5G Network Co-Construction and Sharing Guide

27th February 2023

Overview

This paper is a collaborative work between China Telecom, China Unicom, Datang Mobile, Ericsson, Huawei and ZTE based on experience in China of 5G Network Co-Construction and Sharing conducted in GSMA Foundry.

Since 2019, China Telecom and China Unicom have been working on 5G network co-construction and sharing, with major breakthroughs made in technology development, networking, operations, and management. Together, they have built the world's first, largest, and fastest 5G Standalone (SA) shared network, realising one physical network correlated with two logical networks, and multiple customised private networks. This whitepaper describes the technology development, operations, management, business models, and future evolution of 5G network co-construction and sharing the technologies and solutions which have been proven effective by the Chinese operators.

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 researches, and business deployment. Our sincere gratitude goes to the team members from the following organizations for their contributions to this guide:

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

Contents

Preface

The advent of 5G is a major breakthrough in new-generation information and communication technologies which will enable digital transformation and accelerate future digital economic growth. Thanks to the potentially huge commercial value of 5G, acceleration of 5G network deployments has become the primary focus of global operators.

However, the industry is faced with challenges in 5G network deployment. One challenge is how to reduce network construction and operation costs, and how to benefit the billions of people in regions without advanced 5G communications infrastructure.

To avoid repeated network construction by different individual operators, the 5G network co-construction and sharing solution described in this paper (hereafter termed **"The CT/CU Deployment"**) can reduce costs and energy consumption, effectively improve the spectrum utilisation, and enable broader deployment of advanced mobile networks. The CT/CU Deployment provides means to greatly reduce carbon emissions, and accelerates the development of both digital information infrastructure and the digital economy. The cooperation between operators will bring 5G services to more people in less time and at reduced cost.

Since 2019, China Telecom and China Unicom have been working innovatively and cooperating on their solution, and have made major breakthroughs in 5G network sharing. So far, the operators have tackled many challenges in their network sharing journey, including doubling bandwidth, multi-frequency coexistence, network combination, and 4G/5G coordination, while ensuring good user experience over the network. In addition, they have built the world's first and largest 5G SA shared network, realising one physical network, two logical networks, and multiple customised private networks, and laying a solid foundation for large-scale industrial applications.

This whitepaper describes the technologies, operation and management and business models used in the CT/CU Deployment as well as its future evolution. In this whitepaper, as global leaders in 5G network sharing, China Telecom and China Unicom share their use of technologies, further insights and solutions regarding network sharing with the industry at large. The *5G Network Co-Construction and Sharing Guide* is released by the GSMA as a whitepaper to the industry to facilitate future industry initiatives in network sharing.

1. Current Status of Global 5G Development

1.1 Challenge

Over the past few decades, the mobile communications industry has witnessed the evolution from 1G to 5G. A new mobile network generation emerges typically every ten years, bringing about breakthroughs in mobile technology and communications. Every intergenerational leap or technological progress has greatly promoted industrial upgrade as well as economic and social development, and therefore dramatically changed the way we live and work. From analogue to digital communications, and from voice to data services, the network throughput has increased hundreds of times, and mobile communication networks have created a prosperous Internet economy.

As a new-generation mobile communications network, 5G networks not only provide the ultimate user experience in Augmented Reality (AR), Virtual Reality (VR), and Ultra high Definition (UHD) videos, but also enable communication between people and things, and between things themselves, as well as meeting the application needs of vertical industries such as mobile medicine, internet of vehicles, smart homes, industrial control, and environmental monitoring. To rapidly integrate 5G networks into all walks of life, 5G infrastructure construction is the key to the digital, network-based, and intelligent transformation of the economy and society.

So far, 5.3 billion people around the world use mobile services, accounting for 67% of the world's population. The proportion of 5G connections is expected to increase from 8% in 2021 to 25% by 2025. However, there is still no 5G network coverage in underdeveloped regions and countries. How to enable billions of people in such areas to enjoy mobile communication services, experience the benefits brought by 5G and drive global economic and social development through 5G connectivity are still to be fully addressed by the global communications industry.

1.2 Significance of 5G Network Co-Construction and Sharing

5G network co-construction and sharing is an effective solution to solve this challenge, not only by reducing repeated network investment, but also accelerating the construction of 5G networks and popularising 5G services and capabilities across developed and underdeveloped global geographies. Network co-construction and sharing provides four primary benefits, including; the reduction of CAPEX, integration of operator resources for maximum efficiency, improvement in the quality of 5G services from the user perspective, and reductions of the carbon emissions of base stations.

1. Reduction of CAPEX

The higher network performance of 5G requires higher network infrastructure investment. Therefore, it is difficult for a single operator to achieve large-scale 5G network deployment in a short period of time. Thanks to the CT/CU Deployment, the two operators can coordinate their existing network resources, therefore providing better network performance through pace and scale of deployment, achieving a synergistic effect.

2. Integration of operators' resources for maximum efficiency

The 5G spectrum at 3.5 GHz and 2.1 GHz of China Telecom and China Unicom are adjacent, so only one set of equipment is required to provide better network performance. Moreover, the network resources of the two operators are highly complementary in a number of ways, including spectrum and ownership of physical assets, in the southern and northern regions of China. Through the win-win cooperation on the construction and sharing of one 5G Radio Access Network (RAN) nationwide, the two operators achieved full 5G network coverage across the country, developed 5G service capabilities, enhanced the market competitiveness of 5G networks, and improved network and operational efficiency of assets.

3. Improvement in the quality of 5G services from the user perspective

With continuous development of the digital economy, 5G now carries expectations of both consumers and industries, but the process from nationwide coverage to the application and popularity of 5G networks is gradual. Network co-construction and sharing shortens the waiting time for 5G service provisioning, whilst seeing a significant reduction in infrastructure construction expenditure. With the greater benefits of 5G services, the industry should make every effort to shift from 4G to 5G networks and promote the development of 5G networks, and to provide users with stable and high-quality 5G services.

4. Reduction of the carbon emissions of base stations

Co-construction and sharing can dramatically decrease the number of nodes deployed in a network, improve the utilisation rate of nodes, and provide more services with increased social and economic benefits without increasing energy consumption, thereby effectively reducing network power consumption and promoting green and innovative development.

1.3 Best Practice: 5G Network Co-Construction and Sharing between China Telecom and China Unicom

China Telecom and China Unicom, signed the *5G Network Co-Construction and Sharing Framework Agreement* in September 2019 for the construction of a nationwide 5G RAN by sharing 5G frequency resources while building 5G core networks independently. The two parties clearly defined their respective construction areas and the responsibilities in construction, investment, maintenance, and costs. In the subsequent implementation of 5G co-construction and sharing, China Telecom and China Unicom continued to innovate in technical solutions, cooperation models, and management mechanisms. On September 30, 2020, China Telecom and China Unicom completed the phase-1 construction and commercial deployment of the world's first and largest 5G shared network, promoting 5G network construction and end-to-end SA network evolution.

By December 2022, China Telecom and China Unicom had deployed about 1,000,000 base stations, accounting for more than 40% of all 5G base stations around the world, and built the world's first and largest 5G SA shared network, realising large-scale industrial applications. In addition, the sharing of 4G RANs between the two operators was promoted, saving over USD 40 billion in network construction, and reducing network operations costs by USD 4 billion, electricity usage by more than 10 billion kWh, and carbon emissions by 10 million tons per year.

China Telecom and China Unicom have proposed 12 contributions to international standards for 5G network co-construction and sharing, established the first national standard for RAN sharing technologies in China, and led development and implementation of global mobile communication network sharing. China Telecom and China Unicom, together with their partners, have won various awards for the huge achievements of this work, including; the iF Design Award in 2020 and 2021, the TM Forum Outstanding Catalyst – Impact Society and Sustainability Award, the GTI Innovative Breakthrough in Mobile Technology Award, and the GSMA GLOMO and AMO awards.

Over the past three decades, an ICT globalisation system based on the unification of standards, globalisation of technologies, products, supplies, and free flow of data has been taking shape. The 5G network co-construction and sharing advocated by China coincides with the vision of the Internet of Everything pursued by the telecommunications industry. The CT/CU Deployment will further promote the unification of industry standards, globalisation of supply chains, digitisation of society, free flow of data, and circulation of capital within the industry.

China Telecom and China Unicom are global pioneers in nationwide full-lifecycle 5G network co-construction and sharing. Through a series of innovative practices in products, technologies, operations & maintenance , and management, China Telecom and China Unicom have accelerated the implementation of 5G network co-construction and sharing, providing a "Chinese Experience" for the global telecommunications industry in the following aspects:

Technology: practice of non-standalone (NSA) and SA network solutions, Dynamic Spectrum Sharing (DSS), power sharing, key technologies for co-construction and sharing management, private network sharing, and international roaming solutions.

Evolution: exploration in deepening 5G network co-construction and sharing in the future in terms of technical routes, geographic scope, number of partners, working frequency bands, and Radio Access Technologies (RATs). Facing the further challenges of millimeter wave spectrum sharing, indoor distribution sharing, edge computing sharing, and 6G sharing in the future, the two operators will continue to explore and innovate.

2. Key Technologies of 5G Network Co-Construction and Sharing

2.1 Evolution of Standards for Mobile Communication Network Co-Construction and Sharing

Since 2000 when the 3G era started, some operators in Europe have been pressing for mobile communication network sharing, and the network sharing of operators around the world has been emerging continuously in various forms. Thanks to network sharing, repeated network infrastructure construction is reduced and mobile communication services are quickly provided, benefiting users all over the world.

From 2003 to 2004, 3GPP issued 3G network sharing standards in Release 6. 3GPP TS 23.251 defined the Multi-Operator Core Network (MOCN), including system information broadcasting, network selection and other basic functions, as well as the network sharing requirements for User Equipments (UEs), base stations, and Core Networks (CNs). 3GPP TS 25.331 and other specifications have defined the related interface protocols and other requirements for network sharing. In Releases 8 and 10, 3GPP has respectively provided 4G and 2G network sharing specifications.

Release 15 and later releases of 3GPP support RAN sharing and 5G MOCN, and standardised RAN sharing in terms of network architectures, air interfaces, NG interfaces, and Xn interfaces. TS 38.331 and other specifications have defined more interface protocols and requirements for further network sharing. 3GPP's requirements for network sharing continue to evolve in later releases. In Release 17, new operator- specific management of shared resources was added to adapt to multi–cell ID scenarios. In Release 18, further research was carried out on the co-construction and sharing management architecture, and the requirements for better O&M management were clarified.

The Network Sharing Timeline in 3GPP is shown in Figure 2.1.

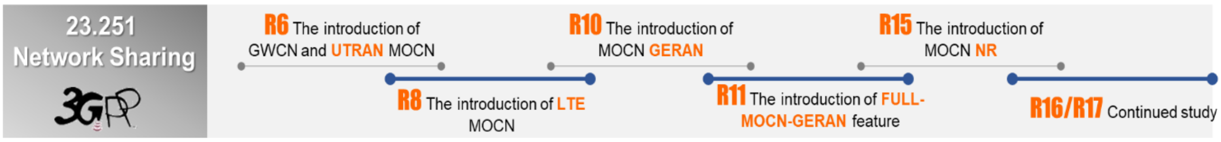

Figure 2.1 Network Sharing Timeline in 3GPP

Mobile communication network sharing refers to the sharing of infrastructure or communication equipment among multiple operators. The infrastructure includes towers, buildings, and equipment rooms used for deploying base stations, whilst the communication equipment includes RAN, transport network, and CN equipment.

In terms of operations management, there are two models of co-construction and sharing for operators. One is to independently build networks and share network resources based on business agreements, and the other is to set up a joint venture which operates independently and undertakes wireless network construction or maintenance. Network resource sharing includes active sharing and passive sharing. Passive sharing refers to the sharing of infrastructure such as antenna poles (towers), and passive equipment in transport networks. Active sharing refers to the sharing of infrastructure in RANs such as base stations, including those used for RAN sharing and national inter-CN roaming.

In most cases, operators obtain their frequency band resources from a regulatory authority and invest them as shared resources in a shared network. As the proportion of shared resources increases, CAPEX gradually decreases, but deployment becomes more difficult to control and the coordination among operators becomes more complex. This whitepaper focuses on active sharing which, in comparison with the relatively mature passive sharing, requires better coordination among operators and more complex technical solutions.

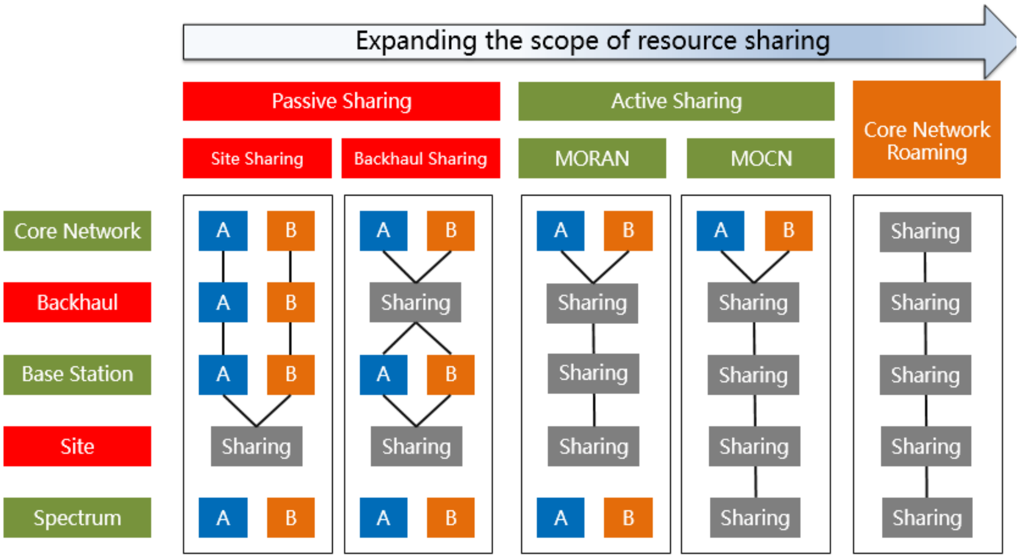

Figure 2.2 Network Resource Sharing Models

Operators generally take cost reduction as the first concern when choosing areas for network sharing. 5G network co-construction and sharing is implemented in areas such as suburbs and rural areas, while in dense and general urban areas, independent networks are deployed to provide differentiated services and ensure differentiated network performance.

2.2 5G Network Sharing

5G sharing includes **RAN sharing** and **national inter-CN roaming**.

2.2.1 RAN Sharing

2.2.1.1 Technical Solutions

3GPP Standardised RAN sharing solutions support operators which intend to share radio resources (carriers). In case of MOCN, a single (logical) RAN node controls the (shared) radio resources. In the case of RAN sharing with multiple cell ID broadcast radios, resources are commonly controlled by a set of logical RAN nodes (one RAN node per cell ID broadcast). Further, the industry adopted the term Multi-Operator RAN (MORAN) to denote a deployment variant where the same RAN infrastructure (antennas, PAs, etc.) is used but each operator uses its own carrier. See Figure 2.3.

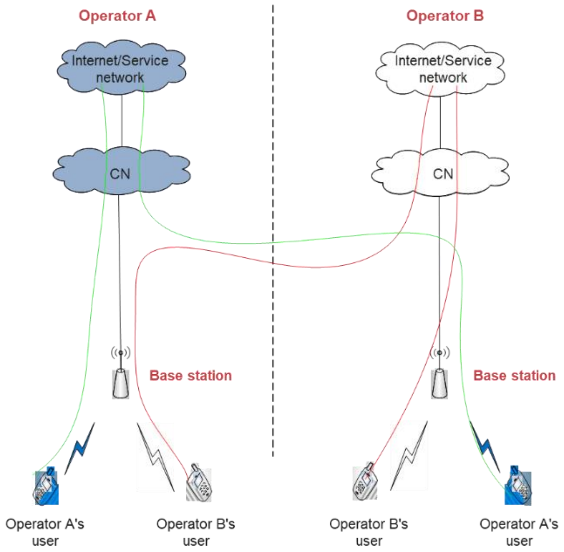

Figure 2.3 Network Architecture for RAN Sharing (both Operator A and B share their RAN)

In MORAN, multiple independent carriers are configured and the PLMN IDs of operators are broadcasted on the carriers. Baseband Units (BBUs) are shared, and connected to Remote Radio Units (RRUs) and Active Antenna Units (AAUs) provided by the same vendor of BBUs. Each carrier is independently configured and managed. The RAN infrastructure provides logically and physically separated cell resources and core network connectivity on a per operator basis. The MORAN solution features simple RAN infrastructure sharing and O&M, and is applicable to scenarios where operators need to maintain service and deployment independence in shared networks.

In MOCN, one or more carriers are configured for frequency sharing. Operators share their cells - physically and logically; in each cell, multiple Public Land Mobile Networks (PLMNs) are broadcasted. Sharing radio resources among participating operators is performed according to service level agreements. Parameterisation of cell-level features needs to be negotiated among all operators. UEs accessing shared cells select one of the broadcast PLMNs and communicate this selection to the gNodeB, which connect UEs to their (selected) core network, see Figure 2.4. The MOCN solution features high resource efficiency and is applicable to operators
that closely cooperate with each other. For example, MOCN is used when operator A has a spectrum license, and operator does not have a spectrum license but would like to use the spectrum of operator A.

RAN sharing with multiple cell ID broadcast is similar to MOCN in the sense that each operator deploys its own 5G Core (5GC), but while MOCN requires the operators to coordinate their allocation schemes of cell identifiers and Tracking Area Codes, RAN sharing allows each operator to deploy respective allocation schemes independently.

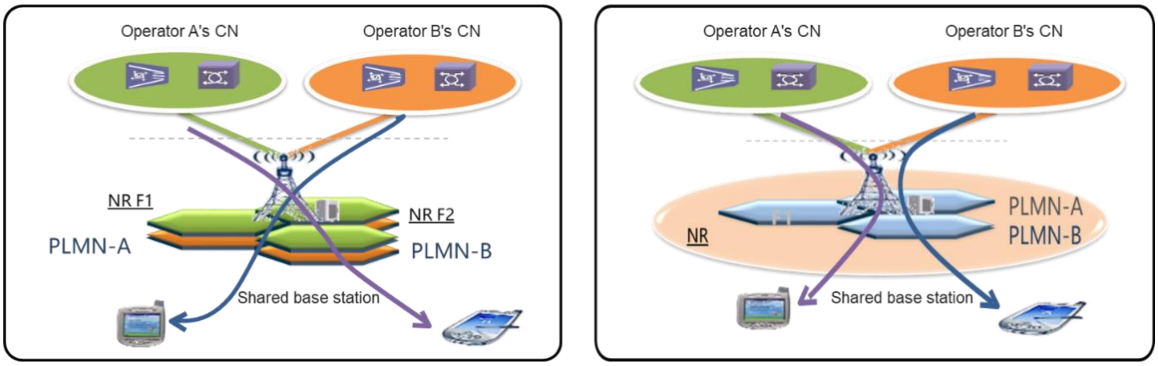

Figure 2.4 MORAN (left figure) and MOCN (right figure)

	MORAN	MOCN
Carriers	Independent	Shared
Cell-level parameters	Configured independently by operators	Configured in a unified way by the hosting operator
Mobility management	Configured independently by operators	Configured in a unified way or independently
Impact on performance	Independent Quality of Service (QoS) Flexible adjustment based on considerable network independence	Independent QoS requiring operators to negotiate in advance More RAN resources available for sharing
Service provisioning	Implemented independently	Implemented by multiple operators together
Hardware	Two carriers deployed, posing higher requirements for the bandwidth and power supported by shared base stations	Fast implementation based on existing hardware

Network adjustment	Implemented independently	Implemented in a unified way

Table 2.1 Comparison Between MORAN and MOCN

2.2.1.2 Evolution from NSA Sharing to SA Sharing

In terms of the network sharing in the NSA phase, core networks are independently established by operators, 5G base stations are shared, and 4G anchor base stations are shared on demand, resulting in a complex network architecture. As shown in Figure 2.5, the X2 interface is required between the 4G base station and 5G base station for UE isolation and interoperation. To implement the co-construction and sharing solution, the following two difficulties must be tackled:

- 4G and 5G base stations must be provided by the same vendor.
- 4G anchor base stations and 5G base stations must be deployed at the same site.

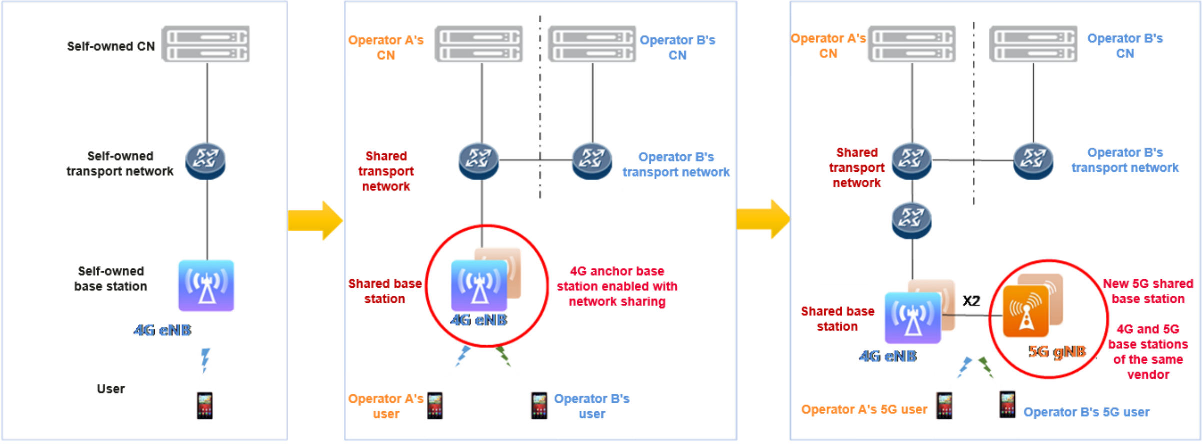

Figure 2.5 Evolution from 4G Sharing to NSA Sharing

There are two technical solutions for NSA sharing: **dual-anchor solution** and **single-anchor solution**. See Figure 2.6.

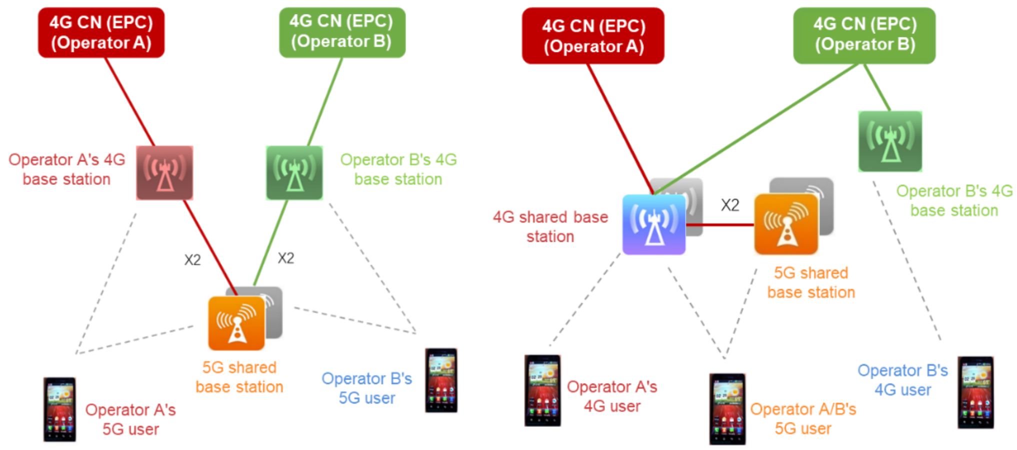

Figure 2.6 Dual-Anchor (left figure) and Single-Anchor (right figure) Solutions

	Dual-Anchor Solution	Single-Anchor Solution
Sharing	● 4G base stations are not shared, and 5G base stations are connected to respective 4G anchor base stations. ● TX2 interfaces are required between 4G and 5G base stations, which must be provided by the same vendor.	● 5G base stations are connected to the same shared 4G anchor base station, and all the base stations must be provided by the same vendor and located at the same site.
Features	● Fast network deployment leads to good user experience. ● The requirements for the areas where networks are to be deployed are strict.	● There are less requirements for the areas where networks are to be deployed.

Table 2.2 Comparison Between Dual-Anchor and Single-Anchor Solutions

The dual-anchor solution is applicable to scenarios where the 4G base stations of all operators as well as the 5G base stations of the hosting operator are provided by the same vendor. Otherwise, X2 interface incompatibility problems may occur. The dual-anchor solution can quickly achieve 5G network co-construction and sharing with minor changes to existing 4G networks.

The single-anchor solution is applicable to scenarios where 4G base stations of operators are provided by different vendors. However, this solution requires a complex reconstruction of existing 4G networks or the establishment of a new 4G anchor. With this solution, 5G networks can be shared while 4G non-anchor base stations are not.

In the NSA phase, voice services are carried over only LTE networks, i.e. Voice over LTE (VoLTE).

The complex technical solutions for NSA sharing involve a large amount of work in reconstruction and cause difficulties in network management and optimisation. Therefore, an evolution to SA sharing, should be performed as soon as possible to improve network quality.

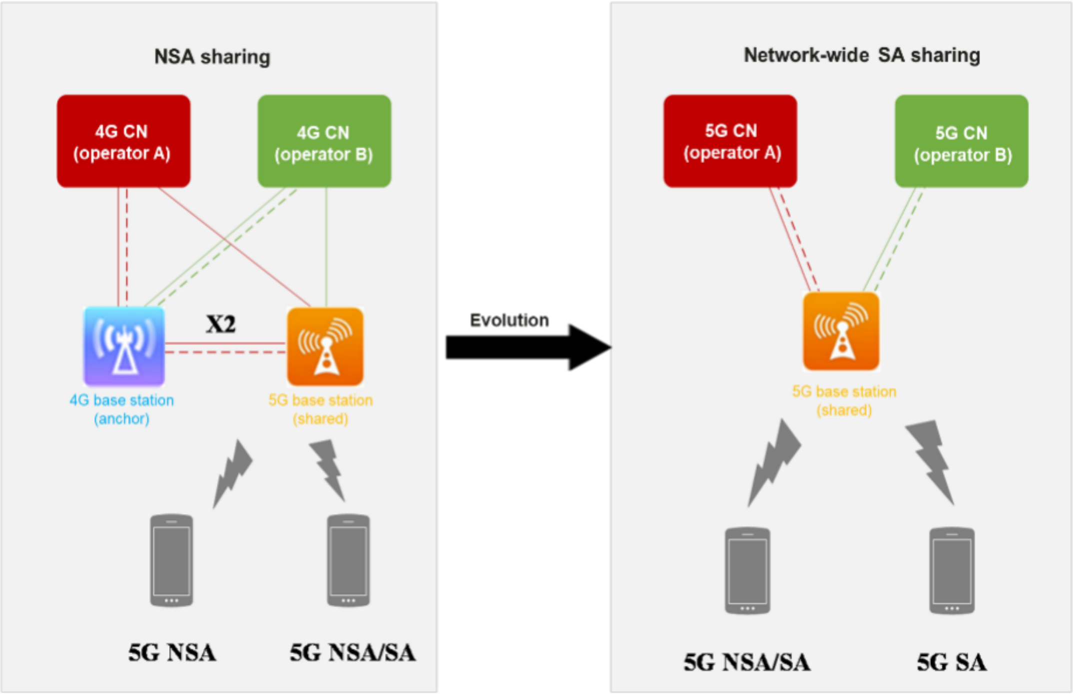

Figure 2.7 Evolution from NSA to SA sharing

After the evolution to 5G SA sharing, operators only need to connect 5G base stations to respective 5GCs, without the reconstruction of 5GCs. In addition, transport networks should be scaled out as required, the base station sharing function should be enabled for 5G base stations, and 4G base stations should be configured as neighbour cells. With the 5G network decoupled from 4G networks, no complex anchor coordination solution is needed, easy optimisation of the 5G network is made possible, and good user experience is guaranteed in both 4G and 5G networks.

In the SA phase, there are two voice service solutions: Voice over New Radio (VoNR) and Evolved Packet System (EPS) fallback.

EPS fallback allows UEs to fall back either to their operators' LTE networks if 5G base stations are shared, or to the hosting operator's LTE network if both 5G and 4G base stations are shared (if 4G base stations have been shared in the NSA phase, they do not need to be reconstructed), see Figure 2.8.

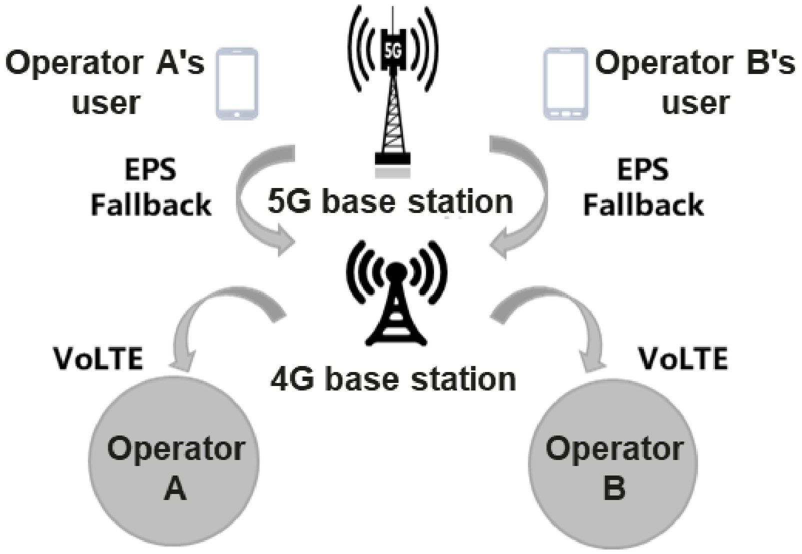

Figure 2.8 Fallback of UEs to their Operators' LTE Networks

After fallback, voice services are provided via LTE networks to ensure voice service continuity, while only data services are in NR networks. If a UE initiates a voice call, a handover is triggered when the gNodeB establishes an IP Multimedia Subsystem (IMS) voice channel in the NR network. In this case, the gNodeB sends a redirection or inter-RAT handover request to the 5GC. After the UE falls back to the LTE network, its voice services are implemented based on VoLTE. EPS fallback allows 5G UEs to camp on NR networks where voice services are not provided. Since there is latency in the fallback procedure, the call setup duration increases.

The VoNR solution requires only 5G base stations to be shared. NR networks are connected to the 5GC while LTE networks are connected to the Evolved Packet Core (EPC). In NR networks, VoNR is used to provide voice services, and at the 5G network edge, UEs are handed over to their LTE networks through the N26 interface and the voice services are continued on LTE. VoNR improves voice quality and allows all the data and voice services of a UE to be implemented in the same NR network.

2.2.2 National Inter-CN Roaming

2.2.2.1 Technical Solutions

The core networks involved in national inter-CN roaming are established by respective operators. The core network of the hosting operator is interconnected with that of the participating operator. Base stations are shared between operators and connected to only the hosting operator's core network, see Figure 2.9. Unlike international roaming, a national inter-CN roaming UE in the visited area may receive signals from the Home PLMN (HPLMN), because the area is covered by the 4G/5G signals of the hosting operator's network and the 4G signals of the participating operator's network at the same time, resulting in a network selection problem for the UE.

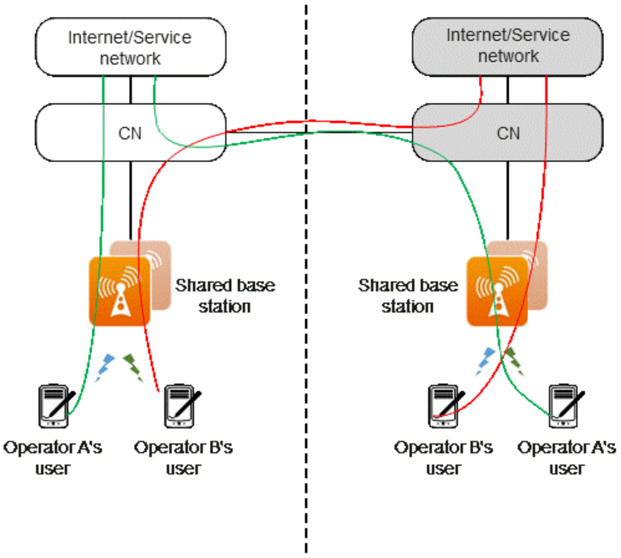

Figure 2.9 Network Architecture for National Inter-CN Roaming with shared base stations

2.2.2.2 4G/5G Core Network Interconnection and Evolution

In the NSA phase, the EPC networks of operators are interconnected, and NSA networks are constructed in different areas. 5G NSA UEs and 4G UEs can use the same roaming policy or different roaming policies, depending on network coverage, planning, and business cooperation. If operators have used national inter-CN roaming in the 4G phase, the same roaming policy is used for 4G and

NSA UEs in the NSA sharing phase. If operators have not used national inter-CN roaming in the 4G phase and need to directly implement NSA sharing, different roaming policies need to be used for 4G and NSA UEs to ensure that NSA UEs roam to the coverage area of the shared NSA network and 4G UEs attached to 4G networks. To implement such roaming policies, on base stations, Mobility Management Entities (MMEs) and other Network Elements (NEs), operators need to configure a mobility management policy and related information based on the RAT Frequency Selection Priority (RFSP), mobility restriction and other technologies to control inter-PLMN mobility.

In the SA sharing phase, a roaming UE can access a 5G Visited PLMN (VPLMN) to use 5G services. In national inter-CN roaming mode, the RANs and 5GCs of operators are independently constructed and managed, and UEs are separately managed. National inter-CN roaming is implemented through home routing. That is, the data of a roaming UE is returned to the HPLMN, and the HPLMN provides services for the UE.

The networks involved in national inter-CN roaming should provide IMS-based voice and video services (including emergency call services), Short Message Service (SMS) over IP (i.e. via IMS), and data services for UEs, and the involved operators should provide services for roaming UEs based on an inter-network roaming protocol.

2.3 Spectrum Sharing

Refarming 4G spectrum for rapid 5G network deployment has become a global consensus, and about 50% of global 5G operators have put such refarming into application. As 4G services and UEs will still exist, a major challenge is how to coordinate the 4G and 5G development strategies and pace of the participating and hosting operators in the 5G co-construction and sharing network, so as to guarantee good user experience. Against such a backdrop, China Telecom and China Unicom adopt the DSS technology. The DSS technology saves network investment by taking account of the different 4G and 5G development strategies and deployment timescales of operators.

2.3.1 Dynamic Spectrum Sharing (DSS)

Challenges

In the early stage of 5G, 4G traffic is much heavier than 5G traffic, so there exists an opportunity to optimise the use of spectrum when deploying standalone 5G networks.

Innovation

China Telecom and China Unicom have proposed the DSS technology to promote the coordinated development of 4G and 5G based on the LTE 2.1 GHz frequency band that features strong penetrability – see Figure 2.10. With the DSS technology, 5G networks can be rapidly deployed without affecting 4G user experience, effectively improving spectrum efficiency and meeting different service requirements of both 4G and 5G users.

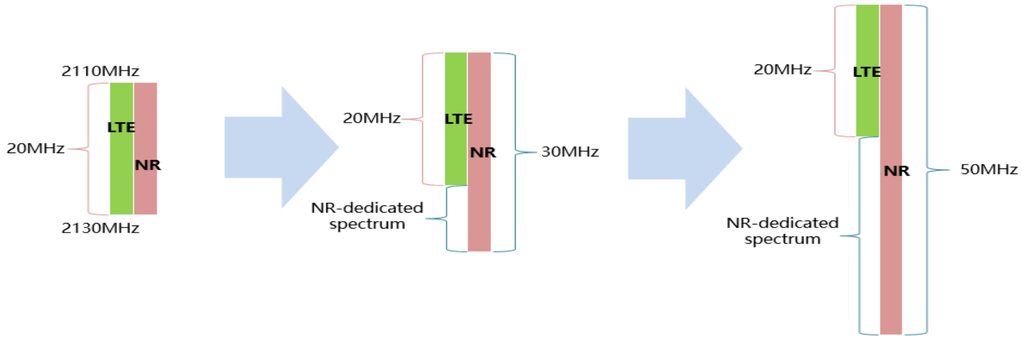

Figure 2.10 DSS Technology

In this solution, both 4G and 5G service requirements should be collected and prioritised, and spectrum resources be allocated based on the priorities, so that the 4G and 5G spectrum resources can be dynamically shared. Figure 2.11 shows how the DSS solution works. For dynamic spectrum sharing, LTE and NR services use the same spectrum, and the interference between them can be prevented or reduced by using such technologies as Cell-Specific Reference Signal (CRS) rate adaptation, Multimedia Broadcast Multicast Service Single Frequency Network (MBSFN) subframe, and Zero Power Channel State Information Reference Signal (ZP CSI-RS). The potential increase in the overhead of 4G and 5G Physical Downlink Control Channels (PDCCHs) after the DSS solution is used can be minimised through efficient PDCCH allocation.

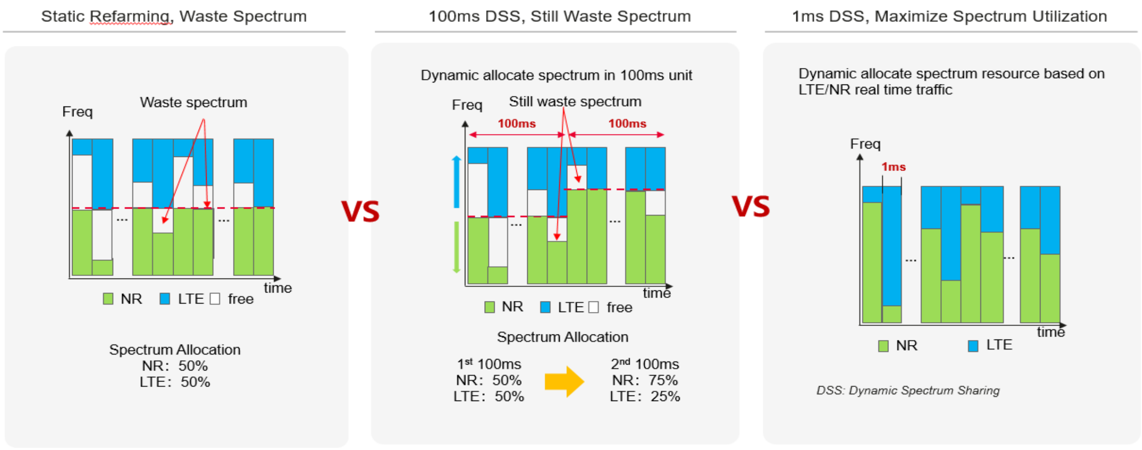

Figure 2.11 DSS Solution

The spectrum resources allocated for NR and LTE can be dynamically adjusted in accordance with the number of connected 4G and 5G UEs, thus ensuring the optimal uplink and downlink performance. In addition, 4G and 5G Physical Downlink Shared Channels (PDSCHs) and Physical Uplink Shared Channels (PUSCHs) can be shared in real time and scheduled at millisecond level based on service requirements to improve spectrum efficiency.

Technical Achievements

By taking 4G and 5G service requirements into account and coordinating the development strategies and service requirements of operators involved in network sharing, the DSS technology provides an intelligent adaptation policy for the long-term network evolution. The DSS solution won the Best Mobile Technology Breakthrough award in 2018.

2.4 Power Sharing

2.4.1 Inter-Carrier Dynamic Power Sharing

Challenges

Currently, the maximum transmit power of an AAU with Massive Multiple Input Multiple Output (MIMO) on the 3.5 GHz frequency band is 320 W, and the transmit power of each 100 MHz cell is 200 W. In the CT/CU Deployment , the minimum bandwidth shall be 200 MHz on the 3.5 GHz frequency band. If a second carrier is enabled, the average power of each carrier is only 160 W, resulting in 1 dB lower power in coverage. Therefore, how to enable the second carrier without deteriorating the coverage performance becomes an urgent issue.

Innovation

To address this issue, power resource pooling and dynamic power sharing are introduced. As shown in Figure 2.12, the power resource pooling technology allows dynamic power sharing between two carriers and flexible power allocation in a unified manner. The dynamic power sharing technology actively allocates power to two carriers based on service requirements. This ensures lossless coverage performance when the second carrier is enabled in lightly-loaded networks.

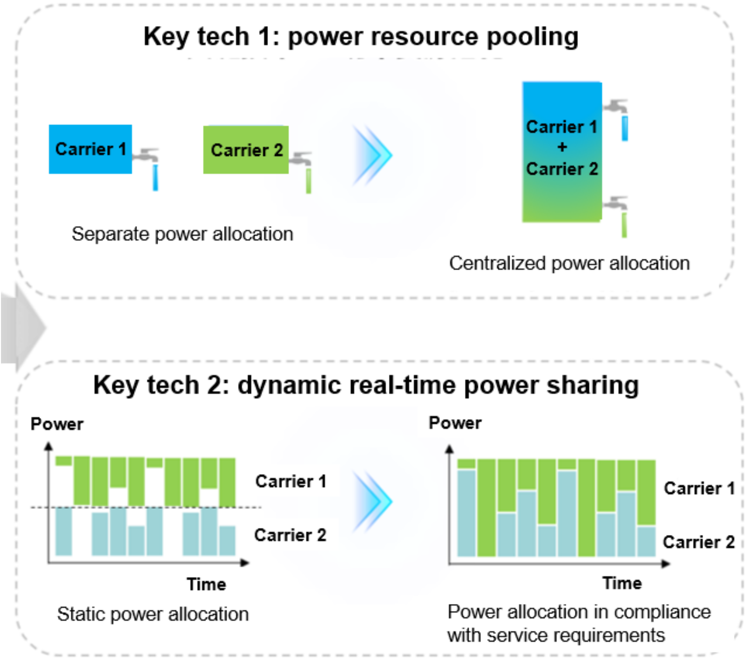

Figure 2.12 Dynamic Power Sharing

Technical Achievements

The application on the live network in Anhui province shows that the average user experience in downlink services improves by 5% to 20% after the dynamic power sharing technology is used.

2.5 China Telecom and China Unicom Promoting Standards and Industrialisation of 5G Network Co-Construction and Sharing

2.5.1 Taking the lead in the project initiation of seven 5G international standards and seven industry standards, significantly enhancing the influence of 5G network co-construction and sharing on industry chains

China Telecom and China Unicom took the lead in the initiation of four 3GPP specification projects: 2.1 GHz 40/50 MHz bandwidth Frequency Division Duplexing (FDD) NR, NSA 26 dBm high-power UE, FDD Massive MIMO, and 5G Quality of Experience (QoE). The 2.1 GHz 40/50 MHz bandwidth FDD NR greatly promotes the technical evolution of FDD NR high bandwidth, and provides strong impetus for FDD spectrum refarming and improvement in network competitiveness. China Telecom and China Unicom launched the world's first base station (with a RRU) that supports both the 1.8 GHz and 2.1 GHz frequency bands and can operate at full power, and implemented the first 2.1 GHz 40/50 MHz bandwidth test in April 2020, promoting the development of high-bandwidth FDD NR UEs.

China Telecom and China Unicom led the project initiation of the following industry standards in the CCSA: *Research on Smart Energy Saving of 5G Base Stations*, *Technical Requirements for 5G Network Co-Construction and Sharing*, *Test Methods for 5G Network Co-Construction and Sharing*, *Technical Requirements for 5G Digital Indoor Distribution*, and *Test Methods for 5G Digital Indoor Distribution*.

2.5.2 Taking the lead in the outdoor 200 MHz bandwidth technology and achieving the peak downlink data rate 2.7 Gbps

To take advantage of spectrum sharing, improve the competitiveness of 5G networks, and fully implement high-bandwidth capabilities, the operators enable base stations to support 200 MHz bandwidth in conjunction with Carrier Aggregation (CA). This enables 5G networks to meet the application requirements whilst making full use of the high bandwidth and large capacity of the 3.5 GHz frequency band and achieving a peak downlink data rate of 2.7 Gbps to a single user. See figure 2.13.

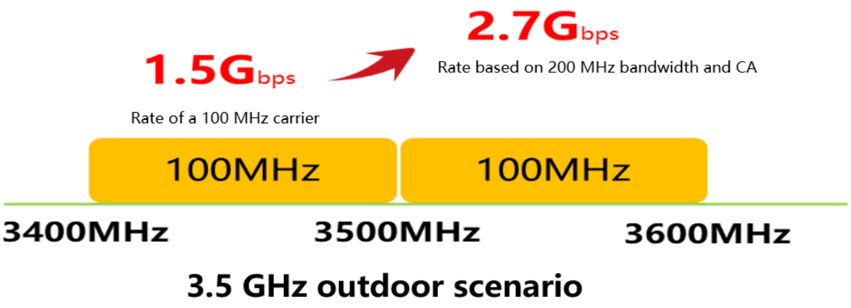

Figure 2.13 Outdoor 200 MHz Bandwidth Technology

3. International Roaming in 5G SA Network Co-Construction and Sharing Scenarios

3.1 International Roaming Under National Inter-CN Roaming

3.1.1 Scenario Description

In the 5G SA scenario, an operator can deploy a shareable network. For example, operator 1 (OP1) shares its RAN with operator 2 (OP2), and operator 3 (OP3) is a roaming partner of OP2. In this case, the UEs of OP3 can connect to the shared RAN of OP1 to access the services of OP2. Figure 3.1 illustrates the network architecture for national inter-CN roaming in the 5G SA scenario.

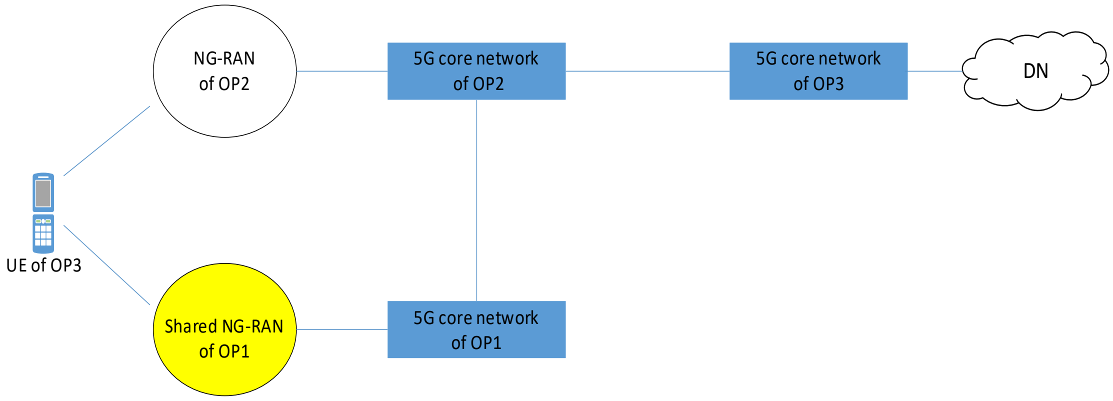

Figure 3.1 Scenario of International Roaming Users in national Inter-CN Roaming

As shown in the figure, three operators (OP1, OP2, and OP3) are involved in this scenario.

OP1 not only shares its RAN with OP2, but also makes its core network shareable for inbound roamers of OP2.

OP2 signs a 5G network sharing agreement with OP1 for sharing the RAN of OP1.

OP3 is a roaming partner of only OP2 (that is, they have signed a roaming agreement).

Since OP2 has signed a 5G network sharing agreement with OP1, the UEs of OP2 can connect to the shared RAN of OP1 to access the services of OP2. In addition, OP3's UEs roaming in OP2's dedicated RAN or OP1's shared RAN can access the services of OP2 through the corresponding RAN.

3.1.2 New requirements in 3GPP and GSMA

In Release 18, 3GPP TS 23.501 only supports 5G MOCN, and 3GPP specifications describe roaming covering both national and international roaming in the 5G SA scenario. 3GPP SA1 initiated in Release 19 the Feasibility Study on Network Sharing Aspect, documented in TR 22.851, attaching greater importance to the feasibility of more sharing modes. Section 5 of TR 22.851 covers "Use case on International Roaming Users in a Shared Network" and includes as potential new requirements to support the use case.

[PR 5.4.6-001] The 5G system shall enable the shared access network of a hosting operator with indirect connection between the shared access network and a participating operator's core network to provide services for inbound roaming users.

In addition, GSMA PRD NG.113 (5GS Roaming Guidelines) only supports bilateral roaming. Unlike the serving networks in bilateral roaming, a serving network in national inter-CN roaming involves multiple operators. Therefore, how to increase support for international roaming under national inter-CN roaming in the 5G SA scenario requires further work in the GSMA.

3.2 International Roaming Under RAN Sharing

In RAN sharing, multiple operators share one 5G RAN, but their 5GCs are independent. As shown in Figure 3.2, the shared 5G RAN is connected to the 5GCs built by respective operators via Next Generation (NG) interfaces.

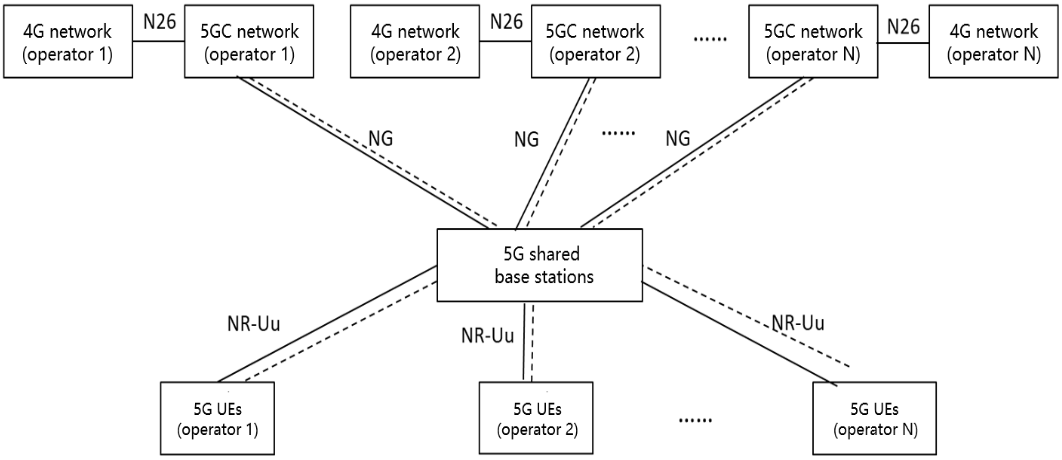

Figure 3.2 Roaming Under RAN Sharing in the 5G SA Scenario

Roaming under RAN sharing in the 5G SA scenario includes Home-Routed (HR) roaming and Local Breakout (LBO) roaming. The international roaming procedure in the 5G SA scenario after a UE accesses the corresponding PLMN is the same as the standard international roaming procedure. 3GPP has defined the interfaces related to international roaming in the 5G SA scenario. For details, refer to GSMA PRD NG.113, 3GPP TS 23.501, and 3GPP TS 23.502.

4. Prospects for 5G Network Co-Construction and Sharing

4.1 Deepening Cooperation on 5G Network Co-Construction and Sharing

Figure 4.1 illustrates the evolution of 5G network co-construction and sharing from the perspective of technical routes, geographic scope, number of partners, operating frequency band, and RAT.

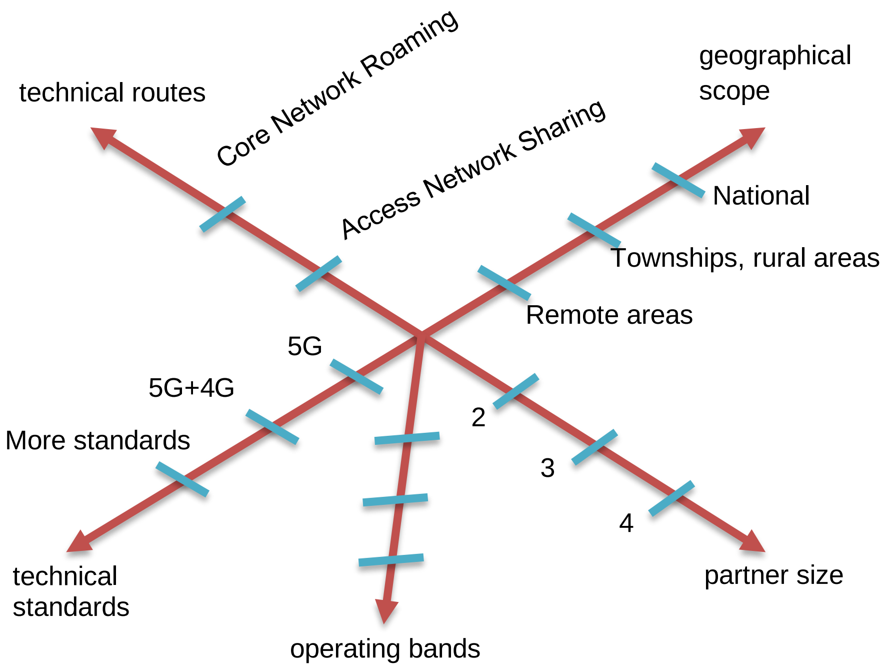

Figure 4.1 Evolution of 5G Network Co-Construction and Sharing

1) Technical routes: Focusing on RAN sharing, operators should also determine other technologies such as national inter-CN roaming for 5G network co-construction and sharing.
2) Geographic scope: Operators should consider the geographic scope for 5G network co-construction and sharing, including indoor scenarios.
3) Number of partners: Operators can also extend 5G network co-construction and sharing to more than two partners.
4) Operating frequency band: 5G systems can operate on multiple frequency bands, such as 3.5 GHz, 2.6 GHz z, 2.1 GHz, 700 MHz, and 800 MHz. With the deepening of 5G network co-construction and sharing, more frequency bands such as millimeter wave will be used.

5) RAT: As 5G network co-construction and sharing advances, 4G RATs, including 4G Narrowband Internet of Things (NB-IoT) and Enhanced Machine Type Communication (eMTC), may also be involved.

The above aspects should be comprehensively taken into account for further development of 5G network co-construction and sharing. For example, to provide more options for such scenarios as indoor infrastructure sharing, vendors should continue to develop new devices in terms of device forms and deployment modes. In addition, they need to choose the most optimum operating frequency band to meet different geographic requirements. For instance, in remote areas, sub-1GHz bands should be used for 5G network co-construction and sharing.

4.2 Future Technology Evolution for Network Co-Construction and Sharing

4.2.1 Millimeter Wave

Featuring high bandwidth and low latency, millimeter Wave (mmWave) is crucial for both current and future 5G network development. The mmWave frequency bands will coexist with other frequency bands in the long term, as 5G networks need both high and low frequency bands. ER-UTRA NR Dual Connectivity (EN-DC), NR Dual Connectivity (NR-DC) and Frequency Range 1 (FR1) + Frequency Range 2 (FR2) Carrier Aggregation (CA) enable optimal utilisation of high and low frequency bands in different stages of 5G development, making mmWave play a full part in 5G network co-construction and sharing scenarios.

With the global popularity of 5G, mmWave frequency bands can be used as a supplement to the main frequency bands (medium and low frequency bands) of 5G networks. When using high-traffic services, a terminal can use mmWave to offload traffic. NR-DC/CA can be adopted to implement better inter-frequency coordination for the devices from the same vendor, and only the frequencies in FR2 are used for the devices of different vendors in 5G network co-construction and sharing. The priority-based carrier scheduling and load balancing help to maximise the utilisation of medium and low frequency bands.

4.2.2 Edge Computing

To achieve ultra-large-scale computing and short latency, cloud servers and edge servers should be deployed close to users to run applications with stringent requirements on computing and latency in 5G networks, thus ensuring the good operation of industrial applications through cloud-pipe-terminal coordination.

The Edge Computing (EC) technology introduced in 5G networks supports a variety of industrial applications that impose high requirements on network latency and data security. In a shared network, the hosting operator and participating operators can share the computing power of the edge servers, which coordinate with the cloud servers and terminals to flexibly schedule and transfer computing resources. In this way, the QoS of edge computing applications as well as the coverage of edge computing is improved, thus attracting more third-party applications and ultimately providing better user experience.

4.2.3 6G Technologies

With the acceleration of 5G network construction, a variety of applications are flourishing in vertical industries. As a new generation of mobile communication systems emerge about every ten years, it is predicted that 6G will be commercially available around 2030.

At present, many countries have issued whitepapers on 6G visions. The expectations for next-generation networks, especially those for key technologies, are all incorporated into the 6G visions.

The 6G visions include instantaneous speed, ubiquitous 3D connectivity, integrated sensing & communication, intrinsic intelligence, smart simplicity, security & trust, sustainability & sharing, and flexibility & openness.

To realise these visions, various network virtualisation technologies have been proposed, such as mmWave and terahertz, satellite-integrated space-air-ground-sea connectivity, high-frequency multi-sensory data fusion, intelligent semantic communication, cloud-network convergence and computing power networks, instinct security, and intelligent energy saving.

6G network co-construction and sharing is still in the research stage. With the development of key 6G technologies, the following three aspects are expected to become the focus in the next few years:

Smart simplicity: In the face of massive service access and dynamic network requirements in the future, network design should be oriented towards simplicity and decentralisation, unifying basic interface protocols and access management
modes. In co-construction and sharing, multiple operators can share network resources, thus providing seamless network access.

Network compatibility: The 6G network should be compatible with traditional networks. In co-construction and sharing, smooth voice and data services can be guaranteed during inter-PLMN or inter-RAT handover.

So far, many countries have started to promote research on 6G technologies, which will definitely drive the mobile communication industry to new heights. Unified international communication standards are essential for the success of 6G. Therefore, China Telecom and China Unicom will unswervingly participate in the formulation and update of the standards, promoting 6G globalisation and the development of the community with a shared future for mankind.

Glossary

1G – 1st Generation (of Mobile Technology)
2G – 2nd Generation (of Mobile Technology)
3G – 3rd Generation (of Mobile Technology)
4G – 4th Generation (of Mobile Technology)
5G – 5th Generation (of Mobile Technology)
5GC – 5G Core (Network)
6G – 6th Generation (of Mobile Technology)
AAU – Active Antenna Unit
AI – Artificial Intelligence
AR – Augmented Reality
BBU -Baseband Unit
CA – Carrier Aggregation
CAPEX – Capital Expenditure
CCSA – China Communications Standards Association
CN – Core Network
CRS - Cell-Specific Reference Signal
DSS – Dynamic Spectrum Sharing
ECGI – E-UTRAN CGI
FR1 – Frequency Range 1
FR2 – Frequency Range 2
EC – Edge Computing
eMTC –Enhanced Machine Type Communication
EN-DC – E-UTRA-NR Dual Connecttivity
EPC – Evolved Packet Core
EPS – Evolved Packet System
E-UTRA – Evolved UMTS Radio Access
FDD - Frequency Division Duplexing
HPLMN – Home PLMN
ICT – Information & Communications Technology
ID – Identity
IP – Internet Protocol
IMS – IP Multimedia Subsystem
KPI – Key Performance Indicators
LBO – Local Break-Out
LTE – Long Term Evolution
MBSFN - Multimedia Broadcast multicast service Single Frequency Network
MES – Manufacturing Execution System
MIMO – Multiple Input Multiple Output
MME – Mobility Management Entity
MOCN – Multi-Operator Core Network
MORAN – Multi-Operator Radio Access Network
MU-MIMO – Multi-User MIMO
NB-IoT – Narrow Band Internet of Things
NG – Next Generation
NR – New Radio
NR-DC – NR Dual Connectivity
NSA – Non-Standalone
O&M – Operations & Maintenance

PDCCH - Physical Downlink Control Channel
PDSCH – Physical Downlink Shared Channel
PUSCH – Physical Uplink Shared Channel
PLMN – Public Land Mobile Network
QoE – Quality of Experience
QoS – Quality of Service
RAN – Radio Access Network
RAT – Radio Access Technology
RFSP – RAT Frequency Selection Priority
RRU – Remote Radio Unit
SA – Standalone
SMS – Short Message Service
TDD – Time Division Duplexing
TNR – TDD NR
TTI – Transmission Time Interval
UE – User Equipment
UHD – Ultra Hi-Definition
UMTS – Universal Mobile Telecommunications System
UPF – User Plane Function
USD – United States Dollar
VPLMN – Visited PLMN
VoLTE – Voice over LTE
VR – Virtual Reality
ZP CSI-RS - Zero Power Channel State Information Reference Signal

About this whitepaper

About GSMA

The GSMA is a global mobile industry association that represents the interests of mobile operators worldwide, uniting more than 750 operators with almost 300 companies in the broader mobile ecosystem, including handset and device makers, and software companies. The GSMA also holds the industry-leading events such as Mobile World Congress (in Barcelona, Shanghai and Los Angeles) and the Mobile 360 Series.

GSMA Foundry is the go-to place for cross-industry collaboration and business development, where GSMA members and industry players come together to rapidly develop real-world solutions to industry challenges, nurture new ideas through initial commercial trials and scale proven solutions at a regional and global level to forge our digital future.

For more information, please visit www.gsma.com/futurenetworks .

GSMA HEAD OFFICE

1 Angel Lane
London
EC4R 3AB
UK
www.gsma.com