGIs] and NR CGIs [NCGIs]), base station IDs (including eNodeB and gNodeB IDs), and Tracking Area Identities (TAIs) in a unified way.

3. Coordinated Physical Cell Identity (PCI) Planning at the Boundaries of RAN Hosting Areas

Operators need to plan PCIs in a unified way to avoid PCI conflict.

3. Coordinated Physical Random Access Channel (PRACH) and Root Sequence Planning at the Boundaries of RAN Hosting Areas

Operators need to plan PRACHs and root sequences at the boundaries of RAN hosting areas in a unified way to avoid preamble conflict.

3.1.2 Unified KPIs

In the RAN sharing scenario, to ensure the same good performance in RAN hosting areas and the same good user perception in each RAN sharing area, operators need to unify the KPIs and evaluation method, and comply with them in RAN hosting areas. For details, refer to Table 3-3.

Table 3-3
Unified KPIs

ITEM	DESCRIPTION
Evaluation	All operators jointly formulate KPIs and criteria, organize acceptance tests, and determine results.
KPIs	All operators jointly develop a method for collecting KPIs and establish rating levels, so that networks in different hosting areas are evaluated in the same way in accordance with the same standards.

3.1.3 Unified Key Policies and Parameters

3.1.3.1 Handling of Network Management for a Shared System

In a shared 5G network, operators need to configure and query data of base stations using the different Operator's network management systems. Therefore, specific functions are needed for the sharing and co-management of base stations to meet users' network requirements and operators' needs for O&M. Handling of network management system sharing mainly involves the configuration of shared base stations, management of permissions and capabilities, and support for northbound interfaces.

1. Configuration of Shared Base Stations

1. **RAN sharing configuration for base stations:** The network management system should control whether to enable RAN sharing for base stations. Shared base stations can be configured only after RAN sharing is enabled.
2. **PLMN configuration for base stations:** The network management system should provide the following PLMN-related functions:

> Handling of network management system sharing mainly involves the configuration of shared base stations, management of permissions and capabilities, and support for northbound interfaces

   a. Set the same PLMN ID (in shared carrier mode) or different PLMN IDs (in independent carrier mode) for different cells of the same BBU in a 5G shared base station.
   b. Set a cell of a shared base station in multiple PLMN lists (PLMNInfoList). The network management system should allow multiple operators to correspond to a single PLMN ID (PLMNIdentityInfo) and the PLMN lists (PLMNInfoList) of a cell to be completely different.
   c. Configure Xn interfaces of shared base stations by PLMN, and configure the PLMN ID and gNodeB ID in the global RAN node ID at each Xn interface as required.
   d. Configure NG interfaces of shared base stations by PLMN. That is, NG interfaces can be provided between shared base stations and respective 5GCs of operators by PLMN.

3. **Operator-based cell reselection policy configuration:** The network management system should support the configuration of frequencies and priorities for dedicated cell reselection based on PLMNs and UE capabilities.
4. **Operator-based inter-cell handover policy configuration:** The network management system should support the configuration of neighbor cell lists, cell measurement events, and handover thresholds based on PLMNs and UE capabilities.

2. Management of Permissions and Capabilities

Regarding the management of permissions and capabilities, the network management system should have the following capabilities:

1. Set permissions based on role. The hosting operator should have all rights while participating operators have read-only and export permissions.
2. Set cell-specific capabilities based on role. The hosting operator should have all capabilities related to the equipment of shared and non-shared base stations, while participating operators only have capabilities related to the equipment of shared base stations.
3. Set the cell-level and interface-level tracing capability. The hosting operator should have the capability to initiate cell-level and interface-level tracing tasks for all shared and non-shared base stations, while participating operators can only view historical cell-level tracing records.
4. Set the user-level tracing capability. Both the hosting and participating operators should have the capability to initiate tracing tasks for their own users (through respective 5GCs).

3. Support for Northbound Interfaces

To meet different characteristics of data types and differentiated needs of operators, the network management system should support various northbound interfaces, including dual-northbound interfaces, single-northbound multi-user interfaces, and single-northbound single-user interfaces.

3.1.3.2 Operations Data Sharing

5G network co-construction and sharing saves the cost of network construction. However, due to limited management permissions, participating operators cannot directly obtain data about the network operating status. In order to solve this problem, data sharing can be implemented based on operators' operations architecture. China Telecom and China Unicom use a three-layer data sharing architecture. For details, refer to Table 3-4.

Table 3-4
Three-Layer Data Sharing Architecture

LAYER	SHARED DATA	FUNCTION	REMARKS
1	Equipment management data	Supports the daily maintenance work of provincial branches	The hosting operator can view and manage all the information of dedicated and shared Network Functions (NFs).The participating operator can view, query, and export all the information of shared NFs, but cannot modify or configure it.
2	Raw data of provincial branches	Provides automatically collected raw data for the participating operator's group and provincial branches.	The hosting operator's Operation and Maintenance Center (OMC) uploads northbound data to the collection platform of its provincial branches, and then the platform sends shared data to the collection platform of the participating operator's provincial branches. The shared data includes the automatically collected Configuration Management (CM), Performance Management (PM), Fault Management (FM), and MR data of shared NFs.
3	Group-level data	Provides a basis for group-level policies.	Data is shared among operators through group-level system interfaces, including manually maintained basic data, automatically collected data, and analysis results collected from upper-level application systems.

3.1.4 Service Consistency and Differentiated Operations in Network Co-Construction and Sharing

Network sharing provides the same network foundations, and users of different operators equally share network resources and service capabilities. On this basis, the deployment of network slices in the 5G RAN sharing scenario also needs to ensure differentiated user perception in accordance with priorities of UEs and services.

In a shared network, the deployment of diversified services based on slicing faces greater challenges. UEs are grouped based on Public Land Mobile Network (PLMN) IDs and network slice IDs, and different radio parameters and mobility policies are set for different user groups. Therefore, various network capabilities and features can be provided for slices of different operators. For instance, UEs in a China Unicom slice are preferentially handed over to the specified frequency, or a dedicated cell re-selection priority is configured for UEs in a China Telecom slice, so that UEs in slices of different operators can reside in different cells.

3.2 Blockchain-Based Data Exchange and Co-Governance Platform for Shared Networks

3.2.1 Challenges

In spite of the wide use of network sharing, no standard mechanism is in place for reaching mutual trust in data configuration and in shared networks, causing inconvenient and delayed data exchange, unmanaged network configurations, and inefficient collaboration.

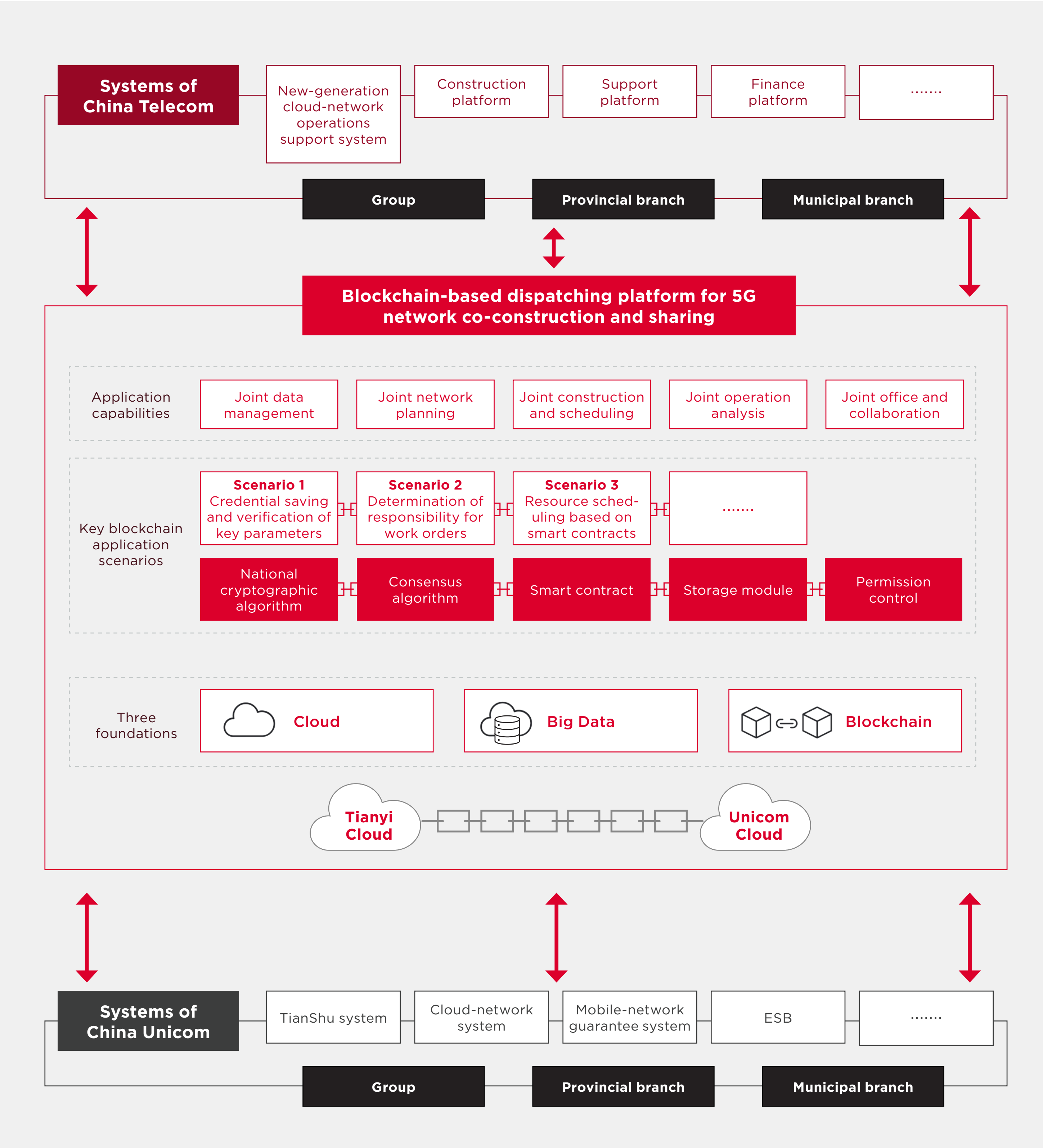
3.2.2 Innovation

To meet the operational requirements of all departments in 5G network co-construction and sharing, a data exchange platform based on the blockchain technology is proposed in the IT domain shared by both operators. This platform tackles three issues, namely, agreed data saving and consensus of essential parameters, determination of responsibility for work orders, and over-the-top exchange of essential parameterst based on smart contracts. In this way, cross-operator cloud deployment, cross-operator cloud blockchain creation, and heterogeneous cloud collaboration are implemented, accelerating network co-construction, sharing, maintenance, and optimization.

Block Chain technology is used in the Shared network's operation and management. It's based on Over-The-Top solution under which the Radio and Core network elements were left unchanged and using their current standard interfaces. Further Block Chain technology application or other kind of solutions are to be explored as part of telecom standardization development. The inter-operator Blockchain as a Service (BaaS) architecture is used to implement cross-cloud internetworking and network governance. This solution has doubled the operational efficiency. See Figure 3-1 for further details.

Figure 3-1

Blockchain-Based Dispatching Platform for Co-Construction and Sharing



1. Data Traceability, Improving Collaboration and Trust

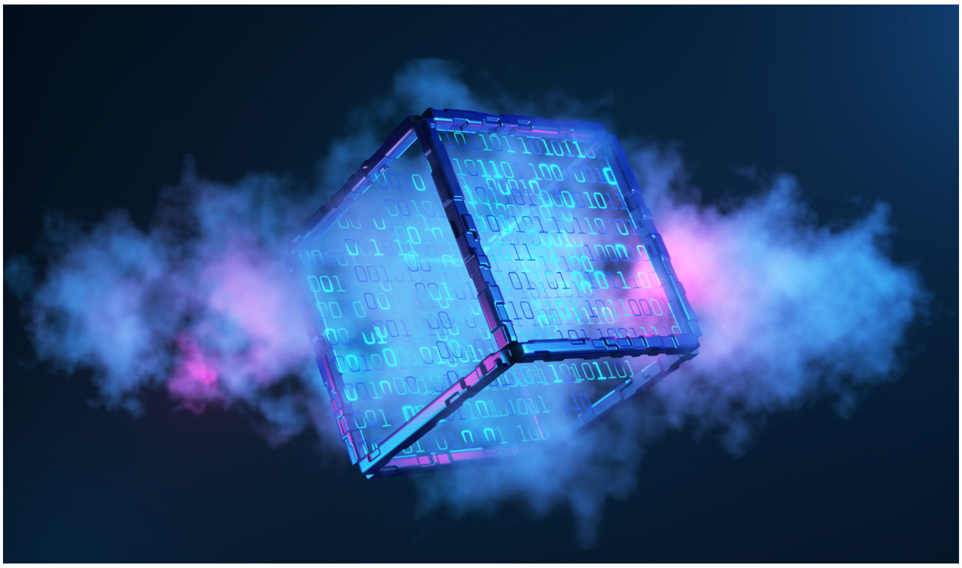
Data anti-tampering and traceability: With the blockchain technology, anti-tampering key-data storage, traceable data query, and trusted point-to-point transmission can be implemented.

Achieving credibility consensus: Thanks to decentralization, immutability, transparency, and security properties of the blockchain technology, data credibility can be achieved during cooperation among parties.

2. Smart Contract, Improving the O&M Efficiency

As a computer program running on a blockchain, a smart contract technology can be automatically executed and mutually recognized by participants, automating trusted and irreversible data transactions. Compared with traditional technologies, the smart contract technology can save time, and reduce manpower and maintenance costs for customers.

Deployed on a private cloud in a distributed manner, the blockchain-based data exchange platform uses the cross-cloud networking technology to establish an end-to-end blockchain network with encrypted communication channels, implementing endorsement and accounting based on the pre-negotiated endorsement policy and smart contract. The upper-layer application capabilities support three application scenarios, which are agreed data saving and integrity of essential parameters, determination of responsibility for work orders, and exchange of essential parameters based on smart contracts..



3.2.3 Application Scenarios

The blockchain-based data exchange platform for co-construction and sharing is designed with three blockchain application scenarios: agreed data saving and integrity of essential parameters, determination of responsibility for work orders, and exchange of essential parameters based on smart contracts. Boasting full-process coordination, the platform comprehensively improves the capability and efficiency of network co-planning, co-construction, co-maintenance, and co-management.

Scenario 1: Agreed Data Saving and Integrity of Essential Parameters

Through the platform, agreed essential parameters from shared 5G network domain can be uploaded for agreed data saving and integrity verification by peer parties. Data synchronization problems caused by misconfiguration can be avoided or rectified.

Scenario 2: Determination of Responsibility for Work Order

The blockchain-based platform shows the work order handling progress when a fault occurs in the shared RAN or transport network on a real-time basis, so that the fault cause, estimated time for repair, solution, and implementation situation are visible to all parties. This greatly improves the timeliness of O&M, enhances information transparency, and improves the communication efficiency among all parties.

Scenario 3: Consensus of Essential ParametersBased on Smart Contracts

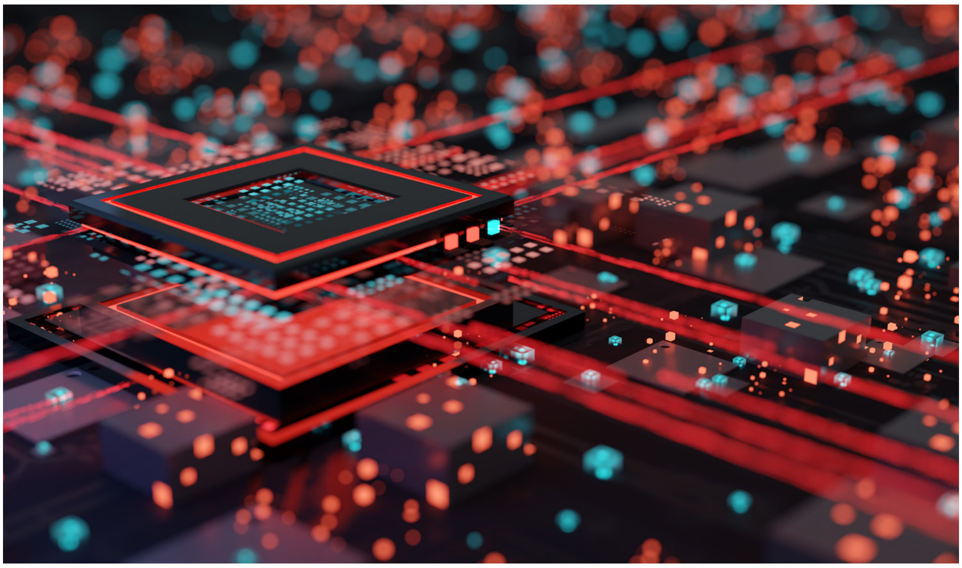
In accordance with the agreed network resource allocation rules, the network sharing parties construct an automatic resource allocation rule engine for the smart contract on the blockchain, minimizing manual involvement and improving efficiency of parameter consensus.

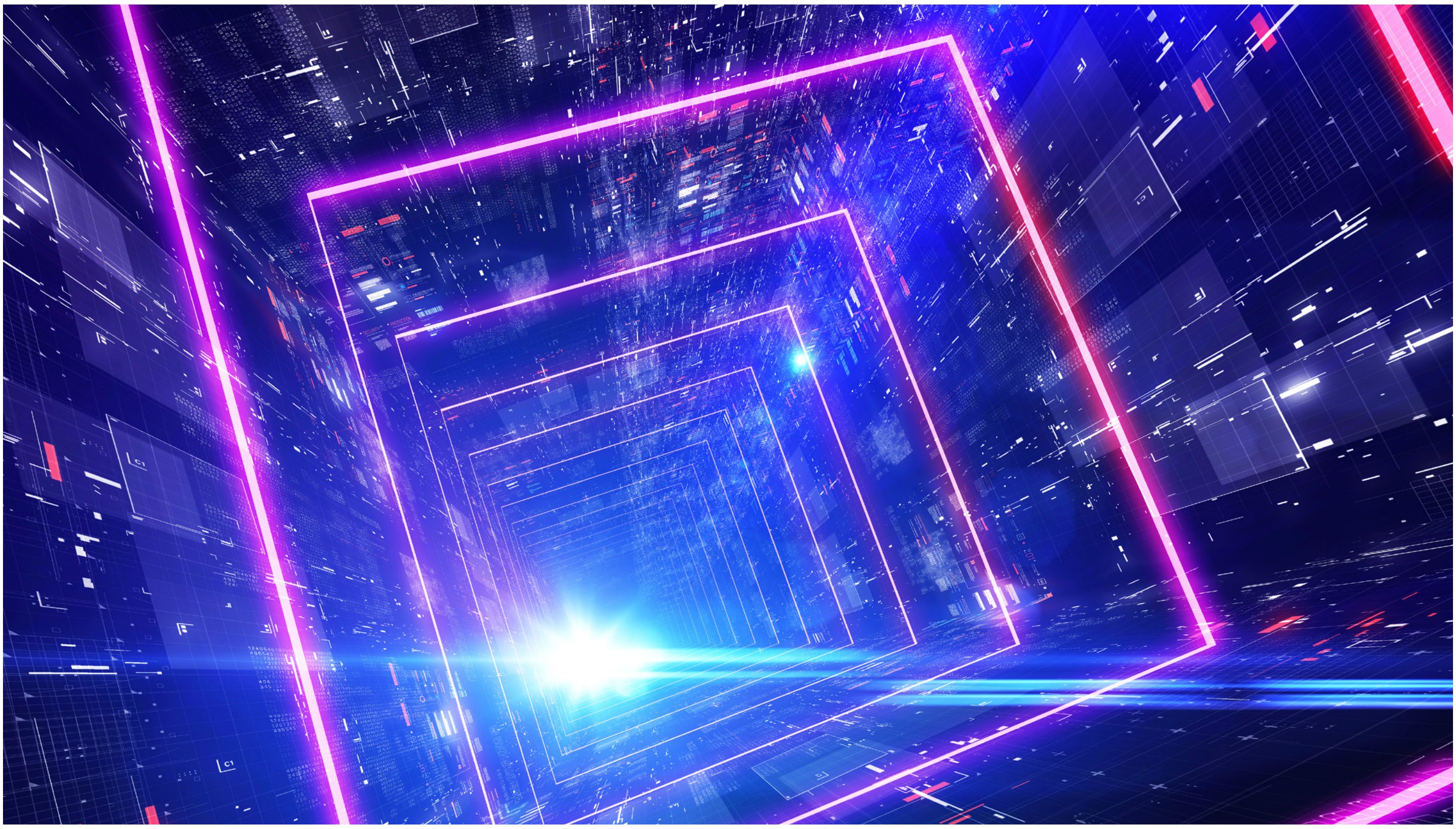
> Boasting full-process coordination, the platform comprehensively improves the capability and efficiency of network co-planning, co-construction, co-maintenance, and co-management

3.2.4 Achievements

Based on the blockchain technology, China Telecom and China Unicom constructed a trusted data foundation for multi-party network sharing, to fully leverage cloud services, and existing system capabilities of all parties. By deploying the data foundation on the Tianyi Cloud and Unicom Cloud, and constructing a cross-cloud blockchain, the operators worked together to create an intelligent network operations system with five application capabilities, namely: joint data management, joint network planning, joint construction and essential parameter integrity, joint operations analysis, and joint office and collaboration.

The intelligent 5G network operations system of China Telecom and China Unicom is the world's first cross-operator 5G data exchange system based on blockchain technology. The inter-operator BaaS architecture is used to implement cross-cloud internetworking and network governance. All of these provide a brand new solution for efficient data exchange between shared networks. Currently, China Telecom and China Unicom share over 300 networks in 31 provinces in China by using the blockchain-based data exchangeplatform, and have doubled their operations efficiency as preliminarily estimated.





3.3
Digital Twin-Based Network Assurance Technology

3.3.1 Challenges

As a 4G/5G shared network supports the connection of UEs of the participating and hosting operators, coordinated network operations involve a large number of UEs, different operators, multiple RATs. frequency bands, and various scenarios and services. This brings the following challenges:

1. Operators use disparate tools for monitoring network quality and operational status, leading to inefficient and non-transparent network operations.
2. Due to the delay in obtaining network KPIs, it is difficult to further improve the efficiency of locating and solving problems affecting network performance.
3. In a highly complex shared network, the involved parties may invest considerable time in reaching consensual decisions that serve each party's interests while guaranteeing the integrity of the entire network.

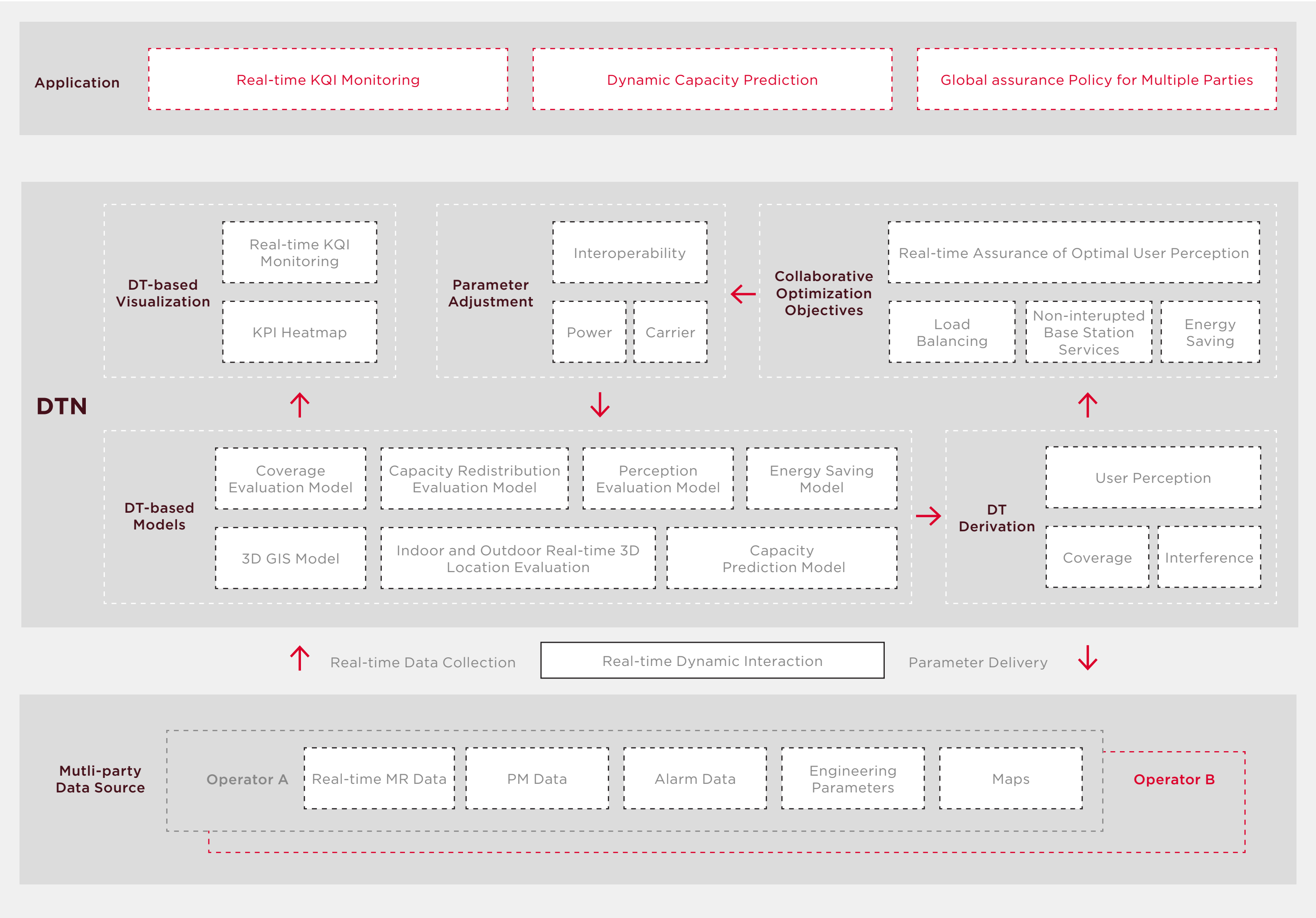
Given the lack of experience in this field, it is imperative to introduce new ideas and technologies to bring in more efficient coordinated network operations.

3.3.2 Innovation

The digital twin technology is used to build a virtual replica of a shared network for real-time interaction and information mapping. It enables real-time, intensive, transparent, and globally smart governance spanning the lifecycle of the network. See Figure 3-2.

Figure 3-2

Digital Twin Architecture



End-to-end real-time data processing: The transmission of the OMC data of the participating operator is improved through real-time collection and analysis of code streams of base stations, MR-based real-time positioning, high-performance data cleaning, and integration of real-time Geographic Information System (GIS) presentation and rendering technologies.

High-precision Three-Dimensional (3D) mirroring: In terms of environment, 3D Building Information Model (BIM) is employed for comprehensive monitoring of key areas. At the network level, MR-based high-precision positioning (in meters) and image processing technologies help present accurate network KPIs and spatial distribution of pico Remote Radio Unit (pRRU) cells. From the perspective of services, data are integrated and intelligently managed based on service characteristics, facilitating the accurate visual representation of operators, RATs, and KPIs of different services.

Digital twin-based network operations: Based on knowledge-driven and AI-driven modeling, the digital twin-based network operations integrate existing network data and the network propagation mechanism into an AI model. Specifically, with a relationship model between network parameters/population distribution and major network KPIs such as network coverage and capacity, it enables quantitative and visual prediction of the effects of the changes in network parameters and population distribution on those KPIs. In addition, with a dynamic time-series prediction model, it is able to continuously predict the network status for early warning, assisting the participating and hosting operators in implementing transparent, efficient, secure, and stable coordinated network O&M.

Collaborative and intelligent optimization for multiple objectives of different parties: The objectives of shared network optimization include not only each party's optimal user perception but also global network and equipment security. However, experience-based or black-box-based network assurance policies are not the optimal solution for the entire network, as they may not act in the best interests of each operator and thus cause poor user experience. Against such a background, an intelligent decision-making module is built based on heuristic and reinforcement learning algorithms to formulate a 3-level network assurance policy in terms of optimal user perception, network security, and equipment security. The policy helps determine the optimal scenario-based KPIs, such as PRB usage, the number of RRC connections, and coverage rate. Firstly, the intelligent decision-making module generates such initial network parameters as power and down tilts for one or more cells in the shared network. These parameters are fed into the digital twin, which outputs a quantitative evaluation result of network KPIs. Then, the evaluation result is fed into the intelligent decision-making module for network parameter adjustment, and the adjusted parameters are provided for the digital twin. Finally, this intelligent decision-making module outputs the optimal network parameters and presents their impact on network KPIs in a quantitative and visualized manner.

In summary, with the AI, big data, and communication technologies integrated to real-time data collection, image visualization, twin modeling, and intelligent parameter optimization, a digital twin is built for the shared network.

3.3.3 Application Scenarios and Achievements

3.3.3.1 Coverage Optimization

With the digital twin technology, network problems can be identified automatically, and the autonomous and intelligent optimization capability of a shared network can be improved in terms of equipment, coverage, planning, and parameters, thus improving network quality and user experience.

Scenario: High Ratio of 5G UEs Camping in 4G Networks

The large-scale deployment of 5G networks signifies the importance of 5G networks in future data service transport. However, due to challenges in equipment, 5G network coverage, and parameter settings, some 5G UEs may camp in 4G networks. The digital twin–based auto RF technology can be used to reduce the ratio of 5G UEs camping in the 4G network, specifically:

1. A grid map showing the 5G cells and areas with most 5G UEs camping in the 4G network is built based on the MR data and KPIs of both operators, so that targeted measures can be taken by scenario.
2. For camping caused by weak coverage, the auto RF technology is used preferentially to adjust SSB beam weights and digital azimuths and tilts, achieving intelligent RF optimization in areas with poor or unreasonable coverage.
3. A grid map showing the distribution of 5G UEs (of both operators) camping in the 4G network is built, and optimization objectives can be set accordingly. The 4G/5G inter-operation parameters can be set based on these objectives to reduce the ratio of 5G UEs camping in the 4G network.
4. For the areas where the ratio of 5G UEs camping in the 4G network remains high after auto RF and parameter optimization, precise planning of new base stations can be provided based on the operators' 4G and 5G MRs. This ensures the maximum value for the operators and improves the coverage in key scenarios, thus increasing the 5G camping ratio and the satisfaction of 5G users.

Achievements

As an example, consider a a project for increasing the ratio of 5G UEs camping in the 5G network. Auto RF and Massive Multipl-Input Multiple-Output (MIMO) weight optimization were used to provide reasonable azimuths, tilts, and beam weights for coverage. By doing so, the average Reference Signal Received Power (RSRP) was improved by 3.17% and the average SINR was improved by 2.66%. A total of 1772 cells were optimized by adjusting the 4G/5G interoperation parameters, and 60 new base stations were added to the existing network. As a result, as well as a great improvement in the optimization efficiency of the shared network, a 6% increase in the 5G traffic ratio and an 80% decrease in the number of on-site antenna adjustments was observed.

3.3.3.2 Load Balancing

At present, 4G/5G network co-construction and sharing faces complicated network conditions, such as hybrid network architecture involving multiple frequency bands, RATs, and vendors. In the aspect of load balancing, in most scenarios, equipment vendors can provide a complete load balancing solution. However, in a hybrid network constructed by different operators and vendors, load balancing cannot be implemented due to the private policy of each vendor. After network sharing, a large load gap between adjacent base stations of different operators and vendors may occur, which is difficult to address. Therefore, it is necessary to establish a unified load balancing system and solution for the network involving multiple RATs and vendors.

The automatic load balancing solution for multi-vendor, multi-RAT, and multi-frequency networks involves the following innovations:

1. Using the unified load evaluation KPI for cell load evaluation

The load level indicator based on the maximum number of RRC-connected UEs can be used as the unified KPI for cell load evaluation. Proper load thresholds can be configured based on Time Division Duplex (TDD), Frequency Division Duplex (FDD), and bandwidth factors. In this way, a unified evaluation rule can be set despite different vendors, RATs, and bandwidths.

2. Evaluating the comprehensive load balancing capability of each target cell based on the capacity and coverage, and determining the load balancing priority for the cell

1. The overlapping coverage degree in an MR is used to calculate overlapping coverage between the target cell and the high-load cell.
2. The load balancing capability of the target cell is measured by considering the capacity and load levels of the neighbor cells.
3. The load balancing priority of the target cell is dynamically evaluated by taking into account both the coverage and capacity.

3. Making a handover parameter adjustment policy

By mining the data value of the RSRP in an MR, this solution analyses the relationships between the RSRP range (overlapping bands) and handover parameters (handover bands), and provides guidance on accurate iterative optimization of handover parameters to achieve load balancing.

4. Implementing automatic iterative optimization

Real-time network performance evaluation employs minute-level performance indicators. When the load of the cell reaches the preset load balancing threshold, automatic parameter adjustment is implemented in accordance with the preset automatic load balancing optimization algorithm. An adaptive step policy is used to automatically and accurately control the handover band and threshold in accordance with the equivalent load capacity of the serving cell and neighbor cells, overlapping coverage degrees, and real-time load. After the network load is reduced, the system can automatically roll back network parameters level by level.

Note: If no cell meets the load balancing conditions, the cell coverage shrinking solution or cell expansion solution should be applied to solve the high load problem.

Achievements

In a city, the 4G networks of China Unicom and China Telecom are fully shared, and the load balancing policy for the system using equipment from the same vendor is enabled in each operator's network. However, in the shared area, significant load disparities exist among neighboring base stations of different vendors. For solution verification, China Telecom and China Unicom chose the cells from different operators and vendors, with the same coverage or over 60% overlapping coverage degree and dramatically different load. After the solution was deployed, handover parameters could be optimized precisely and quickly for cells with unbalanced load. After the optimization, the downlink traffic of high-load cells was reduced by 30.84%, the number of users was reduced by 32.92%, the downlink traffic of load-sharing cells was increased by 22.27%, and the number of users was increased by 43.15%. Through automatic handover parameter adjustment, load balancing optimization was implemented among the cells of different operators and vendors.

3.3.3.3 Network Assurance for Major Events

Scenario 1: Real-time multi-dimensional monitoring for a shared network:

The shared network is monitored in a comprehensive way at a granularity of five minutes with a minute-level delay. By operator, hosting operator, and RAT (4G or 5G), the dynamic distribution of 3D grid-level heat and network KPIs (such as coverage and capacity KPIs) of users are monitored. The health status of the cell/pRRU is monitored to ensure that the monitored objects have a one-to-one correspondence with the physical objects. The related KPIs (such as the delay and time granularity) should be the same to ensure fast, accurate, and full-dimension insight into the shared network where a large number of UEs access the network.

Scenario 2: Real-time accurate and dynamic capacity prediction for a shared network:

The system dynamically monitors and accurately predicts the capacity and traffic KPIs of the cell/pRRU at a granularity of five minutes with a minute-level delay, and sends the possible peak capacity value to the monitoring screen to allow sufficient time for formulating the subsequent optimization policy. Benefiting from the reduction in the delay, the duration of algorithm-based prediction can be further reduced to decrease the accumulated errors of the prediction algorithm and enhance the accuracy of early warning and prediction.

Scenario 3: Global assurance policy for multi-objective coordination between the two operators.

After it is predicted that a large number of UEs may access the cell, the optimization objectives such as equipment security in the shared network, load balancing network security, and user perception of the two operators shall be considered. Global and quantitative pre-evaluation for impact on network KPIs shall be conducted by using the twin network. Based on the intelligent optimization algorithm, the system outputs the optimal assurance policy within one minute, and pre-presents the optimization effect, achieving global, transparent, and secure collaborative assurance in one twin network.

After the optimization, the downlink traffic of high-load cells was reduced by 30.84%, the number of users was reduced by 32.92%, the downlink traffic of load-sharing cells was increased by 22.27%, and the number of users was increased by 43.15%

Achievements

The digital twin network for co-construction and sharing demonstrated high-efficiency and high-quality 24/7 assurance for the 19th Hangzhou Asian Games within its 16 day duration, including the opening ceremony, closing ceremony, and forty-eight sports events, and covering 600000 4G/5G users. As an intelligent neural hub, the digital twin network for co-construction and sharing implemented minute-level global dynamic insight and prediction. This resulted in a reduction of the time delay for locating poor voice quality problems to the minute level by over fourfold, a 72% enhancement in problem location efficiency, a 93% improvement in assurance policy generation efficiency to the second level, a reduction of the overall co-ordination duration for addressing poor voice quality problems by 78% to 10 minutes or less, and a decrease in the major failure rate to 0%. Empowering the shared network and enhancing the user perception of the two operators, the digital twin network achieved the following assurance effects in the 19th Hangzhou Asian Games: the hour-level peak traffic of 4.2 TB in the main venue, a 4G/5G call connection rate of 99.82%, a dropped-call rate of 0.05%, an average uplink and downlink data rates at 8.80 mega bits per second (Mbps) and 17.40 Mbps in the 4G network, an average uplink and downlink data rates at 19.38 Mbps and 159.84 Mbps in the 5G network, and a 1.6% ratio between the average data rates of the two operators, achieving equal optimization.

3.4
AI-Based Full-Time Energy-Saving Technology for Shared Networks

3.4.1 Challenges

The traditional energy-saving technology for base stations is implemented by manually configuring timing energy-saving policies. However, difficulty in discovering energy-saving base stations, guaranteeing energy-saving security, and dealing with unexpected issues, as well as complicated deployment of massive base stations, and time-consuming evaluation and optimization make it hard to achieve elaborate energy-saving management because of large traffic differences between base stations. In the case of multi-network collaboration, energy saving may even affect user experience for all operators. Therefore, how to implement elaborate, secure, high-efficiency, and large-scale energy saving, and prevent the impact on the services in 5G network co-construction and sharing has become an industry-wide subject.

3.4.2 Innovation

To solve the above problems, a network-wide AI-based energy-saving platform for base stations is developed, boasting the following three advantages:

AI-based energy-saving algorithm: The platform can accurately predict energy-saving time periods based on "One Sector, One Solution," and continuously optimize the algorithm in accordance with the traffic trend and 5G traffic proportion of shared base stations.

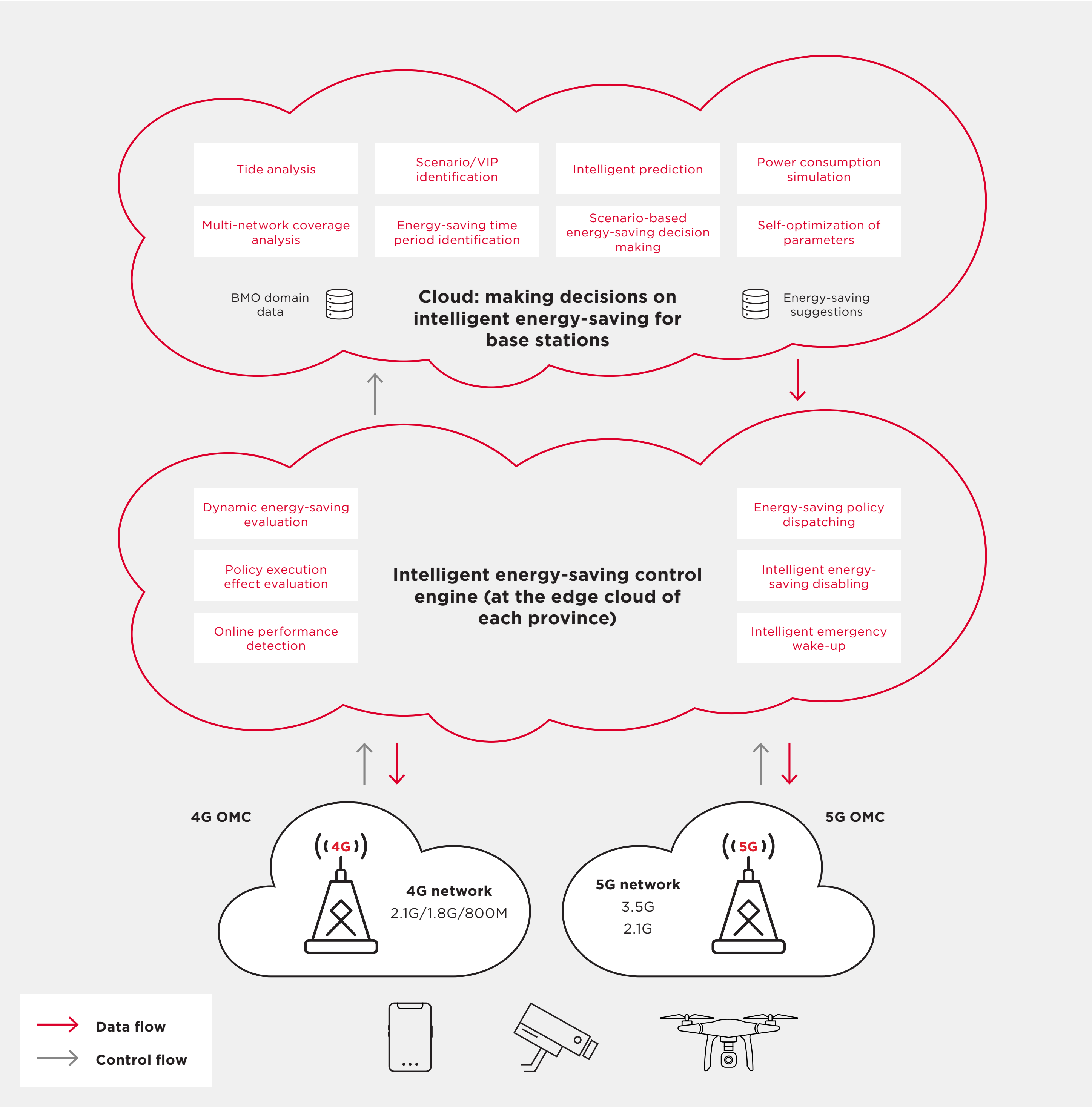
Energy-saving protection: For bursty services, the platform can monitor traffic changes of adjacent base stations on a real-time basis. In case of severe network fluctuations, the platform can immediately wake up the base stations in energy-saving mode to ensure that user experience is not affected.

Energy-saving instructions: The platform executes massive energy-saving instructions reliably by using the 5G instruction interface, and introducing the priority queue, multi-threading and concurrency technologies, breaking through the "last mile" of energy-saving.

> In the case of multi-network collaboration, energy saving may even affect user experience for all operators. Therefore, how to implement elaborate, secure, high-efficiency, and large-scale energy saving, and prevent the impact on the services in 5G network co-construction and sharing has become an industry-wide subject

By using AI, big data, and network control technologies, China Telecom and China Unicom have built a network-wide AI-based energy-saving platform for base stations. The energy-saving analysis capability and decision-making capability provide a reference for the platform to make decisions. The energy-saving control engine converts the decisions into instructions, executes the instructions, and performs evaluation and feedback as shown in Figure 3-3.

Figure 3-3
All-Time AI-Based Energy Saving Platform



3.4.3 Application Scenarios/Implementation

Energy saving analysis capability: The platform collects, processes, and analyzes the data of all the base stations of the whole network in a unified manner, and introduces machine learning, deep learning, and enhanced learning technologies to implement digital modeling for "One Sector, One Profile." In addition, the traffic trends and 5G traffic proportions of shared base stations are optimized. The scheduling, energy-saving analysis, and energy consumption evaluation of model algorithms such as tidal analysis, scenario identification, energy-saving time period identification, intelligent prediction, and multi-network coverage analysis are implemented.

Intelligent energy-saving decision-making capability: An integrated two-level decision-making system is built to strengthen the precision of the decision-making. The cloud decision-making engine generates energy-saving suggestions based on energy-saving profiles of sectors, supports scenario-based policy management and policy template sharing (involving energy-saving policies, and wakeup-upon emergency policies), and supports self-optimization of energy-saving policy parameters.

Energy-saving control capability: After receiving energy-saving suggestions and policy templates from the cloud, the energy-saving control engine at the edge cloud of each province manages local policies, and automatically generates and delivers energy-saving instructions. In addition, in accordance with traffic changes of adjacent base stations, the engine automatically executes wakeup policies in a timely manner in case of severe network fluctuations to ensure that user experience is not affected. After the period for energy saving ends, the engine automatically reports the policy execution result and effects to the cloud for subsequent evaluation.

3.4.4 Achievements

5G network co-construction and sharing helps reduce the power consumption of the 5G networks of China Telecom and China Unicom by 50%. The AI-based energy saving platform brings an additional gain of over 15% in terms of average energy consumption. As the first energy-saving platform that can be used in the co-constructed and shared 5G networks, this platform has been widely deployed on the 5G base stations of China Telecom, covering 31 provinces in China.

5G network co-construction and sharing helps reduce the power consumption of the 5G networks of China Telecom and China Unicom by 50%

3.5

User Experience Assurance Based on Multi-dimensional Data Association

3.5.1 Challenges

Because users on shared 4G/5G networks may be served by either operator's wireless resources, the operators face significant challenges in addressing complaints about experience, as it can be difficult and slow to reproduce, locate, demarcate, and analyze the problems. In this context, there is an urgent need for multi-dimensional data association across the RAN and core network to accurately pinpoint and efficiently handle user complaints on shared networks.

3.5.2 Innovation

Based on real-time association of data from the RAN and core network, a smart user complaint detection and end-to-end (E2E) closed-loop management approach is established by utilizing AI-based spatial perception and high-precision positioning, as well as a rule engine that encapsulates expert experience. This approach enables the reproduction, root cause analysis, and resolution of user experience issues on a shared network.

3D reproduction of user behavior: The real-time association of RAN MR, FM, CM, and PM data and core network data from both operators facilitates the reconstruction of specific user behavior in terms of time, space, and network. This is achieved through the utilization of AI-based spatial perception and high-precision positioning technology. The system automatically identifies abnormal CDRs and paths, with a positioning precision within several meters.

Automatic root cause analysis: The system automatically diagnoses the abnormal CDRs from complaining users based on MR, path, FM, CM, and PM data and the rule engine that encapsulates expert experience. It helps identify the primary serving cell associated with a specific user to determine if the issue lies with the host or guest operator's cell. By further analyzing the alarms, parameters, KPIs, and operation logs of the primary serving cell, the root cause of poor cell quality can be determined, enabling efficient resolution of user experience complaints.

3.5.3 Application Scenarios

This technology enables quick identification of the root causes of user complaints and poor user experience, determining whether issues originate at the host or guest operator's cell on a shared network. By pinpointing the key factors that cause these problems, the technology streamlines problem analysis and resolution, ensuring a prompt and efficient resolution process.

1. In terms of user experience, the real-time association of core network data and RAN MR, FM, CM, and PM data allows for the quick determination of whether the problem is caused by the host or guest operator's cell.
2. By conducting lightweight locating analysis on multi-dimensional wireless data, including engineering parameters, MRs, FM, and PM, this technology enables cause demarcation and offers optimization suggestions for capacity, quality, coverage, and interference, helping with the formulation and implementation of rectification solutions.
3. The KPIs and user experience of the involved cell are evaluated after optimization to verify the problem resolution.

3.5.4 Achievements

This solution has been implemented in a province in China to resolve the issues of more than 3000 poor quality cells (1900 from operator A and 1100 from operator B) that incurred 4000 user complaints, contributing to a comprehensive issue resolution rate of over 80% and a reduction of user complaints by 31%. In addition, the accuracy of user complaint analysis is improved by 20%, and 29.7% fewer onsite tests being required during complaint handling. This helps the average complaint handling duration to be shortened from 2 hours to 0.5 hours, leading to a 75% increase in efficiency.

4 Prospects for Network Co-Construction and Sharing

In the future, China Telecom and China Unicom envision the creation of a simplified and efficient operations mode for smart co-governance of shared networks by employing AI, big data, large model, blockchain, and digital twin technologies.

- **Simplified O&M:** Through physical-virtual mapping, optimization, and synchronization, the digital twin technology provides real-time, visual, and predictive decision-making capabilities, generating an integrated solution for network planning, construction, maintenance, and optimization of co-constructed and shared networks, thereby greatly simplifying the network O&M and improving O&M efficiency.
- **High operational efficiency:** By simulating network operations conditions, the digital twin technology implements more effective management for network resources, optimizing bandwidth allocation, and reducing energy consumption. It also simulates user experience and user behaviors to improve service quality in response to increasing user requirements. As a result, the overall network operations efficiency can be further improved.
- **Intelligent mobile networks:** Used together with AI, foundation models, and blockchain, the digital twin technology focuses on core values and service processes to create more flexible, efficient, and intelligent mobile networks, providing users with better communication services.

> China Telecom and China Unicom envision the creation of a simplified and efficient operations mode for smart co-governance of shared networks by employing AI, big data, large model, blockchain, and digital twin technologies

Acknowledgement

With continuous efforts for over one year, the project team has developed this white paper, which elaborates on the joint operations and management for 5G network co-construction and sharing by leveraging blockchain, big data, AI, and digital twin technologies to cope with the challenges on co-maintenance and co-optimization of the shared network. This white paper describes how China Unicom and China Telecom have solved key issues in network planning, construction, operations, operations optimization, regulation, and settlement to ensure good user experience and high network O&M efficiency, providing useful references for the industry.

China Unicom and China Telecom would like to thank the project team, experts, and the review committee for their contributions to this white paper. In the future, China Unicom and China Telecom will continue to work with global partners to explore more innovative technologies and applications in verticals, opening up more opportunities for network co-construction and sharing, and sharing our experience with the world. China Ubnicom and China Telecom will continuel to be active participants in the ecosystem to constantly develop next-generation information technologies, making them a driver of the digital economy and social development, a catalyst for industrial transformation, and a foundation for digital information infrastructure construction. It is hoped that such ongoing collaboration can shape the future new digital economy.

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Glossary

Term	Description
3D	Three Dimensional
4G	4th Generation (of mobile technology)
5G	5th Generation (of mobile technology)
5QI	5G QoS Identifier
AAU	Active Antenna Unit
ARCN	Absolute Radio Frequency Channel Number
BaaS	Blockchain as a Service
BBU	Baseband Unit
BIM	Building Information Model
BWP	Bandwidth Part
CA	Carrier Aggregation
CAPEX	Capital Expenditure
CGI	Cell Global Identifier
CM	Configuration Management
E2E	End-to-end
ECGI	E-UTRAN CGI
EMS	Element Management
E-UTRAN	Evolved UMTS Terrestrial Radio Access NetworkFDD – Frequency Division Duplex
FM	Fault Management
GIS	Geographic Information System
ID	Identity
IMS	IP Multimedia Subsystem
IP	Internet Protocol
KPI	Key Performance Indicator

Term	Description
KQI	Key Quality Indicator
LTE	Long Term Evolution
Mbps	Mega bits per second
MIMO	Multipl-Input Multiple-Output
MWC	Mobile World Congress
NCGI	NR CGI
NF	Network Function
NMS	Network Management System
NR	New Radio
O&M	Operations & Maintenance
OMC	Operation and Maintenance Center
OPEX	Operational Expenditure
PCI	Physical Cell Identity
PLMN	Public Land Mobile Network
PM	Performance Measurement
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
pRRU	Pico RRU
QCI	QoS Class Identifier
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RFSP	RAT Frequency Selection Priority
RRC	Radio Resource Control
RRU	Remote Radio Unit
RSRP	Reference Signal Receiving Quality

Term	Description
SA	Standalone
SLA	Service Level Agreement
SSB	Synchronization Signal Block
TAC	Tracking Area Code
TAI	Tracking Area Identity
TB	Terabytes
TCO	Total Cost of Ownership
TDD	Time Division Duplex
UE	User Equipment
UMTS	Universal Mobile Telecommunications Service
VoLTE	Voice over LTE
xDR	Extended Detection and Response

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