GTI
NSA Commercial Network Deployment
White Paper

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Table of Contents

1 Abbreviations

Abbreviation	Explanation
2/3G	The 2/3rd Generation Telecommunication Technology
3GPP	The 3rd Generation Partnership Project
4G	The 4th Generation Telecommunication Technology
5G	The 5th Generation Telecommunication Technology
AR	Augmented Reality
CPE	Customer Premise Equipment
CSI-RS	Channel State Information-Reference Signal
DAS	Distributed Antenna System
DC	Dual Connectivity
DIS	Digital Indoor System

Abbreviation	Explanation
DL	Downlink
DRB	Data Radio Bearer
DRX	Discontinuous Reception
eMBB	Enhanced Mobile Broadband
EN-DC	E-UTRA-NR Dual Connectivity
FR1	Frequency Range 1
FR2	Frequency Range 2
gNodeB	NR node
ISD	Inter Site Distance
LTE	Long Term Evolution
MCG	Master Cell Group
MCS	Modulation and Code Scheme
MeNB	Master eNB
MIMO	Multiple-Input Multiple-Output
MN	Master Node
mMTC	Massive Machine Type Communication
MR	Mixed Reality
MU	Multi User
MU-MIMO	Multi-User MIMO
NAS	Non-Access Stratum
NG Core	Next Generation Core Network
NR	New Radio
NSA	Non-Standalone
PDCP	Packet Data Convergence Protocol
PMI	Precoding Matrix Index
QCI	QoS Class Identifier
RAN	Radio Access Network
RLC	Radio Link Control
RRC	Radio Resource Control
RSRP	Reference Signal Received Power
SA	Standalone
SCG	Secondary Cell Group

Abbreviation	Explanation
SFN	System Frame Number
SFTD	SFN and Frame Timing Difference
SgNB	Secondary gNB
SINR	Signal to Interference plus Noise Ratio
SN	Secondary Node
SRS	Sounding Reference Signal
SSB	Synchronization Signal Block
SU	Single User
THP	Throughput
UE	User Equipment
UL	Uplink
URLLC	Ultra-Reliable and Low Latency Communications
VoLTE	Voice over LTE
VoNR	Voice over NR
VR	Virtual Reality

2 Overview

With 5G industry developing and availability of commercial smartphones, 5G becomes a hot topic all over the world. 5G provides bigger throughput, short latency and massive connections, and 5G network let all services like eMBB, uRLLC and mMTC to co-exist and develop. Within our expectation, 5G not only provides better user experience for everyone, but also will foster new services and businesses, promote traditional industries evolve to digitization, like intelligent power grid, remote control, and digital factory and farms etc.

As time of 5G commercial smartphones availability is almost synchronized with network, 5G user number reaches more than 3 million till now after 5G network launches in Korea. As VR & AR service which require download speeds a factor of ten or higher compared to conventional video, arise with 5G network as a differentiation, average 5G usage was 24GBytes per subscription per month in Q2 2019 according to MSTI, compared to 9.5GB on 4G in Korea. China has launched 5G commercialization recently and various trial scenarios for 5G commercial network have already been finished and verified by CMCC and its partners.

GTI, as an industry consortium, together with its worldwide partners has actively participated in the 5G large scale trials around the world and promote 5G industry process. This white paper will serve as a platform to share and present the results of the test and the strategies of the 5G NSA commercial network deployment, parameters and performance optimization experience, thus provide a reference to industry partners, so as to jointly promote the 5G industry maturity, accelerate its scale commercialization and evolution to SA, and embrace the property of 5G ecosystem.

3 5G Industry Progress Update

3.1 Standard Progress Update

With great effort in 3GPP group, the first version of NR specs (release 15) has been completed, which include NSA (option 3) in early drop, SA (option 2) in normal drop and additional architecture options (option 4, 7 and NR-NR DC) in late drop. ASN.1 code for NR release 15 has also been stabilized for system implementation.

3GPP group is currently working on Release 16 contents with full speed, which is expected to be closed in March of 2020 and ASN.1 frozen in Jun of 2020. The contents in release 16, include some enhancements for both eMBB and critical MTC, e.g. MIMO enhancement, UE power saving, 5N V2X and URLLC enhancements, NR on unlicensed band, so on.

Release 17 is planned to start in the beginning of 2020, and it will take 15 months to finish it. The proposal of detailed contents is under discussion and will be finalized in coming Dec meeting. Some new items and enhancements on existing technical area are discussed via email now, including: NR light, NR above 52.6GHz, NR multicast / broadcast, etc

3.2 Global Spectrum Auction Progress Update

As 5G market is growing very quickly, many countries have completed or will complete their spectrum allocation, auctions and licensing process between 2019~2021. According to the updated GSA (Global Mobile Supplier Association) spectrum report in August, 34 countries have completed 5G-suitable allocations or licensing procedures in at least one spectrum band (including technology-neutral licences, or licences for mobile broadband services).
In Europe, 17 countries have already completed auctions of 5G suitable (dedicated or technology neutral) spectrum (Albania, Austria, Croatia, Czechia, Denmark, Finland, Germany, Greece, Ireland, Italy, Latvia, Norway, Slovakia, Spain, Sweden, Switzerland and the UK). Twenty-one countries are known to have definite 5G-suitable (dedicated or technology neutral) spectrum auctions/allocations planned between 2019 and 2021 (Austria, Belgium, Cyprus, Czechia, Estonia, France, Greece, Hungary, Kosovo, Luxembourg, Macedonia, Netherlands, Norway, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Sweden and the UK).

There are planned 5G-suitable auctions/allocations confirmed in at least nine countries in Asia Pacific (Australia, Hong Kong, India, Malaysia, Myanmar, New Zealand, Singapore, Taiwan and Thailand) between 2019 and 2021. Some have already been completed. In June 2018, the Republic of Korea completed a 5G auction for spectrum in the 3.42–3.7 GHz and 26.5–28.9 GHz frequency bands; Australia has auctioned 5G spectrum at 3.5 GHz; Japan allocated spectrum in various bands; Hong Kong and Thailand have recently issued spectrum on technology-neutral terms; And China has started and announced 5G commercialization recently, and 5G spectrum mainly focus on 2515M~2675M, 3400~3600M and also 4.9G at present.

In the Americas, the USA typically issues spectrum on a technology-neutral basis, making any such awards potentially useable for 5G. Recently, it has issued spectrum on a technology-neutral basis that can be used for 5G in the 600 MHz range. It has also confirmed rights to use the spectrum that was awarded many years ago at 28 GHz (27.5–28.35 GHz) and 39 GHz (37–40 GHz) for 5G and in October 2018, changed the rules to make CBRS spectrum more attractive to 5G investors. In January 2019, it completed an auction of spectrum at 28 GHz, and in May 2019 completed an auction of spectrum at 24 GHz.

Operators in the USA will also use 2.5 GHz band for 5G. Mexico has auctioned spectrum between 2500 MHz and 2690 MHz for 4G and 5G. Canada completed an auction of spectrum at 600 MHz in April 2019. Meanwhile, Argentina, Brazil, Canada, Colombia, Ecuador, El Salvador, Mexico and the USA have announced timetables for future auctions/allocations of spectrum potentially suitable for 5G.

Of the countries in the Middle East and Africa, Saudi Arabia has concluded two auctions of spectrum suitable for 4G and 5G services at 2300 MHz, 2600 MHz and 3500 MHz, plus auctions of spectrum at 700 MHz, 800 MHz and 1800 MHz for next-generation high-speed wireless data services; UAE has allocated spectrum to enable network rollout in advance of WRC-19; Oman and Qatar have awarded spectrum for 5G services; Tanzania has awarded spectrum at 700 MHz for ICT services; and Ghana has auctioned spectrum at 800 MHz for mobile services. Most recently, in May 2019 Kuwait awarded spectrum licences at 3.5 GHz, and in July, Bahrain allocated and auctioned spectrum at 800 MHz and 2600 MHz and Israel launched an auction of multiple spectrum bands. Meanwhile, South Africa is planning an auction in the 800 MHz range for IMT services, Hong Kong has a multi-band auction underway and Singapore is planning auctions of spectrum at 3500 MHz, 26 GHz and 28 GHz. Worldwide, in total, 34 countries have recently completed 5G-suitable allocations or licensing procedures in at least one spectrum band (including technology-neutral licences, or licences for mobile broadband services).

Forty countries have announced formal (date-specified) plans for allocating 5G-suitable frequencies between now and end-2021 (including technology-neutral licences, or licences for mobile broadband services).

3.3 Chipset and Terminals Progress Update

Table 3.1 is collected from open information, as can be seen, there are NSA only mode 5G chipset at present, so NSA is still important and there is a transitional period for 5G industry to evolve from NSA to SA.

Table 3.1 5G Chipset Information from Open Information

Vendor	Chipset	Release	Frequency	5G Mode
Hisilicon.	Balong 5000	2019.1	SUB 6G 200Mhz mmWAVE 800Mhz	NSA/SA
Hisilicon.	Kirin 990	2019.9	SUB 6G 100Mhz	NSA/SA
Qulacomm	X50	2018	SUB 6G 100Mhz mmWAVE 800Mhz	NSA
Qulacomm	X55	2019H2	SUB 6G 200Mhz mmWAVE 800Mhz	NSA/SA

Samsung	Modem 5100	2018	SUB 6G 100Mhz mmWAVE 800Mhz	NSA/SA
Samsung	Modem5123	2019.10	SUB 6G 200Mhz mmWAVE 800Mhz	NSA/SA
Samsung	Exynos 980	2019.9	SUB 6G 100Mhz	NSA/SA
MediaTek	Helio M70	2018.12	SUB 6G 200Mhz	NSA/SA
MediaTek	Dimensity1000	2019.8	SUB 6G 200Mhz	NSA/SA

So far, multiple 5G smartphones and terminals are available or announced to be available in the open market from different bands, like Huawei, VIVO, OPPO, SAMSUNG, XIAOMI et al.

There are still many NSA only smartphones with NSA only chipset inside from the open market at present, and the trend is that chipsets for 5G terminals will be NSA and SA dual mode.

Figure 3.1 5G Commercial Smartphones and Terminals

3.4 Commercialization and Large Scale Trial progress

By end of 3rd quarter of 2019, several markets have switched on NSA based 5G commercial network, e.g. in South Korea, United States, and several countries in Europe, Middle east, so on. Particularly, in South Korea, 5G commercial subscribers are more than 3 million by now, following the introduction of several new 5G smartphones. It is reported that 3 operators plan to deploy 5G networks in 85 major cities by end of 2019 and cover around 93% of population.

In China, 5G commercialisation is accelerated as well. 5G networks have been deployed in some top tier cities. Five NR system vendors and five UE chipset vendors attended the trial in different cities. NR basic function, some advanced features and performance were verified for both NSA and SA in field networks, e.g. latency test in SA and NSA mode, peak throughput for downlink and uplink, so on. UE IoDT with NR system also was conducted between among different chipset vendors and system vendors. Detailed results and findings will be shared in following sections in this paper.

4 NSA: Background and Basic Principle

4.1 NSA Background

NSA was proposed at the 3GPP TSG-RAN #72 plenary meeting held in Busan, South Korea, in June of 2016. Described 5G network architectures in RP-161266 become the basis for RAN1/2/3 to discuss the RAN architecture, core network architecture, and related interfaces.

4 types of independent network architecture (SA), including:

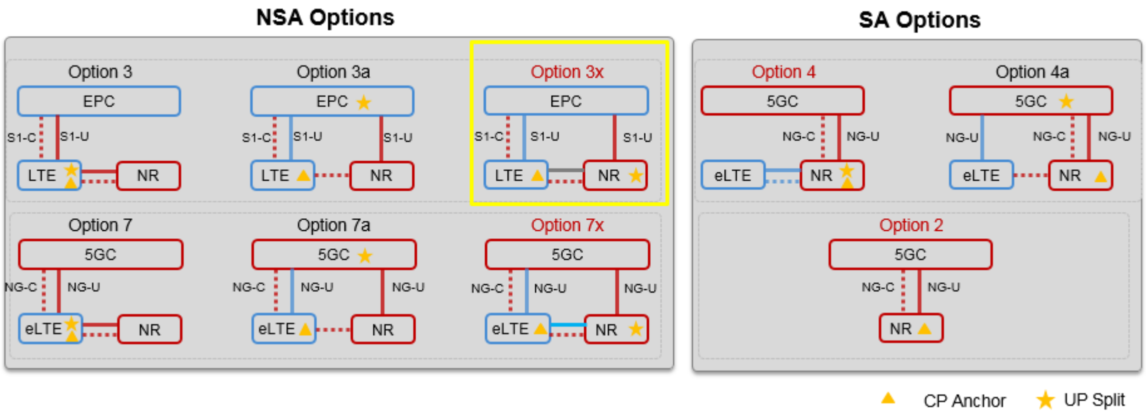
- Option1: Traditional LTE architecture.
- Option2: 5G independent network.
- Option5: The LTE system is upgraded and connected to the 5G core network.
- Option6: The independent 5G network is connected to the EPC (excluded in the discussion of the standard).

8 types of non-independent network architectures (NSA). Including:

- Option3 and Option3a: control plane anchor at LTE side and connected only to the EPC (excluded in the discussion of the standard).
- Option4 and Option4a: control plane anchor at NR side and connected only to the 5GC.
- Option7 and Option7a: control plane anchor at LTE side and connected only to the 5GC.
- Option8 and Option8a: control plane anchor at NR side and connected only to the EPC.

The conclusion of the discussion was Option2/3/3a/4/4a/5/7/7a. In addition, the detailed definition of Option 3/3a/3x, 4/4a and 7/7a/7x are also mentioned in TR38.801.

Based on core network type, CP anchor and UP splitter, different options are classified. Considering fast time to market, NSA is preferred. And NR provides better ability and performance for data splitting, Option 3X is preferred.



	Option 3x	Option 7x	Option 4	Option 2
Ecosystem	3GPP:2017 Q4 Commercial UE:2019H1	3GPP:2018 Q4	3GPP:2018 Q4	3GPP:2018 Q2 Commercial UE:2019H2
LTE Upgrade	●	●	●	
5GC Deployment		●	●	●
Service Readiness (eMBB/uRLLC/mMTC)		●	●	●

Figure 4.1 Overview and Comparison of Key NSA and SA Options

4.2 NSA Basic Principle

EN-DC: E-UTRA-NR Dual Connectivity, in which a UE is connected to one eNB that acts as a master node and one en-gNB that acts as a secondary node.

In EN-DC, the UE has a single RRC state, based on the master node RRC and a single C-plane connection towards the core network.

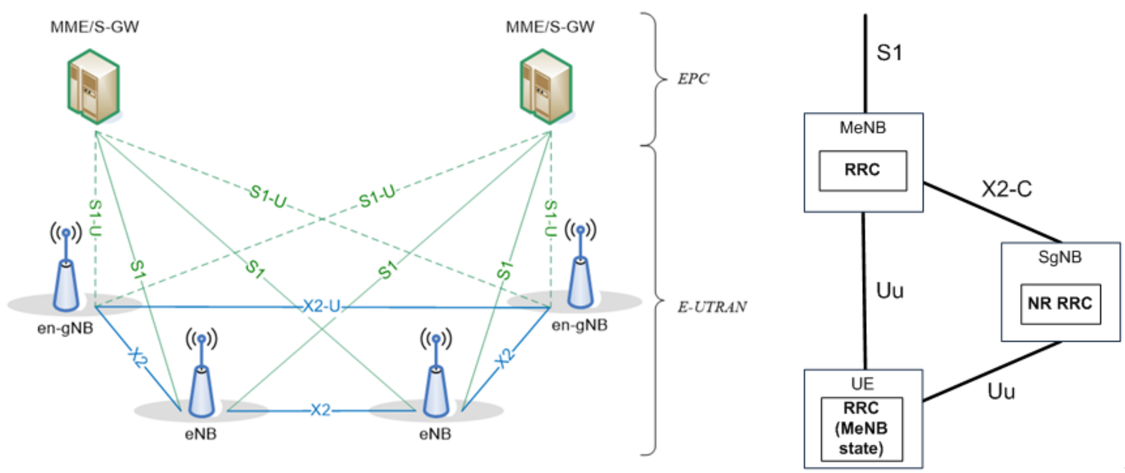


Figure 4.2 EN-DC Architecture

4.2.1 Data Split for User Plane

Downlink user plane data split: split bearer is supported, which means NR PDCP layer distributes data to the LTE RLC and NR RLC layers, and get feedback from RLC by DL data delivery status.

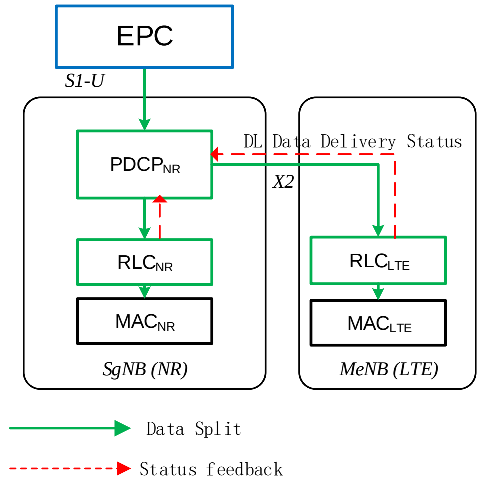


Figure 4.3 Downlink User Plane Data Split

On the UE side, the UE performs uplink data split according to the configuration command delivered by the master base station

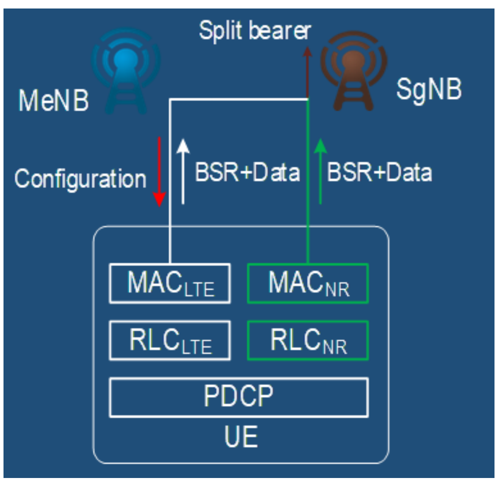


Figure 4.4 Uplink User Plane Data Split

4.2.2 Mobility Management for Control Plane

Mobility Management: Intra-MeNB

MN initiated SN modification is used to perform handover within the same MN while keeping the SN.

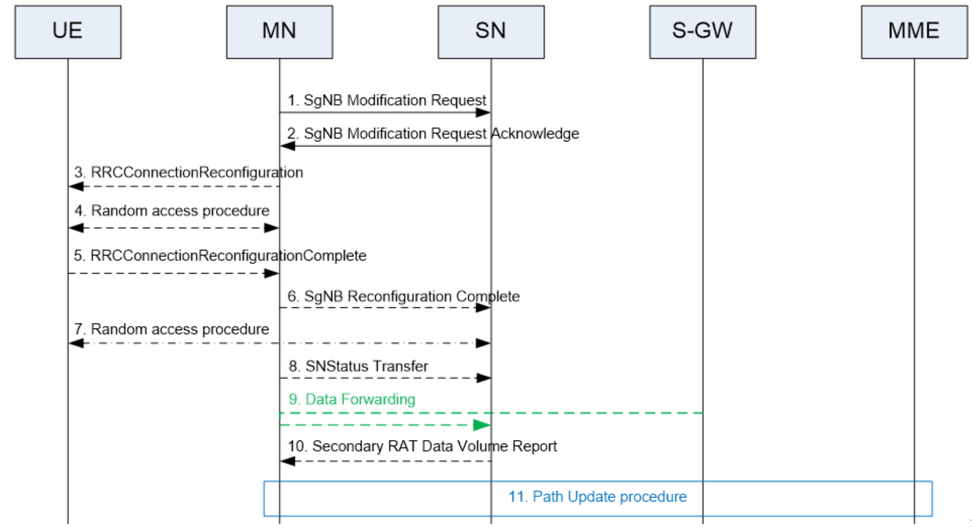


Figure 4.5 Mobility Managerment: Intra-MeNB

Mobility Management: Inter-MeNB

Inter-Master Node handover with/without MN initiated Secondary Node change is used to transfer context data from a source MN to a target MN while the context at the SN is kept or moved to another SN.

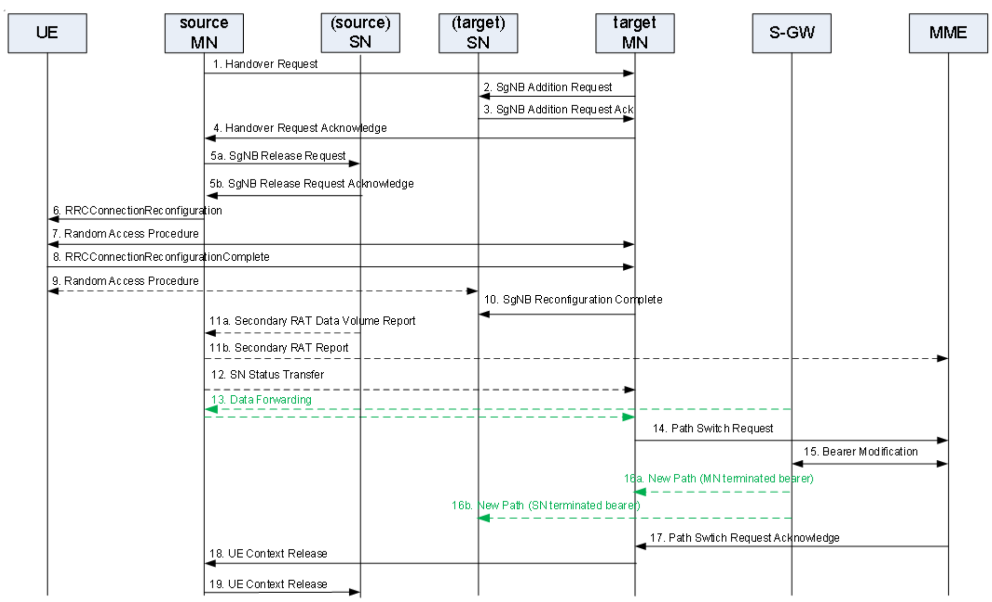


Figure 4.6 Mobility Managerment: Inter-MeNB

Mobility Management: Intra-SgNB

SN initiated SN modification is used to trigger PSCell change.

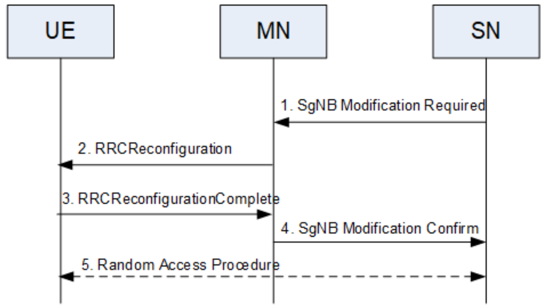


Figure 4.7 Mobility Managerment: Intra-SgNB

Mobility Management: Inter-SgNB

Use the secondary node change procedure initiated by SN to transfer a UE context from a source SN to a target SN.

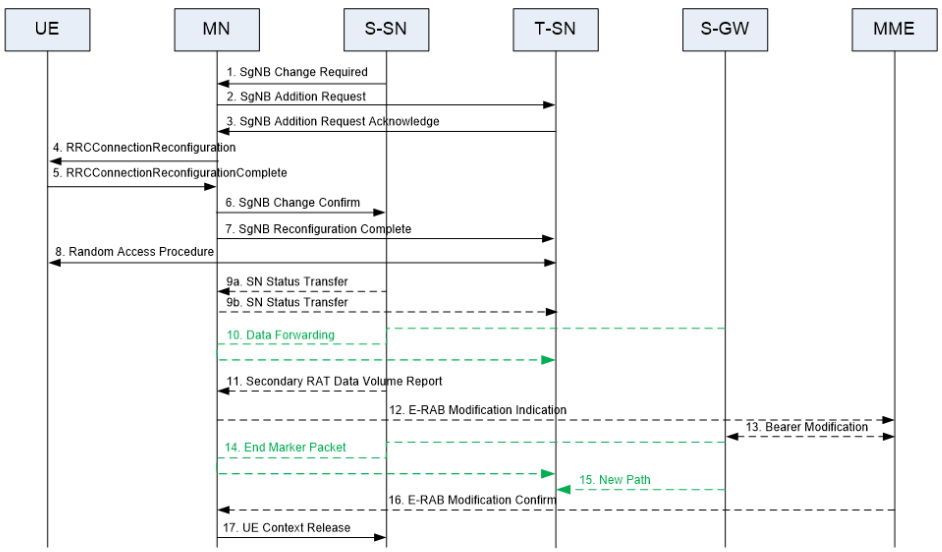


Figure 4.8 Mobility Managerment: Inter-SgNB

Figure 4.5~Figure 4.8 are from 3GPP documents and please refer to 3GPP TS 37.340 for more information and description about NSA mobility management procedures.

5 NSA Networking, Key Challenges and Solutions, Parameters Optimization

5.1 NSA Networking

5.1.1 Service Prospects and Requirements

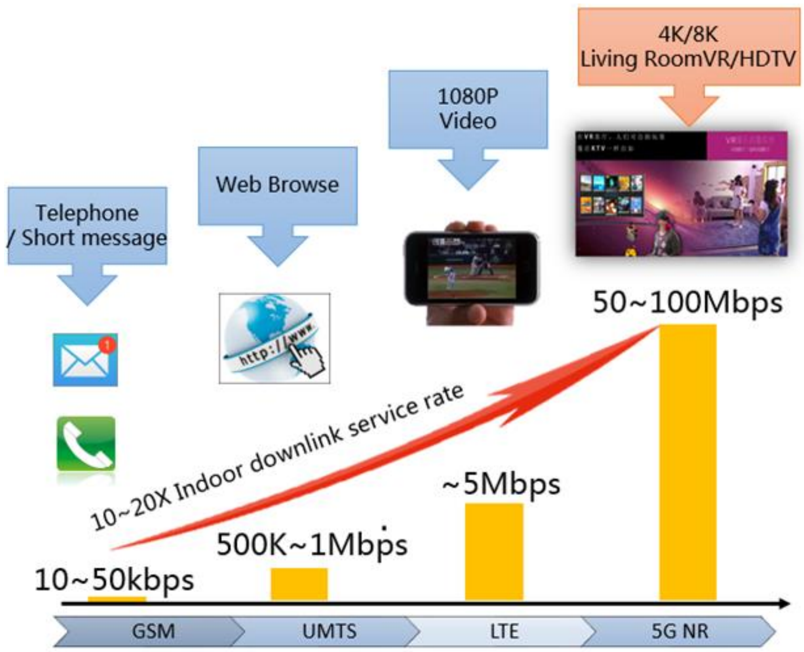


Figure 5.1 Typical Service and Requirement from 2G to 5G

In the 3G/4G network, experiential networking such as xMbps and video coverage has been widely used. Building a network around service and business experience has become an industry consensus. The goal of network construction is to meet and improve the needs of the user experience.

There are three types of 5G applications defined by ITU: eMBB, mMTC and uRLLC. 5G NSA networks mainly focus on eMBB service at present, so 5G NSA target network planning should meet typical eMBB service experience requirements, especially for edge users. eMBB services performances and requirements are defined in GSMA report “5G Implementation Guideline” which was released July 2019. 5G can provide larger capacity for typical eMBB applications, such as 4K/8K high resolution videos and AR/VR services.

Table 5.1 eMBB Service Requirements from GSMA Report

Service	Resolution	2D	3D
Smart Phone / Surveillance	720P	~1.5Mbps	
	1080P	~4Mbps	
	2K	~10Mbps	
4K / Basic VR/AR	4K	~25Mbps	~50Mbps
8K / Immersive VR/AR	8K	~50Mbps	~100Mbps

Considering 5G typical services requirement and actual communication ability for typical commercial network and typical NSA terminals, it is recommended that downlink edge rate should be 50~100Mbps, and uplink edge rate should be 1~2Mbps for eMBB services.

5.1.2 Networking Indicators : SSB and CSI-RS

5G defines following types of measurements:

- **SSB RSRP/SINR**: used to determine the channel strength and quality of the broadcast channel, measurable in idle, inactive and connected state (related to frame structure, can support 1 beam~8 beam for sub6G frequency band).

- **CSI RSRP/SINR**: used to determine the RSRP and SINR of CSI-RS beam (>8 beams measurement ability is recommended for Massive MIMO), only connected state can be measured; It is recommended to determine user rate, because beam quantization granularity of 5G SSB beam (maximum 8 beams for sub6G) is far smaller than that of PDSCH data channel.

- **PDSCH RSRP/SINR**: reflects user PDSCH traffic channel quality and user experience, and it is with dynamic beam weights calculated from SRS or PMI weights.

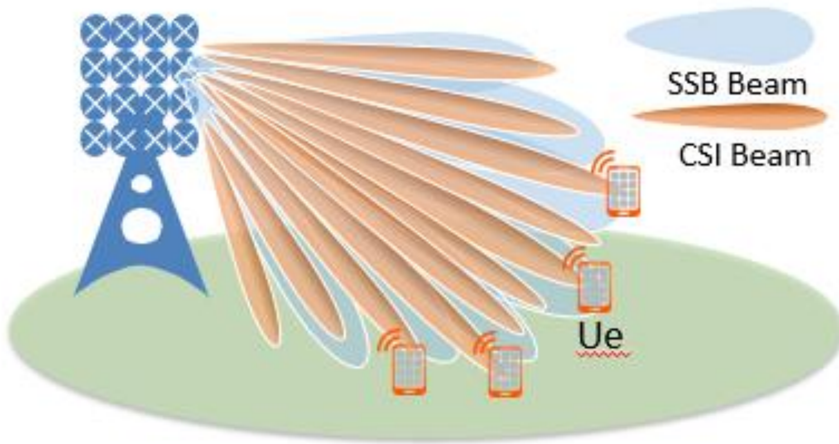


Figure 5.2 Illustration for SSB and CSI-RS Beam Profile

Analysis and comparison are provided in the table below of different measurement types matching 5G coverage and rate.

Table 5.2 Networking Indicators Comparison between SSB and CSI-RS

5G Indicators	Coverage strength			Link quality		
	SSB-RSRP	CSI-RSRP	PDSCH-RSRP	SSB-SINR	CSI-SINR	PDSCH-SINR
Measurable state	Idle, inactive and connected	Connected	Connected	Idle, inactive and connected	Connected	Connected
Beam feature	Static cell beam	Static beam cell & user level	Dynamic user beam	Static cell beam	Static beam cell & user level	Dynamic user beam
Beam number	Beam number<=8	Beam number can be 16/32/64	Dynamic weighting	Beam number<=8	Beam number can be 16/32/64	Dynamic weighting
Analysis	Reflect access strength, Can measure neighboring signal strength	Can reflect user rate performance	Can reflect user rate performance	Can not reflect user rate performance	Can reflect user rate performance	Can reflect user rate performance

SSB RSRP is recommended to be used as camping and serving cell evaluation, because SSB is cell broadcasting channel and it is a better evaluation indicator to determine cell coverage.

CSI-RS is recommended for user rate evaluation. The CSI beam profile (for example 32 beams) is closer to that of Massive MIMO traffic channel. So CSI-RSRP is recommended to be used as an evaluation indicator for uplink user rate, while CSI-SINR is recommended to be used as an evaluation indicator for downlink user rate.

And CSI-RSRP/SINR may be activated on demand, and may be deactivated when there is no need to do this performance evaluation for commercial network.

5.1.3 Macro Station Equipment Type Selection

The multi-user pairing gain of 64T64R massive MIMO can provide a larger capacity compared with 32T32R and traditional 8T8R. The multi-antenna link gain of 64T64R can provide more intensive coverage, including high-building coverage.

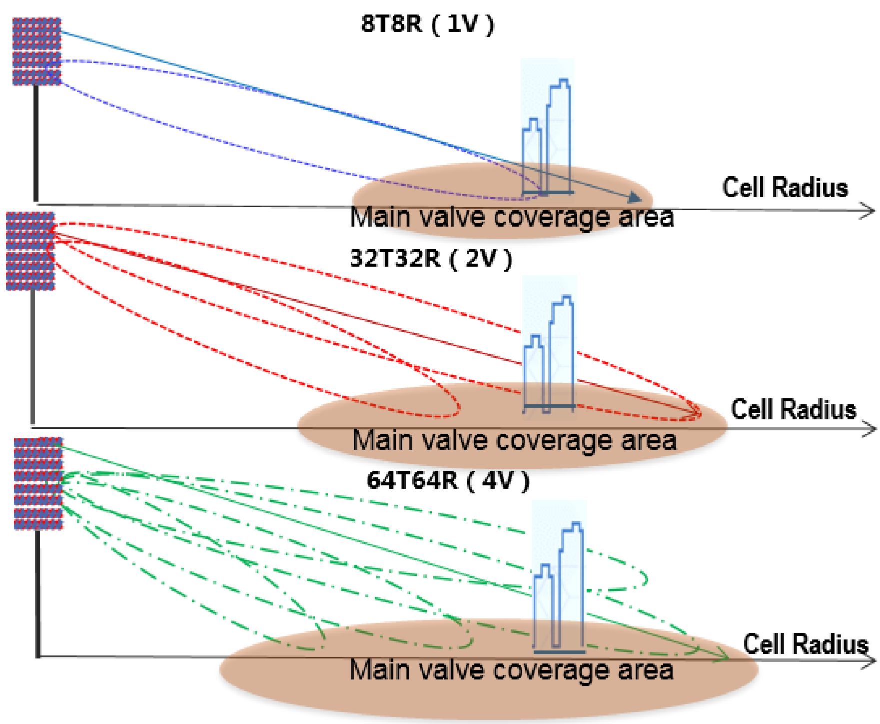


Figure 5.3 Illustration for 64T64R/32T32R/8T8R Main Value Coverage Area

Considering different capacity and coverage of 64T64R, 32T32R, and 8T8T, recommended application scenarios for different TRX channel numbers are as follows

- 64T64R is more suitable for dense urban with high-capacity and deep coverage requirements areas with higher buildings, or CBD, universities, etc.

- 32T32R is suitable for urban and rural areas where buildings are not so high or the capacity demand is not high.

- 8T8R is suitable for sites with difficult implementation of 64T64R and 32T32R product projects, as well as areas with low capacity requirements in rural areas.

5.2 NSA Key Challenges and Solutions

5.2.1 Challenge 1: How to Improve 5G NSA UE User Experience

In EN-DC scenario, NR provide service depending on LTE anchor, which means LTE anchor exceptions will affect the services provided by NR. Therefore, 5G resident ratio under EN-DC becomes key issues to measure NR service quality. In order to ensure the 5G resident ratio, the RAN can acts as following.

- Support independent EN-DC anchor priority policy, select the best frequency (such as the frequency with continuous coverage, considering UE supported EN-DC band combination) as the anchor, and avoid camping on high load cells to ensure the EN-DC continuous service. Similarly, directional handover to an EN-DC anchor should be supported if the EN-DC user is in a non-anchor cell.

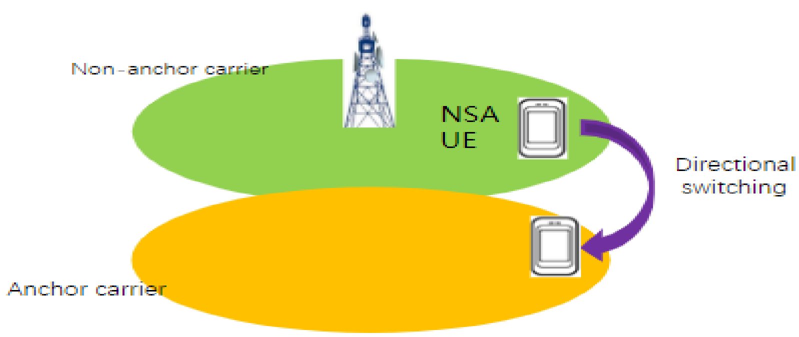


Figure 5.4 Directional Switching and Handover for NSA UE

- By configuring a dedicated cell reselection priority for NSA UE, the idle state NSA terminal preferentially resides on the anchor carrier. The method does not affect the inventory 4G terminal residing strategy and enables the NSA UE to preferentially reside on the anchor carrier, which can carry out 5G services and facilitate load balancing between carriers.

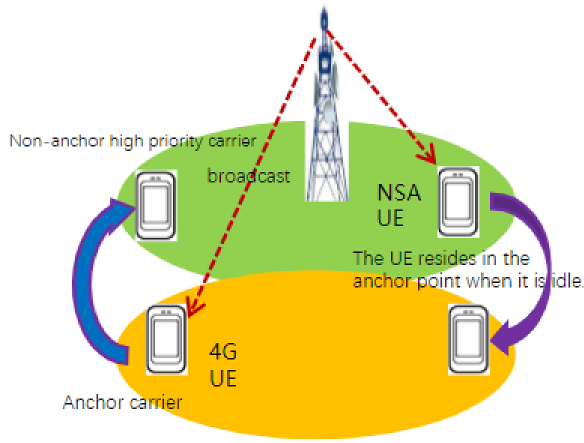


Figure 5.5 Dedicated Cell Reselection Priority for NSA UE

- 4G only UE reselects carrier based on carrier priority configured by 4G side, as 4G UE selecting carriers based on low and high carrier priority configured by 4G side showed in figure below. However, NSA UE should be HO to anchor carrier preferentially, which may be not the high priority carrier configured by 4G side. In order to increase anchor carrier camping ratio for NSA UE and improve NSA UE experience, it is better to provide an independent coverage based mobility policy for EN-DC UE, so that EN-DC UE can stay at the EN-DC anchor as much as possible during mobility, and avoiding being handover to non-anchor cell by the coverage based mobility algorithm.

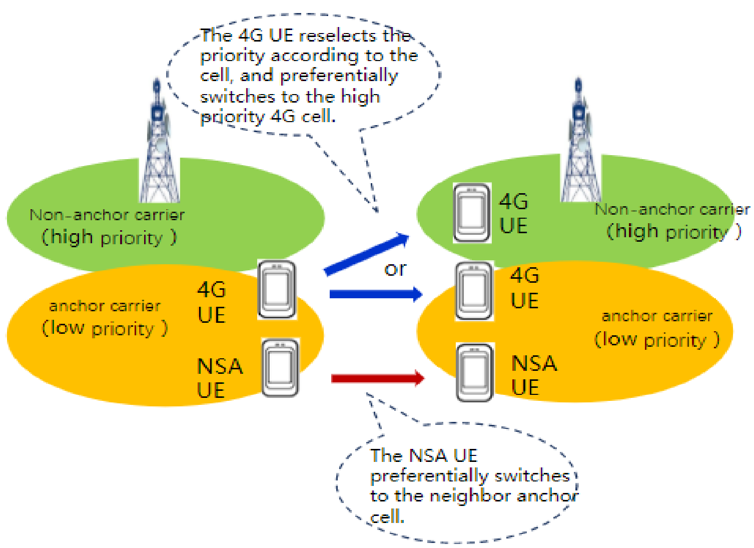


Figure 5.6 Anchor carriers should be Preferentially Selected for NSA UE

- In order to provide better live experience for 5G NSA users, MCG handover with SCG is recommended if possible, like in areas or scenarios where base stations are from same vendors. Besides, SCG failure could happen during EN-DC, like triggered by SCG radio link failure, then UE will report the SCG failure information to MN and may also include measurement results of SN. And a potential optimization could be suggested that MN may use reported measurement information for aiding SCG change.

5.2.2 Challenge 2: How to Improve EN-DC Uplink Coverage

For 2.6GHz or C-band NR, uplink coverage is not good as 4G LTE. In EN-DC scenario, the most effective method is to make full use of LTE anchor which is usually with lower carrier frequency, to supplement the uplink coverage for NR. With UL fall back to LTE, the uplink data is transmitted through LTE anchor carrier, and only UCI information would be transmitted through NR PUCCH, which can effectively improve the overall uplink coverage of EN-DC.

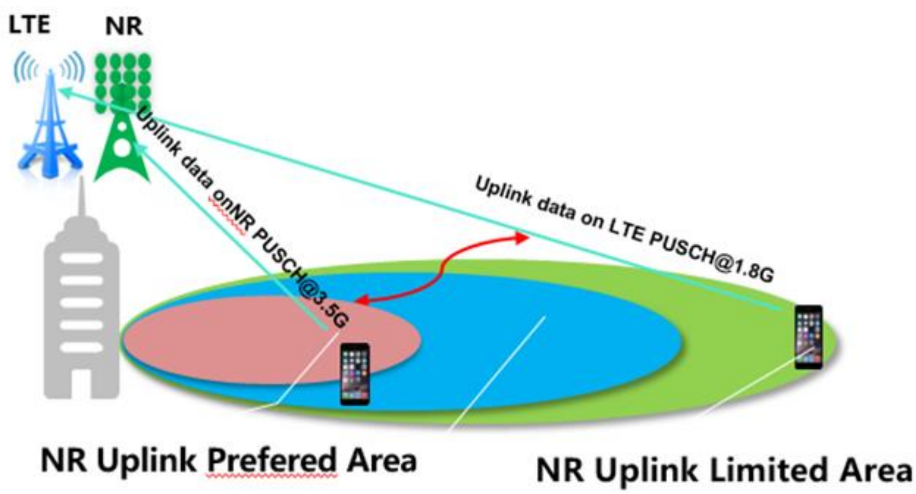


Figure 5.7 UL Fall Back to LTE in NR UL Coverage Limited Area

Also by this way, network side can configure and redirect UL data transmission carrier according to UE's capability. For the UE not supporting UL split bearer, when NR coverage is good, configure UL bearer terminated at gNB; if the NR UL coverage becomes poor while the NR DL coverage is still acceptable, it is can be configured that UL bearer terminated at eNB.

5.2.3 Challenge 3: How to Save Power Consumption for EN-DC UE

The EN-DC UE will work with both LTE and NR, which may result in overall power consumption increase compared to LTE only UE. In order to minimize the power consumption of EN-DC UE, RAN can act like following two solutions.

- Firstly, DRX is a common power-saving technology. But with EN-DC, because the period of DRX is not aligned between LTE and NR, the UE can't get into sleep time for LTE and NR module synchronously, and the energy-saving effect of DRX will be reduced. Therefore, RAN needs to align the DRX cycle to achieve the optimal energy saving effect. If LTE and NR adopt time synchronization, RAN can perform this issue. However, if LTE uses frequency synchronization, the terminal needs to support SFTD to assist the RAN to align DRX period.

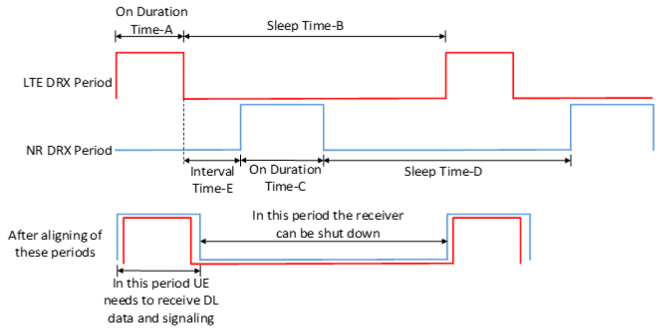


Figure 5.8 DRX aligning between LTE and NR

- Considering light load on NR system in beginning of NR commercial launch and subscriber perception, EN-DC system should consider to add NR leg asap. O&M personnel could tune the inactivity time to trade off UE power efficiency and user perceived performance. As traffic load increase in NR system, operators could consider whether EN-DC system introduce mechanism to control NR leg addition.

5.3 NSA Parameters and Performance Optimization Experience

NSA EN-DC parameters and performance optimization experience provided in this chapter come from large scale field trial, and it may be not the best one for all scenarios. Best and proper parameters can be selected by analysing key and leading factors for different and actual scenarios. NSA relates both NR and LTE systems, and NSA parameters and performance optimization also relates these two systems.

5.3.1 NR Parameters Optimization Experience

➢ **NSA Anchor and Handover**

Table 5.3 Parameters Recommendation for NSA Anchor and Handover

Type	Parameter	Recommendation	Remarks
NSA Anchor	NSA PCC Frequency priority	Based on network planning	Configure this NSA PCC frequency priority If NSA UE has different LTE frequency priority from LTE only UE.
	NSA DC PCELL A4 RSRP Threshold	-105dBm	Indicates the RSRP threshold for event A4 related to NSA DC PCC anchoring. If the measured RSRP of an inter-frequency neighboring cell is greater than this parameter value, the NSA DC UE reports event A4. This parameter should be bigger than A2 Threshold of target cell to prevent ping-pang.
Handover	NSA DC intra-freq/inter-freq handover parameter	Based on current LTE network planning	If current LTE network handover parameter conflict with NSA anchor policy, such as higher A2 threshold which leads to handover from anchor cell to none-anchor cells, dedicated inter-frequency handover parameter is mandatory for NSA DC UE.

As also recommended and described in chapter 5.2.1, following optimization can be carried out for NSA EN-DC UE to improve performance.

Considering not all LTE carriers support EN-DC and UE may support limited EN-DC band combination, network side can identify NSA UE by capability information reporting and try to let it camp on the suitable LTE carrier. For example, network side can identify NSA UE and get its EN-DC combination information from UE capability. UE includes EN-DC capability indication in LTE attach request message, so network side could enquire UE's NR and EN-DC capability in the following UE capability transfer procedure. With the detailed UE NR/EN-DC capability, network side could configure UE accordingly, including UE camping and SCG addition etc.

Network side can handover the NSA UE to the EN-DC capable LTE carrier before or during SCG addition. And also Network side could send specific carrier priority to the NSA UE when RRC release, to keep UE camping on the EN-DC capable LTE carrier in the idle state.

From configuration processing complexity and NR interruption delay perspective, LTE handover with SCG unchanged is recommended to improve NSA user experience.

- **SCG Addition**

Table 5.4 Parameters Recommendation for SCG Addition

Type	Parameter	Recommendation	Remarks
SCG Addition	NSA DC B1 Event RSRP Threshold	-105dBm	Indicates the RSRP threshold for event B1 during NR SCG configuration by the eNodeB. When the measured RSRP exceeds this threshold, event B1 is reported. NR measurement SCG addition is preferred.
	NR B1 Time To Trigger	512ms (depends on UE ability and service experience requirement)	Time-to-trigger for NR frequency measurement event B1. Smaller value is suggested to measure and add SCG quickly, and improve user experience. While considering measurement accuracy, stability for various coming 5G terminals, bigger value is recommended for a commercial network to have a better B1 report from all terminals.

There are two possible methods to add SCG for the UE.

- Blind addition, which means that eNB directly add SCG for the UE without UE measurement. It is suitable for the scenario that the NR gNB is deployed 1:1 as eNB, and the coverage of gNB is also similar with eNB. Although this method is simple, there is possibility that the SCG addition is failed or the gNB added is not the best cell for the UE.
- NR measurement based, i.e. eNB add SCG for the UE based on measurement report from UE. This method is used more widely as it can be used for any scenarios. It needs measurement configuration from Network.

Blind SCG add is not recommended for early deployment as NR coverage is not ubiquitous. In addition, blind addition may lead to higher UE power consumption, especially for FR2. Measurement based is recommended.

➢ **Bearer Configuration**

Table 5.5 Parameters Recommendation for Bear Configuration

Type	Parameter	Recommendation	Remarks
Bearer Configuration	NSA DC Bearer Mode	QCI1, QCI2, QCI3, QCI4, QCI5 MCG_BEARER_EUTRA_PDCP	For delay sensitive and small packets service, MCG data splitter is recommended, or

		QCI6，QCI7，QCI8，QCI9:SCG_SPLIT_BEARER	else SCG data splitter is recommended.

Besides based on RF, traffic could be another factor to be considered in combination with RF in deciding/ implementing on demand SCG add. The traffic consideration may include the underline LTE adv features and capabilities deployed, and the offered traffic and delay requirements, as well as the thresholds and needs for LTE offloading to NR.

It is recommended that network side configure proper PDCP version based on service and UE capability. For example, network side selects NR PDCP version for Internet Data DRB (QCI=9), while for VoLTE DRB (QCI=1 and 5), LTE PDCP should be kept (NR PDCP can be used for VoLTE DRB only when it is indicated in UE Capability).

- **PDCP & RLC Parameter**

Table 5.6 Parameters Recommendation for PDCP & RLC

Type	Parameter	Recommendation	Remarks
PDCP & RLC	AM Mode PDCP SN Length	NSA:18bits (default) NSA:12bits (QCI5)	Indicates the length of a PDCP sequence number in RLC AM. For NSA UE, 18 bits is recommended for the default bear. While 12 bit is preferred for QCI5.
	Status prohibit timer for UE	DL Split:15ms DL MCG or SCG only:50ms	Indicates the length of the UE-specific timer for prohibiting status reporting from the receiver in AM.
	AM reordering timer for UE	DL Split:15ms DL MCG or SCG only:50ms	Indicates the length of the UE-specific timer for reordering at the receiver in AM.
	UE PDCP Reordering Timer	200ms	Indicates the length of the UE-specific timer for PDCP reordering. This parameter is used for reordering PDCP packets in the two data flows based on the sequence numbers before these packets are delivered to the upper layer.
UL Power	Maximum Allowed UL Transmit Power	LTE 20dBm/NR 20dBm	Also depend on UE capability that whether dynamic power allocation is supported.

5.3.2 LTE Optimization Experience

In NSA networking mode, the control plane of NR and voice services of VoLTE are all carried on the 4G anchor cell. The quality of user residence in 4G anchor cell will directly affect the NR service experience. Therefore, it is necessary to optimize 4G cells to ensure good coverage of 4G anchor cells and reduce weak coverage and cross coverage. At the same time, it can ensure the good mobility of anchor cell, ensure the success rate of access and handover, and avoid ping-pang handover.

NR measurement is an IRAT measurement for LTE. The configuration of measurement from eNB should include

- Measurement object: here measObjectNR-r15 is defined for NR, and it include carrierFreq, rs-ConfigSSB, threshRS-Index etc. The field need to notice is the IE measTimingConfig in rs-ConfigSSB, which specifies the measurement timing configuration (MTC) applicable for SSB based NR measurements i.e. the time occasions for performing these measurements. Network should make sure the measurement gap (if configured based on UE capability) covers SSB transmission timing. More importantly, frame timing sync between gNB and eNB is required for fast and accurate IRAT measurement.
- Report configuration: The event B1, “neighbor cell is better than an absolute threshold” is typically used to trigger the NR cell addition in EN-DC. To maximize NR footprint without impacting experience, the B1 related parameters should be optimized according to deployed scenarios.

6 Large-Scale Trial and IoDT Result Sharing

6.1 Trial Network and IoDT Process

CMCC cooperate with vendors to promote NSA and 5G industry process and maturity in different cities in china, such as Hangzhou, Wuhan, Suzhou, Guangzhou et al. And various NSA trial scenarios and hundreds of test cases are verified and finished.

6.1.1 5G Trial Network and IoDT Process in Hangzhou

Figure 6.1 Outdoor Large-Scale Trial Scenarios in Hangzhou

Various and multiple outdoor large-scale trial scenarios and areas in Hangzhou are selected, just as marked in marked in Figure 6.1, and brief information for these areas is listed below.

- Area 1: dense urban area, 23 NR sites, avg. ISD ~350m, and trial in this area is for network planning verification and different AAU power test compare.
- Area 2: dense urban area, 19 NR sites, avg. ISD ~300m, and trial in this area is for SA networking verification and different PHY channel coverage compare.
- Area 3: urban area, 26 NR sites, avg. ISD ~450m, massive MIMO technical verification and inter-cell interference for LTE and NR hybrid networking test.
- Area 4: highway, 45 NR sites, avg. ISD ~550m, and trial in this area is for 5G Massive MIMO highway performance verification.
- Area 5: urban, 21 NR sites, avg. ISD ~550m, and trial in this area is for IoDT with multiple commercial terminals.
- Area 6: scenic spot, 5 NR sites, avg. ISD ~300m, and trial in this area is for performance and coverage comparison between 4.9G and 2.6G.
- Area 7: urban, 22 NR sites, avg. ISD ~406m, and trial in this area is for drive test.

And also multiple indoor typical scenarios and trial performance are verified in Hangzhou.

Figure 6.2 Indoor Large-Scale Trial Scenarios in Hangzhou

Indoor trial building contains 4 DIS and 1 DAS site types, including different typical scenarios like office building, stadium, mall and hotel.

Table 6.1 Brief Details of Indoor Trial Buildings

	Scenario Type	**Coverage area and floors**	**Indoor situation**	**Site Type**	**NR Cell Number**	**pRRU Number**
IoT RND Center	Office building	10, 11, and 12 floor	Open, only few inner walls	Lampsite	3	8
Stadium	Stadium		Open, only few inner walls	Lampsite	3	6
CMCC office	Office building	1, 6, 28 and 29 floor	Many separate inner rooms and walls	Lampsite	4	13
Silk Trade Center	Mall	1 and 2 floor	Many separate inner rooms and walls	Lampsite	1	3
Hotel Yaduo	Hotel	5, 6, 7, 8, 9, 10, 11 floor	Many separate inner rooms and walls	DAS	1	NA

Besides, to promote 5G NSA end to end industry process and maturity, IoDT are taken with various and multiple NSA commercial smartphones. And basic performance like SU DL/UL peak throughput, time delay for control plane and data plane, and key KPI with data, voice and mobility are all verified. From IoDT and test verification, end to end 5G NSA performance fulfils requirements for large-scale commercialization.

Figure 6.3 IoDT Progress with NSA Commercial Smartphones in Hangzhou

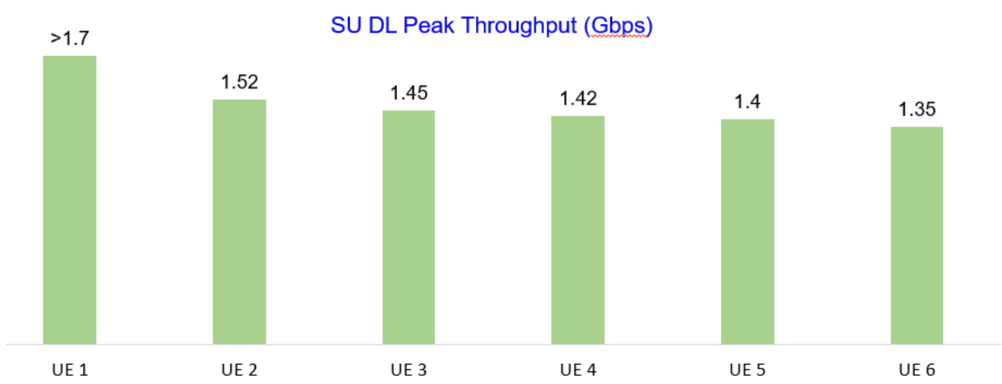


Figure 6.4 IoDT with Commercial Smartphones in HangZhou, SU DL Peak THP

6.1.2 5G Trial Network and IoDT Process in Wuhan

Outdoor and indoor trial and test scenes are verified in Wuhan.

- NSA general urban scene
  - The number of base stations in the region is 19, and the station spacing is 400 meters, which meets the requirements of general urban areas.
  - Hundreds of test cases are conducted and finished in this region.
- NSA room scene
  - Room test area, small high-rise, the first floor is pure DAS, the second floor is pure Pico.
  - Hundreds of test cases are conducted and finished in this region.

The Wuhan trial network is distributed in the main urban area of Optics Valley. A total of 95 macro base stations and 5 room stations are built. The coverage area includes universities, parks, industrial, transportation hubs and so on, and meets the test conditions.

6.1.3 5G Trial Network and IoDT Process in Guangzhou

5G NSA trial network in Guangzhou includes various and multiple scenarios, such as campus, CBD, highway and indoor areas. Basic NSA performance and lots of test case for NSA networking and planning are verified and finished here.

Besides, IoDT are taken with various and multiple NSA commercial smartphones, like Huawei, OPPO, ZTE, VIVO, Xiaomi and et al. with Qualcomm, Hisilicon, MTK chipsets.

6.2 Trial Performance

Lots of performance trial and test cases have been carried out and finished in Hangzhou, Wuhan and Guangzhou. Through these performance result with commercial NSA terminals, it is proved that 5G NSA commercial network can also deployed with extreme user experience.

Without special attention, test equipment and environment for following chapters 6.2.1~6.2.6 are as described below for brief.

- Macro site
  - Massive MIMO AAU with 64T64R
  - Carrier frequency is CMCC 2.6GHz, and system bandwidth is 100MHz (2515M~2615M)
  - Subcarrier spacing is 30KHz
  - Frame structure is 5ms period with “DDDDDDDDSUU”, and S slot is configured with 6:4:4 slot structure “DDDDDDXXXXUUUU”, where ‘F’ means flexible symbol and the four ‘F’ symbol are set for GAP symbol by default
- Terminals
  - Commercial NSA smartphones with 1T4R configuration for 5G
  - UL total maximum transmit power is 23dBm

6.2.1 NSA SU Peak THP

Figure 6.5 SU Peak Throughput Trial

Downlink peak throughput is with 4 data streams and the peak value >1.7Gbps is without LTE MCG contribution. Uplink peak throughput is with only 1 data stream, and also 125Mbps is without LTE MCG contribution.

Table 6.2 Trial Result for SU Peak Throughput

	Throughput	Remarks
Uplink Peak	125Mbps	This THP is NR only, and without LTE MCG contribution.
Downlink Peak	>1.7Gbps	This THP is NR only, and without LTE MCG contribution.

6.2.2 NSA MU Peak THP

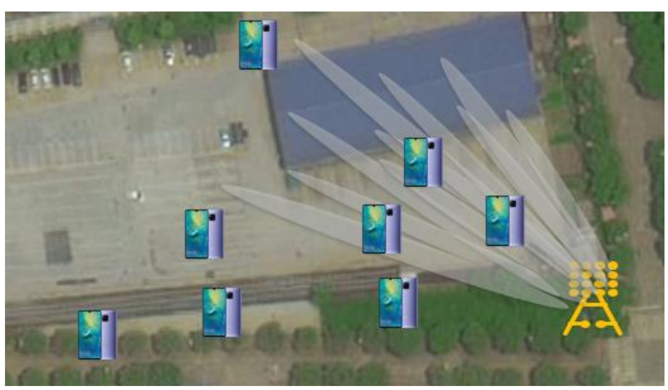


Figure 6.6 MU Peak Throughput Trial

With eight 5G NSA commercial smartphones are distributed in different points, the 64T64R massive MIMO AAU can pair these terminals and let all 8 smartphones share the same 100M NR bandwidth frequency resource together by MU-MIMO spatial multiplexing. By this, DL >5.5Gbps and UL >650 Mbps are reached.

Table 6.3 Trial Result for MU Peak Throughput

	Throughput	Remarks
Uplink Peak	>650Mbps	1) This THP is NR only, and without LTE MCG contribution. 2) This THP is reached with 8 users, and total 8 uplink streams, 1 stream for each user.
Downlink Peak	>5.5Gbps	1) This THP is NR only, and without LTE MCG contribution. 2) This THP is reached with 8 users, and total 16 downlink streams, 2 stream for each user.

6.2.3 NSA Control Plane Delay

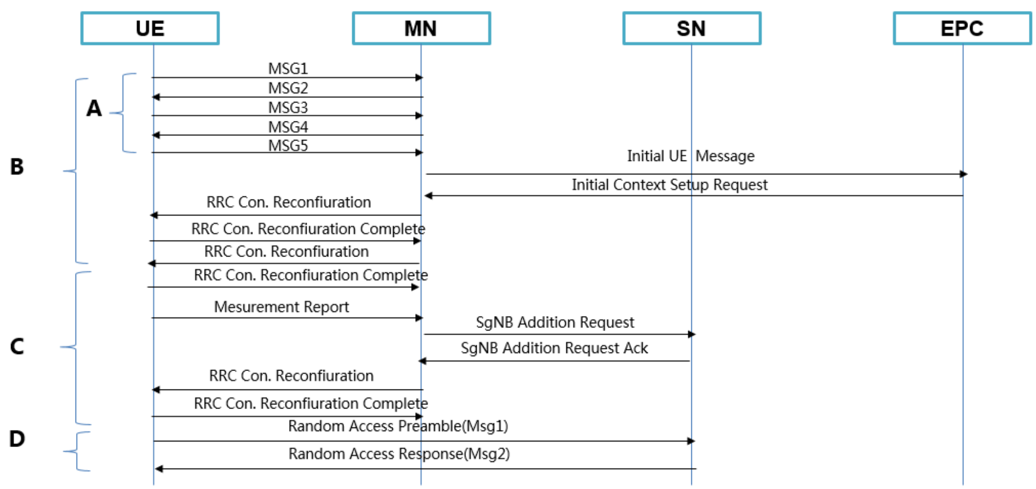


Figure 6.7 Procedures for NSA Control Plane Delay

NSA control plane delay mainly consist 4 parts, listed as **A**, **B**, **C**, **D**.

1) **A** : initial random access procedure in LTE side.
2) **B** : finish all necessary signaling and NAS procedure in LTE side, and start to prepare UE measurement for NR SCG cell.
3) **C** : configure and let UE measure neighboring NR SCG cells. Based measurement report from UE, the best NR SCG cell is selected, and exchange information and prepare for SCG addition.
4) **D** : access, acquire and add the target NR SCG cell.

NSA control plane delay is tested with a massive MIMO AAU with 64T64R, and a 5G NSA commercial smartphone.

After optimizing, result which is less than 340ms is verified for end to end whole procedures.

Table 6.4 Trial Result for NSA Control Plane Delay

A	B	C	D	Total	remarks
<40ms	<120ms	<210ms	<10ms	**<340ms**	**Total** = **B** + **C** + **D** **A** is a part of **B**

6.2.4 NSA User Plane Delay

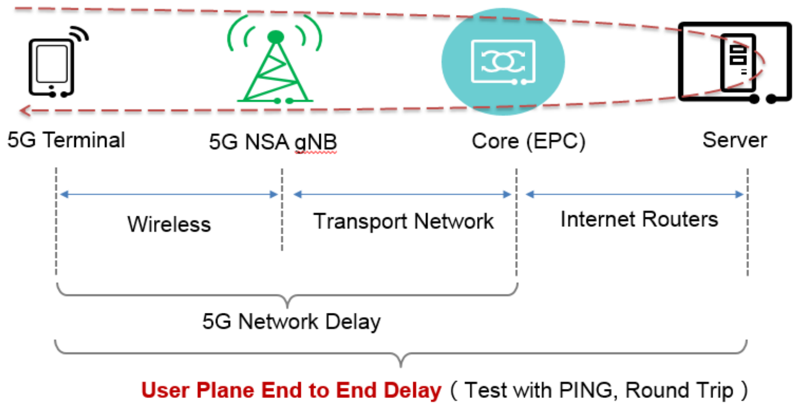


Figure 6.8 Procedures for NSA Data Plane Delay

User plane delay here is end to end and round trip delay, which starts from 5G terminal to internet server, and returns back to 5G terminal. And this delay consists 3 parts: delay for wireless transmission, delay for transport network, and delay for internet routers and server.

NSA user plane delay is tested with a massive MIMO AAU with 64T64R, and a 5G NSA smartphone. And it is carried out with PING 32Byte packets.

Result which is less than 10ms delay is verified for NSA user plane delay with activating uplink pre-scheduling and optimizations.

6.2.5 NSA Outdoor Drive Test

Two kinds of outdoor drive test are carried out. First one is drive test with about ~30kmh in the dense urban area and we drive around almost every street with a 5G NSA commercial smartphone to get enough samples. Second one is to drive test with average ~70kmh on the highway.

Figure 6.9 Drive Test Route in Dense Urban Area

Drive test route in the dense urban area is with 23 sites configured in NSA mode, and avg. ISD is ~350m. The route is 19km long, and vehicle moves at avg. ~30kmh. On average DL throughput >800Mbps without LTE contribution is verified.

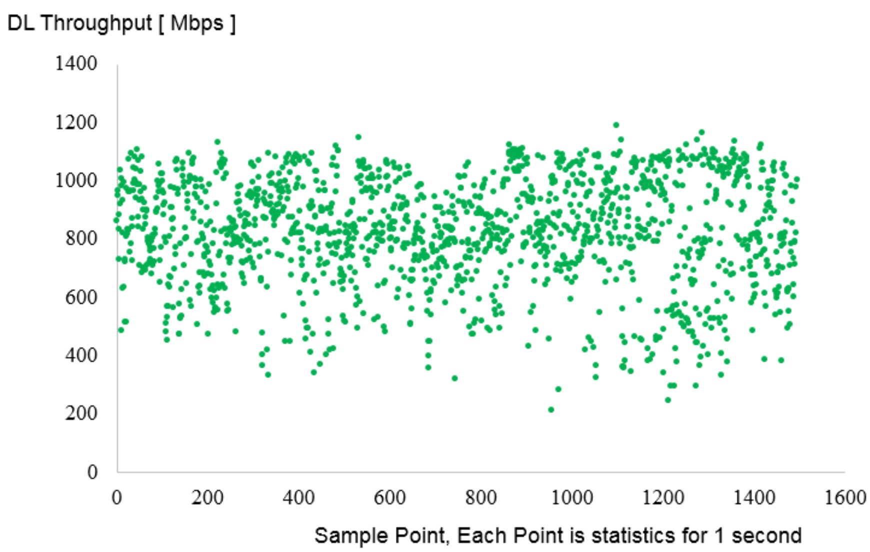


Figure 6.10 Trial Result for Drive Test in Dense Urban Area

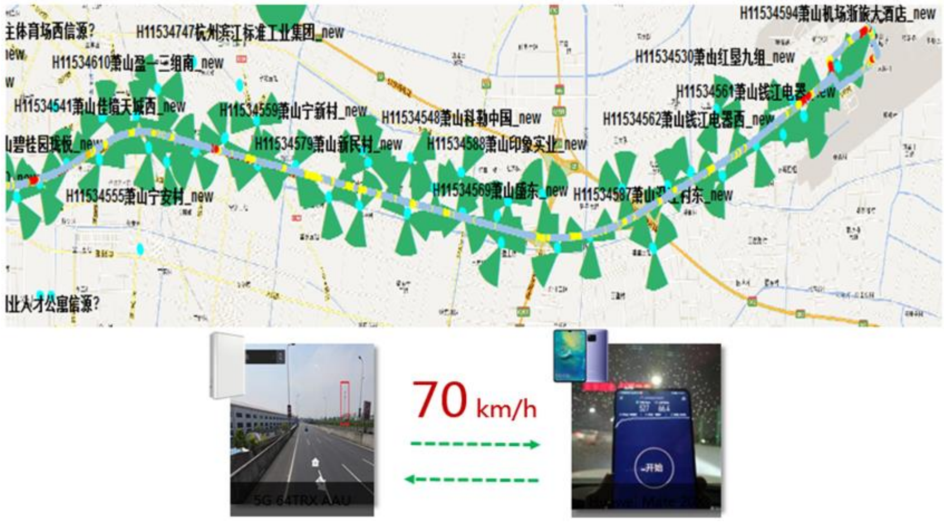


Figure 6.11 Drive Route on the Highway

Highway trial route is about 23km long. 45 sites with 64T64R AAU are deployed along this route with avg. ISD ~500m, and vehicle moves at avg. speed of 70kmh. after performance optimization, avg. DL throughput >700Mbps without LTE contribution is verified by a 5G NSA commercial smartphone.

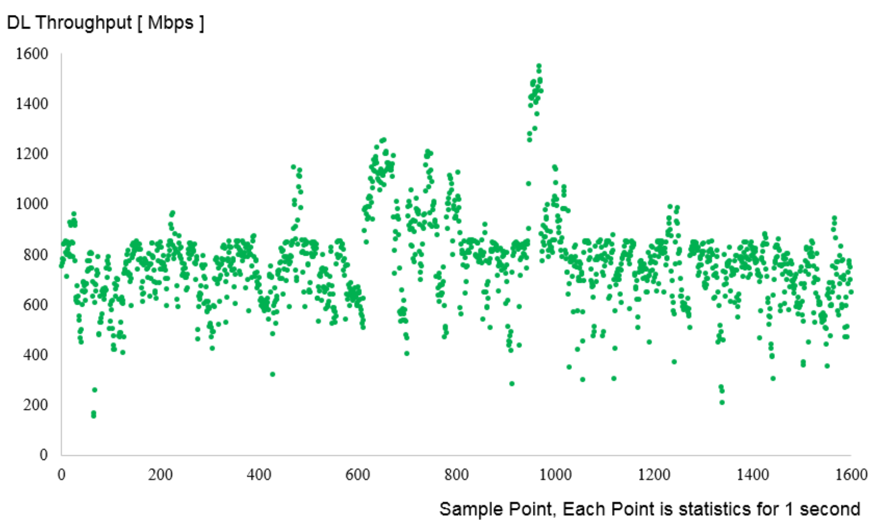


Figure 6.12 Trial Result for Drive Test on the Highway

6.2.6 NSA Indoor Test

Figure 6.13 Indoor Small Cell Trial Scenario

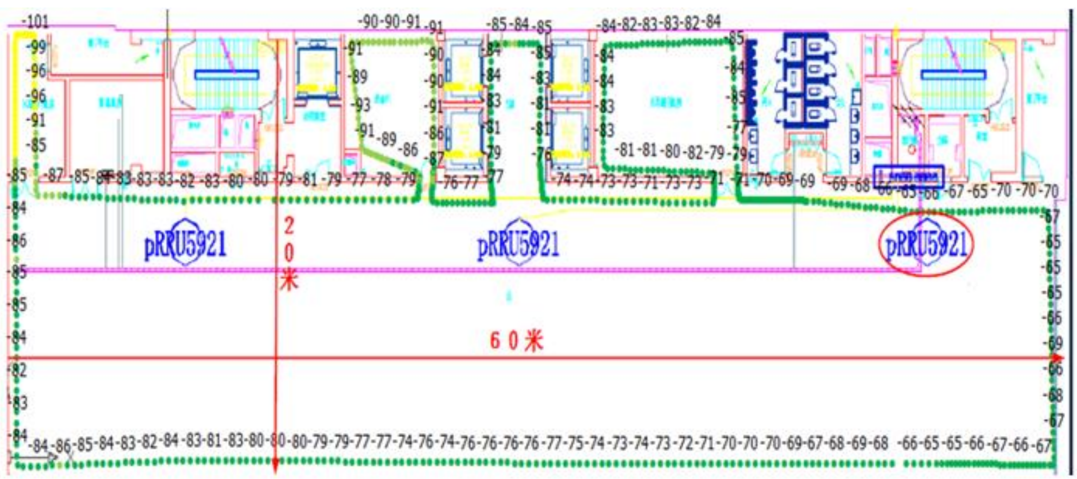


Figure 6.14 Indoor Small Cell Test Route

The Indoor test equipment is 4T4R pRRUs and a 5G NSA commercial smartphone. With test route as showed in Figure 6.14, SU peak throughput for DL > 1.3Gbps and UL > 120Mbps are reached. DL avg. throughput is still above 1.1Gbps, while UL avg. throughput is above 110Mbps for this route. Besides, peak and avg. throughput are NR only and without LTE MCG contribution.

7 NSA Key Findings Sharing

From trial result and issues discussed by 3GPP proposals and documents, some key user capability to improve network performance and NSA user experience are shared in this chapter. It is recommended that 5G terminals should support these capabilities.

7.1 SRS Antenna Switching

7.1.1 Brief Principle

SRS is uplink sounding reference signal, and base station receives the SRS signal to calculate exact uplink channel response by channel estimation, and measure the quality of the uplink channel, and appropriately selects the physical resource and the corresponding MCS according to the measurement result etc.

And what is most important is that uplink SRS channel response is used to calibrate downlink channel response and exactly calculate downlink beam weight and direction for SU and MU scenarios. And downlink beam weight calculated by SRS is much more accurate than CSI and PMI information which is feedback by UE for TDD systems, as downlink channel response is reciprocal to that of uplink using the same carrier. So, SRS antenna switching can indeed improve network performance and user experience for 5G TDD systems.

And for 5G UEs that do not support SRS antenna switching, only partial antennas' channel response can be measured. However, to get and calculate accurate downlink beam weight, all antennas' channel responses is in need by SRS antenna switching, or else performance is lost.

It is typical for 5G UE to be deployed with 4 receiving antennas and 1 or 2 uplink transmitting antennas. Just as defined in 3GPP TS 38.214 and showed as Figure 7.1, it is recommended that 5G UE should support 1T4R SRS antenna switching or 2T4R SRS antenna switching. While 1T2R SRS or UE without full antenna switching, it is not recommended.

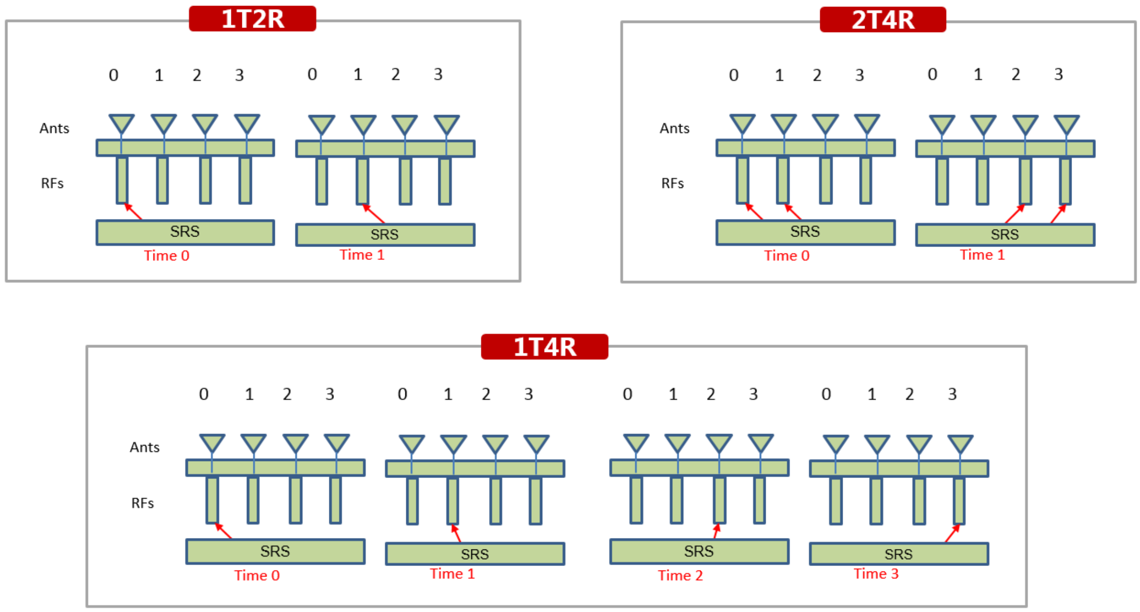


Figure 7.1 Illustration for 1T2R, 1T4R, 2T4R SRS Configuration

7.1.2 Trial Performance Comparison

For performance comparison, downlink beam weight with SRS antenna switching and downlink beam weight with PMI are tested under same environment conditions and terminals. When SRS antenna switching is deactivated, downlink beam weight with Type I PMI is used. What is more, CSI-RS configuration for PMI/CQI/RI feedback stays the same for fair comparison.

As defined in “R1-1907862”, Type I PMI codebook 2/4/8 port is mandatory without capability signaling for FR1 UE. Besides, Type II PMI is also a UE optional feature, which provides beams combination, better performance than Type I PMI, and even with the aim to approach performance of SRS antenna switching. However, it may cause hundreds of payload bits for CSI information feedback, and still needs commercial terminals to support this optional ability and verify its actual performance.

SRS antenna switching can provide 30% gain for SU experience for static point test and drive test. Cell capacity can be boosted and 50~150% capacity gain can be expected with user number growing.

And as UE may support optional features and capabilities, like more CSI-RS ports for Type I PMI measurement and even Type II PMI, SRS antenna switching gain may be different because of PMI performance would be different depending on CSI-RS ports configuration and UE capabilities.

➢ **Average SU Static Experience Improved By ~30%**

Figure 7.2 SU Static Trial Scenario for SRS Antenna Switching

Four test points are selected in Hangzhou, Point A, Point B, Point C and Point D. Test terminal is a commercial NSA smartphone supporting 1T4R SRS antenna switching. In order to compare performance, SRS antenna switching is de-activated and then activated. Under same test points and same conditions, average ~30% downlink user throughput gain is verified.

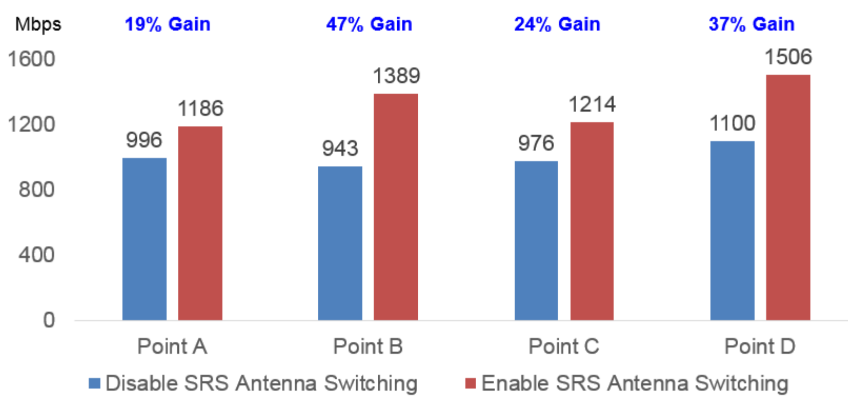


Figure 7.3 DL Throughput Gain for SRS Antenna Switching, SU Static Scenario

➢ **Average SU Drive Test Experience Improved By ~30%**

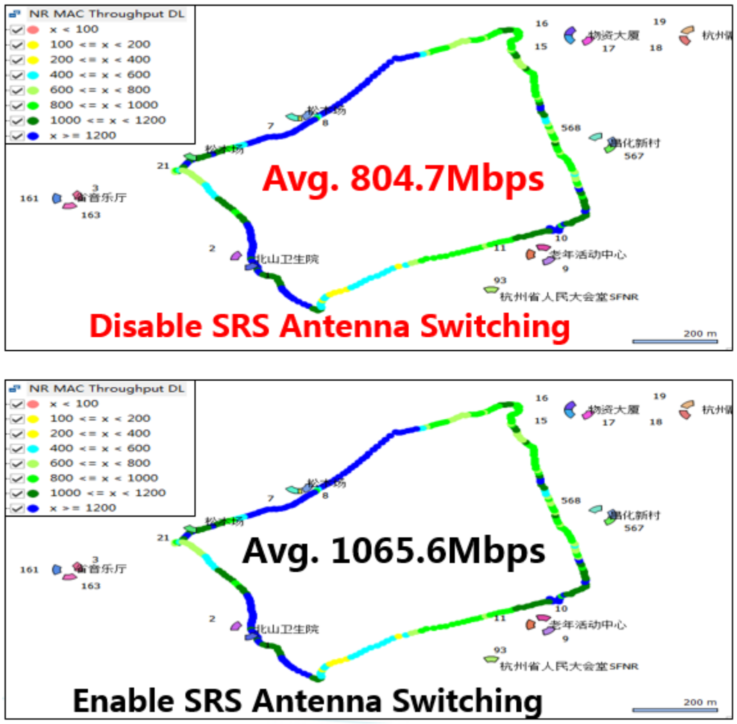


Figure 7.4 DL Throughput Gain for SRS Antenna Switching, SU Drive Test Scenario

With same drive route in Hangzhou and same commercial NSA smartphone supporting 1T4R SRS antenna switching, downlink throughput is tested by disabling and then enabling SRS antenna switching. As showed in Figure 7.4 average 32% downlink throughput gain is verified.

- **MU Reaches 50%~150% Cell Capacity Gain**

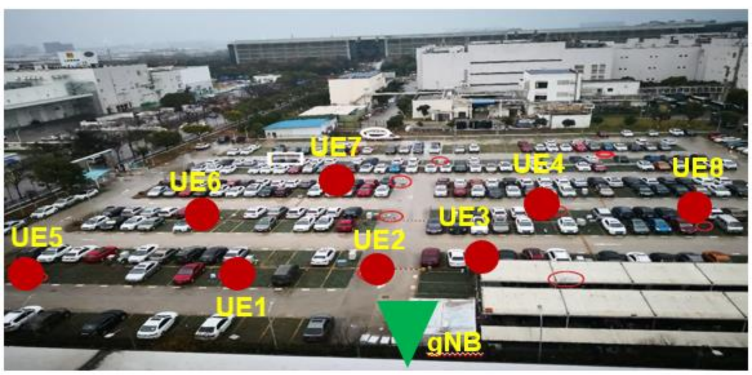


Figure 7.5 MU Trial Scenario for SRS Antenna Switching

8 terminals are distributed in a car park in Shanghai. And these terminals are commercial NSA smartphones supporting 1T4R SRS antenna switching. Downlink cell throughput is observed by disabling and then enabling SRS antenna switching, and adding terminals one by one. Under same user number at same points and same conditions, 50~150% downlink cell capacity gain is verified.

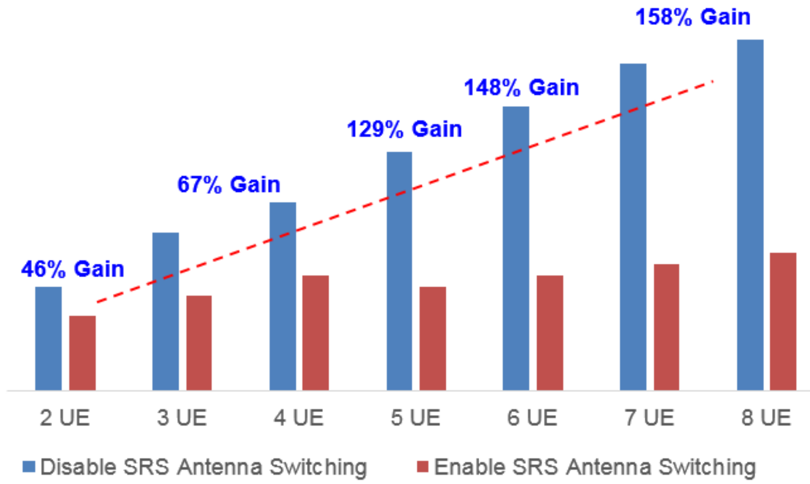


Figure 7.6 DL Cell Capacity Gain for SRS Antenna Switching, MU-MIMO

7.2 CSI-RSRP/SINR Measurement (>8Beam)

- **8 beams for sub6G SSB, more beams can be configured for CSI-RS**

Figure 7.7 Beam Sweeping for SSB and CSI-RS

Maximum 8 SSB beam sweeping for FR1 is defined in 3GPP TS 38.213.

- **20 PRB for SSB, whole band can be configured for CSI-RS**

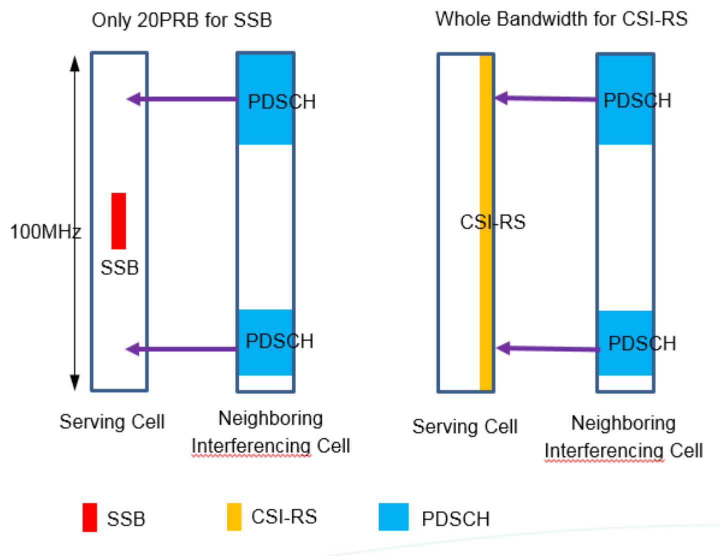


Figure 7.8 SSB may not Reflect Neighboring Cells' PDSCH Interference

As maximum only 20PRB is defined for SSB, SSB may not reflect neighboring cells' PDSCH interference and load, as showed in Figure 7.8. While CSI-RS can be configured on the whole NR bandwidth, CSI-RS SINR can reflect neighboring cells' PDSCH interference and load.

7.3 NSA UL Coverage Improvement

7.3.1 UL Dynamic Power Allocation

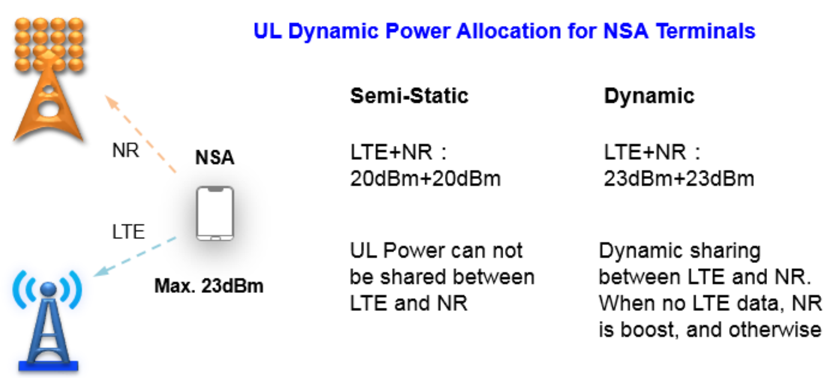


Figure 7.9 UL Dynamic Power Allocation for NSA Terminals

As defined in NR UE features document like "R1-1907862", UE capability for "Dynamic Power Sharing for LTE-NR DC" is mandatory with capability signalling reporting.

By default, NSA UE use semi-static power allocation, and usually UE with maximum 23dBm power is configured with 20dBm LTE + 20dBm NR. And UL power can't be shared between LTE and NR. While UL dynamic power allocation provide freedom to share UL power between LTE and NR, and thus UL coverage can be boosted.

7.3.2 HPUE for TDD LTE+TDD NR

Besides, HPUE (high power UE) for NSA UE with TDD LTE + TDD NR is another straight way to improve UL coverage, and it is proposed in propose document "RP-190315". 3dB power and coverage is expected from HPUE.

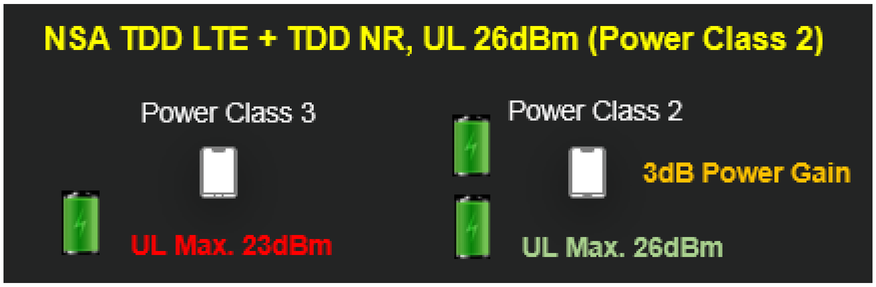


Figure 7.10 HPUE for NSA UE with TDD LTE + TDD NR

7.4 SFTD Measurement for NSA Network Synchronization

In the EN-DC scenario with FDD LTE + TDD NR, FDD LTE networks often use frequency synchronization. In this scenario, LTE side has no ability to determine the exact timing offset between eNB and gNB, following problems may occur.

- Start gap measurement to measure NR: because eNB is unclear about the real timing of NR SSB, gap is placed incorrectly and can't include NR SSB (4G measurement period is usually 40ms and gap is 6ms, while 5G SSB period is 20ms and actual transmission time is 2ms by default). This problem may lead to measurement failure of NR.

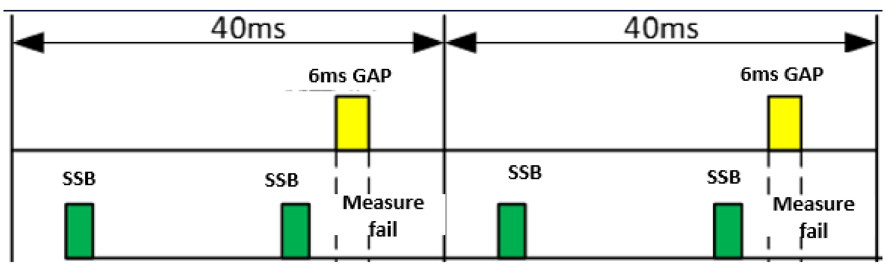


Figure 7.11 Measurement Failure of NR, When LTE and NR Frame Timing is Unknown

- After the SCG is added successfully, gap measurement would be started during inter-frequency handover. Due to the uncertain timing offset between LTE and NR, the gap of LTE and gap of NR are unaligned. UE follows LTE gap and is not aligned with NR gap, which will cause the NR downlink data discarded by the UE and affect the NR downlink throughput.

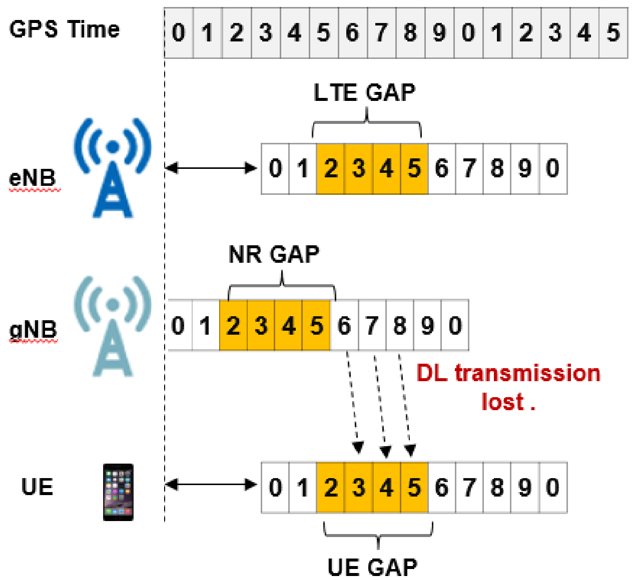


Figure 7.12 NR DL Transmission Lost During 4G Inter-frequency Handover

Change the LTE FDD from frequency synchronization to time synchronization is effective to solve the problems. But it may be hard to do this for the operators with high cost and long time. Since the root cause of these problems is that LTE can't determine the timing offset between eNB and gNB, it is a good idea to obtain it by SFTD measurement.

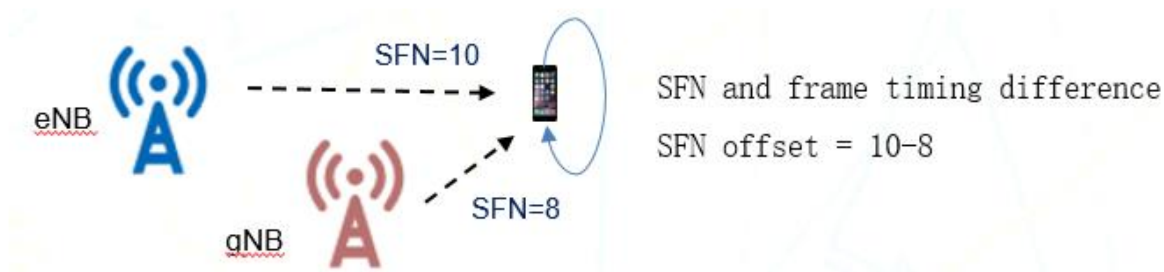


Figure 7.13 Illustration of SFTD Measurement for UE

SFTD is defined in 3GPP as an optional measurement. Like the figure above, SFTD can report the SFN and frame timing difference to eNB, which provides a solution to these problems. The key issue for this solution is: need commercial UE to support ability for SFTD measurement.

SFTD (SFN and frame timing difference) is defined in 3GPP TS 38.215.

SFTD Definition: the observed SFN and frame timing difference (SFTD) between an E-UTRA

PCell and an NR PSCell (for EN-DC), or an NR PCell and an E-UTRA PSCell (for NE-DC), or an NR PCell and an NR PSCell (for NR-DC) is defined as comprising the following two components:

- SFN offset = (SFN_{PCell} - SFN_{PSCell}) mod 1024, where SFN_{PCell} is the SFN of a PCell radio frame and SFN_{PSCell} is the SFN of the PSCell radio frame of which the UE receives the start closest in time to the time when it receives the start of the PCell radio frame.

- Frame boundary offset = $\lfloor (T_{FrameBoundaryPCell} - T_{FrameBoundaryPSCell})/5 \rfloor$, where $T_{FrameBoundaryPCell}$ is the time when the UE receives the start of a radio frame from the PCell, $T_{FrameBoundaryPSCell}$ is the time when the UE receives the start of the radio frame, from the PSCell, that is closest in time to the radio frame received from the PCell. The unit of ($T_{FrameBoundaryPCell}$ - $T_{FrameBoundaryPSCell}$) is Ts.

8 NSA & SA Co-existence, and Evolution to SA

8.1 What is SA ?

8.1.1 SA Provides Enhanced Performance and Features

SA can provide enhanced performance and features in following aspects for example

- **Potential Shorter Delay**: SA NR provide more flexible structure and terminology, and slot period can be shorter than LTE, like 0.5ms for 30KHz subcarrier spacing. SA UE can access NR directly and signaling messages do not need to go around from LTE.
- **UL Performance:** SA terminals are usually and can been deployed with more UL antennas like 2T4R, which can potentially bring higher UL peak throughput. Besides, UE transmit power may not be shared and splitted between NR and LTE.
- **VoNR**: for voice service, NSA is VoLTE and SA can deploy VoNR. The performance and efficiency of EVS codec provides additional performance gain and is by default be adopted by VoNR. And if NR gNodeB is deployed with massive MIMO, the spatial sharper beam provides better coverage and less interference.

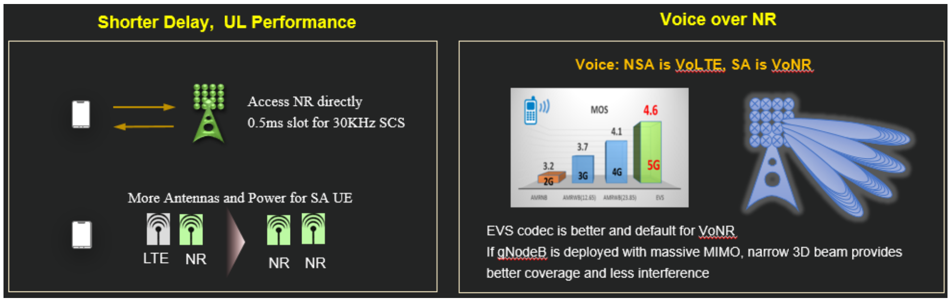


Figure 8.1 SA Provides Enhanced Performance and Features

8.1.2 SA fulfils 5G Vision for All Services

As 5G vision is to provide eMBB, uRLLC and mMTC services, and to accomplish this vision need to satisfy larger throughput, shorter latency and massive connection. SA provides end to end network slicing and 5QI to provide better QoS guarantee for all services, and let these service co-exist in the same 5G network.

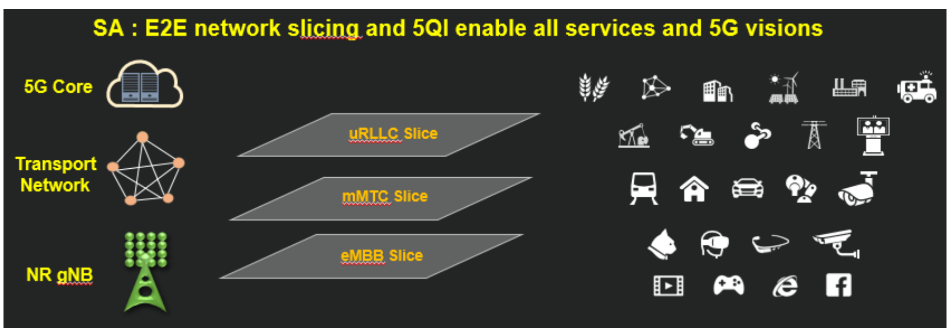


Figure 8.2 SA Provides End to end Network Slicing and 5GI for Better QoS Guarantee

8.1.3 Comparison and Summarize

SA has many advantages over NSA such as service readiness, network complexity, latency and UE power consumption. However, in order to have a better user experience, SA should provide continuous 5G coverage as soon as possible.

Table 8.1 NSA vs. SA

	NSA (Option3X)	SA (Option2)
5G LOGO	Customization is needed when UE camps on LTE in idle state	OK
Core Network	EPC upgrade to support NSA, Capacity expansion to support NR traffic.	5GC is newly deployed, N26 interface between AMF~MME is needed to support inter-RAT handover
Transport	EN-DC traffic split requires	No interface between LTE eNodeB and NR

Network	short-distance transport between eNB and gNB. LTE transport network may be adjusted.	gNodeB.
LTE eNodeB	Software upgrades LTE and NR are coupled	Software upgrades for LTE and NR are decoupled
NR Coverage	Coverage mainly depends on LTE	Continuous NR coverage is important for better user experience.
Inter-RAT cell neighbor relations	Configuration of LTE&NR neighbor relations in the whole network.	Configuration of LTE&NR neighbor relations only in the border of LTE&NR
Service Type	eMBB	eMBB/uRLLC/mMTC
Voice	• VoLTE • CSFB to 3G	• VoNR • EPS FallBack • EPS FallBack + CSFB to 3G
Latency	CP access latency depends on LTE	CP latency optimized
Terminals	• Dual connection needs 2 modems being activated simultaneously	• Only 1 modem is activated at one time

8.2 NSA & SA Co-existence

By 2020, the problems restricting the deployment of SA network will be solved: a large number of UE supporting SA/NSA dual-mode will come out, while the ministry of industry and information technology of China has also stated that from January 1, 2020 on, NSA only UE is not allowed, and 5GC bidding has been carried out, which can meet the commercial requirement in 2020. Therefore, 2020 will be the first commercial year of SA.

But considering the life cycle of current NSA only UE and the long time for SA network construction, it is suggested to support both NSA only UE and SA UE in a period of time, that is NSA & SA dual mode network. In NSA & SA dual mode network, the NR cell of SA and NR cell of NSA are the same cell on the same hardware equipment. NSA and SA terminals can co-exist in the same network.

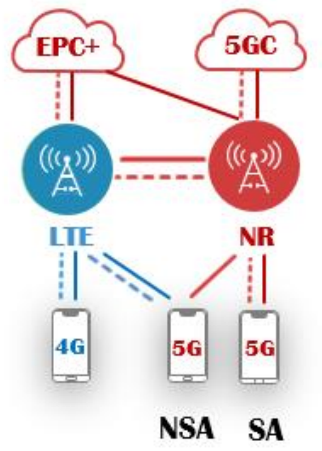


Figure 8.3 NSA & SA Dual Mode

NSA & SA dual mode network has the following advantages:

- It can be compatible with NSA only UE that have been commercialized, and help operators to smoothly evolve to SA.
- Inherit some advantages of NSA. LTE bandwidth and coverage can bring better user experience and performance in some scenarios.
- From NSA to NSA & SA dual mode network, only software upgrade needed for gNB.
- NR network optimization once for both NSA and SA.

The problems for NSA & SA dual mode network are

- If NSA only UE exists for a long time, it will lead to long-term maintenance of this complex architecture with high costs, and is not good for decoupling LTE & NR.

8.3 NSA Evolution to SA

From NSA evolution to SA, its impact to network are

- gNB: software upgrade to support NSA & SA dual mode network.
- 5GC: new 5GC should be introduced.
- Transmission Network: no special requirement to support NSA & SA hybrid network for transmission.
- Terminals: 5G UE should subscribe on both NSA and SA to ensure the successful handover between NSA & SA.

From NSA evolution to SA, it is recommended that

- NSA only UE may camp on LTE network. NSA & SA dual-mode UE should have priority to camp in SA network. And for NSA & SA dual-mode UE, connection to SA has similar downlink throughput and better uplink throughput in near point than NSA
- For the voice scenario, NSA network can use VOLTE or CSFB, while EPS FB may be

deployed for SA network before continuous NR coverage. VoNR is preferred when NR is with continuous coverage.

SA is on its way

- Low-Mid frequency coverage is common trend among global operators, and the coverage challenge of SA architecture is greatly relieved: according to the statistics of GMSA by July 2019, the number of low-mid frequency 5G spectrum allocated by global operators is more than 90, more than 70%. 5G deployment based on low-mid frequency will effectively alleviate the coverage challenge of SA commercial use. In addition, according to incomplete statistics, more than 30 operators are expected to deploy 5G networks based on sub-3G by 2020Q4. Sub-3G network deployment will greatly relieve the coverage pressure of 5G SA deployment, and create good coverage conditions for 5G SA architecture.
- SA-enabled smartphones are already commercialized and the module will be launched in 2020. With development of 5G chips supporting SA, we expect SA-enabled modules to appear around the first half of 2020.
- 2B application is the main driver of SA, and low-cost SA module is the key: from the analysis of SA architecture, the main application scenarios are uRLLC, mMTC and other non-traditional 2C fields, where terminals are diversified, mainly dependent on modules, and price-sensitive. As main cost of the module is subject to 5G baseband chip, and the baseband chip of the module can be cost apportionment through smart phones to a considerable extent, we expect that the cost of 5G baseband chip will decrease with the increase of global penetration of 5G smart phone. IDC predicts that global 5G smartphone shipments will account for more than 15% in 2021, and it is foreseeable that the first 5G SA module for large-scale commercial use will be launched in 2021.

9 Summary

GTI NSA Commercial Network Deployment Whitepaper targets 5G NSA large scale trial experience sharing. This document is conducted to be the technical, solution, parameters and performance optimization references for 5G NSA commercial network deployment. Addresses the key aspect of NSA architecture, principles, challenges and solutions, trial performance and key finds in the commercial trial cases.

According to process and evolution of commercial terminals, 5G network will also have a transitional procedure and evolution to SA. There will be some issues that need to be discussed in the updated version of this whitepaper in the future.