5G Devices SA Migration Scenarios

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by NGMN Alliance

Version:	1.0
Date:	21.06.2022
Document Type:	Final Deliverable (approved)
Confidentiality Class:	P - Public
Authorised Recipients: (for CR documents only)	

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Abstract

The purpose of this document is to provide an overview of the available 5G deployment options and to analyse the migration strategies adoptable by the Mobile Network Operators (MNOs) to progressively switch from an NSA (Non-Standalone) to SA (Standalone) 5G architecture as smoothly as possible. Migration strategies are evaluated in the timeframe 2022-2029 by considering 5G devices and subscriptions uptake forecasts along with the expected evolution of device capabilities.

Contents

INTRODUCTION

3GPP has defined two major 5G architectures – 5G Non-Standalone (NSA) and 5G Standalone (SA). NSA architectures feature the use of both LTE and 5G New Radio (NR) to connect to either an existing 4G Core Network (CN) or to a (new) 5G Core Network. In contrast, SA architectures use either LTE or NR as the Radio Access Network (RAN) whilst the Core Network is either a 4G CN or a 5G CN. By defining the two major architectures and the possible options (RAN and CN) within each approach the industry has created a toolbox for evolving from 4G to 5G.

Taking a devices perspective, this white paper looks specifically at how Mobile Network Operators (MNOs) who currently operate 4G and 5G NSA networks can evolve to support 5G SA networks.

To ensure the coexistence of 5G and 4G Devices, enabling the use of the new 5G Core Network, operators need to manage a transition period in which both 5G deployment architectures are present.

This paper presents a way to handle and optimize this transition. The goal is not only to guarantee an effective usage of the most valuable FDD and TDD Sub-6 bands (< 6GHz) but also effective usage of all frequency assets.

The re-farming strategies that can be implemented by Operators will inevitably be influenced by the speed of penetration of 5G Devices and the frequency bands that they support. Accordingly, a potential migration timeline has been defined.

1 5G NETWORK DEPLOYMENT OPTIONS

To provide flexibility in the evolution from 4G to 5G, 3GPP has defined a number of different deployment options.
They can be grouped into the following two architectures:

- NSA (Non-Standalone)
- SA (Standalone)

NSA deployment enables MNOs to combine multiple radio access technologies, LTE and NR, while SA involves the use of a single radio technology, LTE or NR.

Among the available NSA options, the most common is the Option 3 (Figure 1).

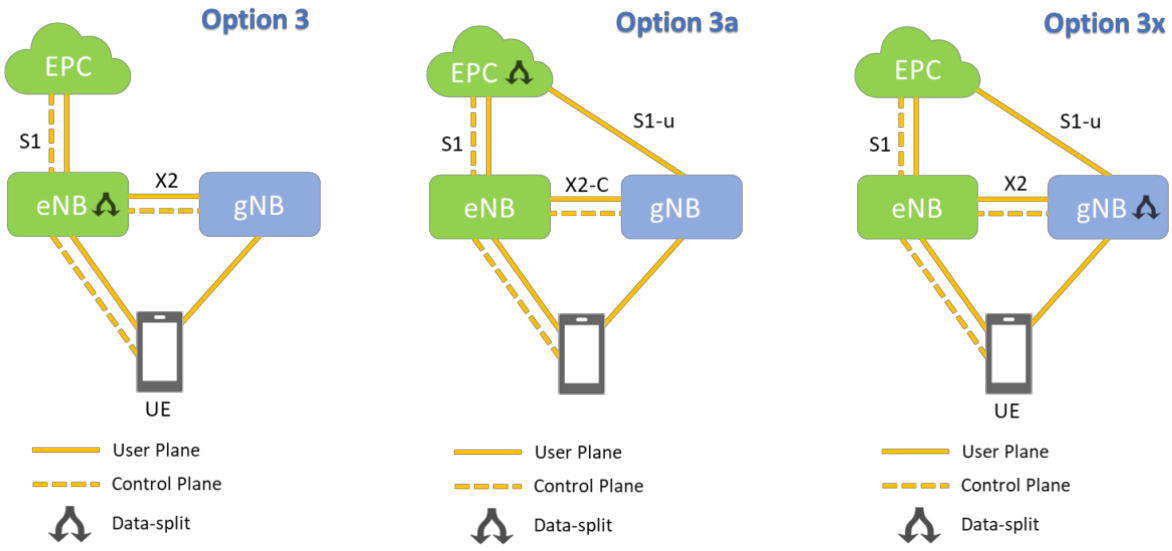

Figure 1 - Options 3, 3a, 3x schemes [4]

In particular, the **Option 3x** has been widely adopted by MNOs since it places the data split anchor on the 5G base station (gNB), avoiding major changes, like hardware and software upgrades, on the existing 4G CN and RAN and enabling the use of the new NR frequencies with relatively small initial investments. For these reasons, the Option 3x is the most common and recommended choice for 5G NSA network deployment.

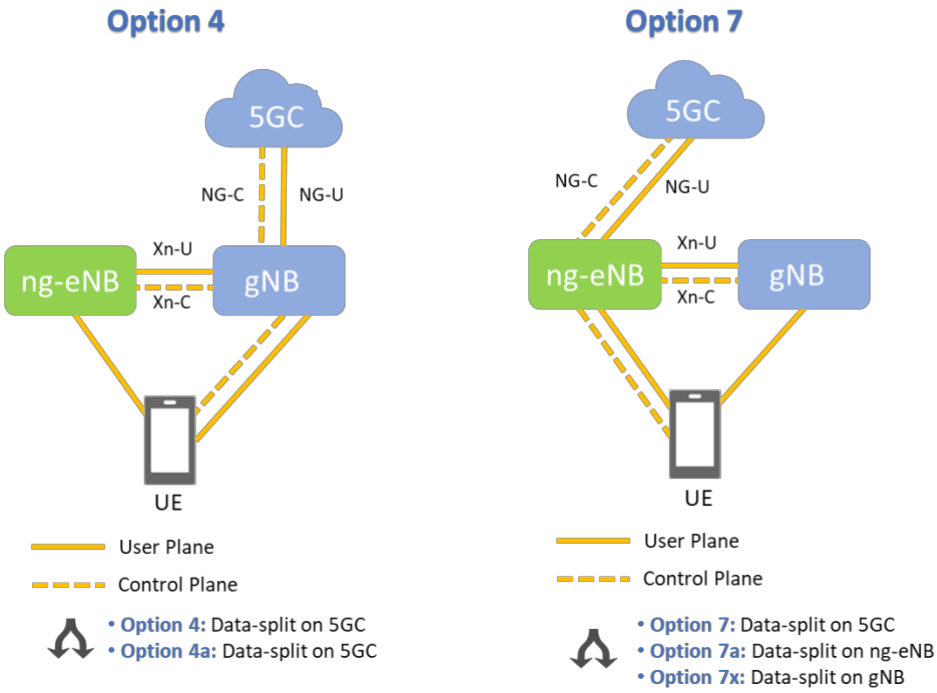

Figure 2 - Option 4 and Option 7 schemes [4]

Option 4 could be a valid choice to enable a smooth path for NSA to SA migration [2], however so far (Q1 2022) the authors are unaware of infrastructure, devices or deployments offering this approach.

Likewise, Option 7 has also not gained industry traction, therefore it is very unlikely that there will be Option 4 or Option 7 capable devices available by the end of 2023 or 1H 2024. This delay makes these solutions very difficult to adopt, as there would be a shift forward of at least 1 year compared to Option 2 readiness, which instead will be supported by most of 5G devices as early as 2H 2022 / 1H 2023.

Excluding the (SA) Option 1 which is a full-4G architecture, there are two possible 5G SA deployments: Option 2 and Option 5.

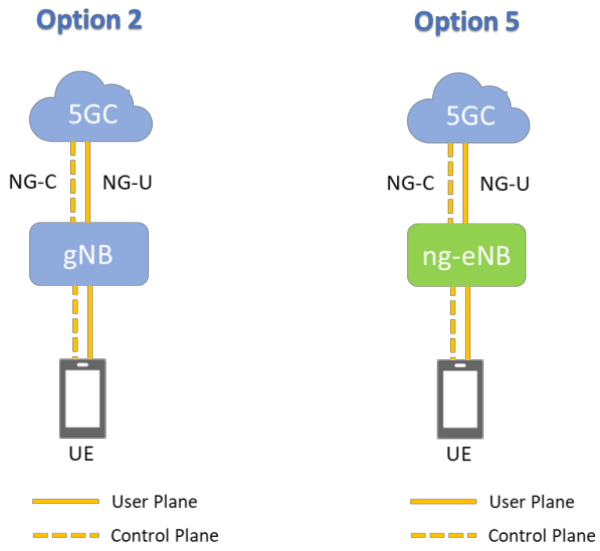

Figure 3 - Option 2 and Option 5 schemes [4]

Like NSA Option 4 and 7, SA Option 5 is very unlikely to be chosen by MNOs since no device supplier is currently focusing on this scenario: this is because its deployment would require devices to support new 5GC NAS and new LTE radio capabilities. Also, further software and baseband hardware upgrades would be needed on LTE RAN, requiring investment in LTE technology for a long time and this is evidently a significant drawback.

From what has been said, it seems clear that Option 2 is the most realistic, and probably the only, adoptable solution for a short-term 5G SA deployment.

All this leads to the need for the MNOs to manage a transition period, which will be shorter the faster the spread of 5G SA devices will happen. In this transition period, there will be coexistence between NSA and SA deployments (Option 3x + Option 2). During this period Dynamic Spectrum Sharing (DSS) technique will be instrumental in guaranteeing an effective usage of the valuable Sub-6 bands assets, providing a proper co-existence between 4G and 5G SA devices.

2 5G FORECASTS

In this chapter 5G trends will be presented, with specific focus on devices penetration, capabilities evolution and subscription growth. Based on these forecasts, the possible migration scenarios from NSA to SA in the reference time frame (2022-2029) will be analysed in chapter 3.

2.1 5G Devices diffusion and Subscriptions

By end-December 2021, considering both 5G NSA and SA capable devices, over 1200 models have been announced (+125% in the last year) and around 850 are already commercialized (+120% in the last year).
Focusing on 5G SA devices, 645 models have been announced and 381 of these are commercially available for sub-6 bands.
This statistic [3] considers all 5G device categories: smartphones, tablets, FWA CPEs, modules, dongles, industrial routers and so on.

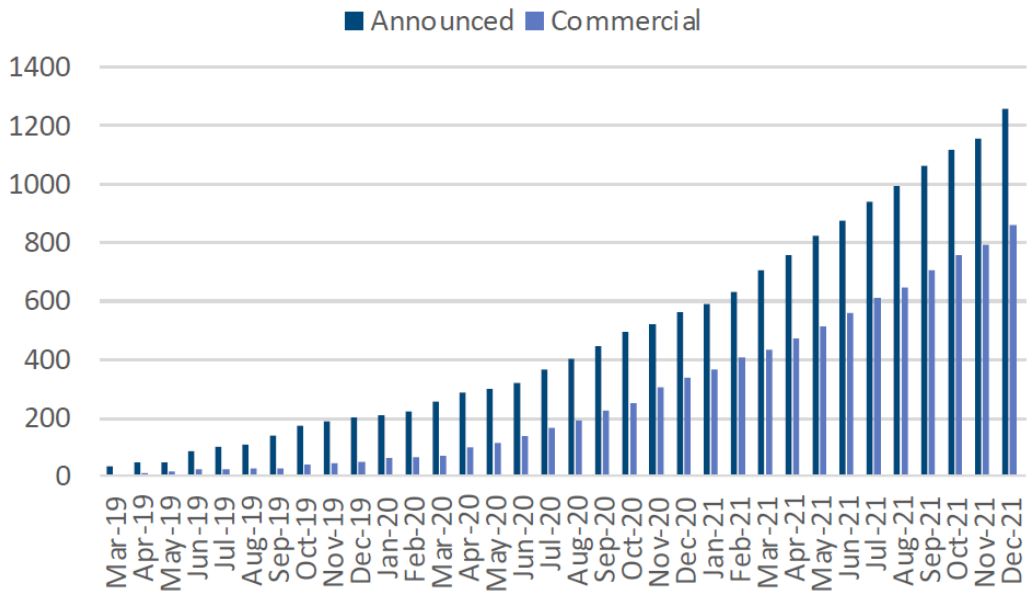

Figure 4 – Announced and commercial 5G device models [3]

In the last year (2021), a NGMN Western Europe MNO witnessed sustained double-digit MoM (Month-over-Month) growth for 5G smartphones (Table 1).

Date	***5G Devices MoM growth***
Jan-21	***+27,9%***
Feb-21	***+19,7%***
Mar-21	***+18,3%***
Apr-21	***+13,4%***
May-21	***+12,8%***
Jun-21	***+11,7%***
Jul-21	***+12,8%***
Aug-21	***+11,4%***
Sep-21	***+10,1%***
Oct-21	***+13,6%***
Nov-21	***+11,7%***
Dec-21	***+17,1%***

Table 1 – 5G devices growth for a NGMN Western Europe MNO [5]

Making the following assumptions, the share of 5G devices in this MNOs network is likely to reach 90% by the end of 2027:

- Robust 5G growth trend confirmed for the next years.
- By 2H 2023, all new announced/launched Smartphones are expected to be 5G-cabable and moreover SA-capable or upgradable to SA, boosting the 5G uptake even more.
- Average Smartphone replacement period: 4 years.

Whilst this forecast refers to a specific Western Europe MNO it is plausible to expect a similar trend in other MNOs operating in other countries of the region. Other regions (e.g. North America and China) are currently ahead of Western Europe in terms of their 5G deployments so, the migration steps reported in the chapter 3 may occur over a shorter timeframe in those markets and over a longer timeframe in markets where 5G deployment is lagging Western Europe.

5G Subscriptions

Analysing the trends of mobile subscriptions, 5G growth is forecast to be significantly faster than for 4G (see figure 5).
At the end of 2021 it is estimated that more than 660 million 5G subscriptions have been activated [1].

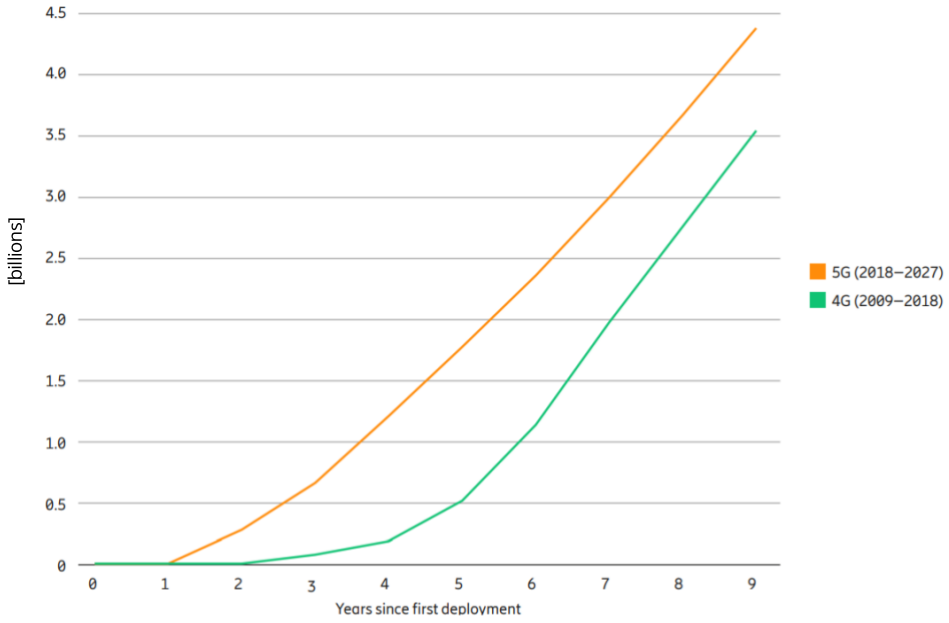

Figure 5 – 4G vs 5G subscriptions uptake in the decade after the first deployment [1]

At the end of 2027 it is expected that 5G will account for 90% of all subscriptions in Western Europe.

2.2 5G Capabilities evolution

At present (January 2022), the first 5G flagship devices already support 2CC NR Carrier Aggregation (DL NR CA) on mid-bands (Sub-6 GHz) in NSA configuration and we consider that devices will be able to aggregate 3CC in downlink and 2CC in uplink starting from 2023.
Regarding the SA capabilities, 3CC NR Downlink CA (3 FDD, 2 FDD + 1 TDD or 1 FDD + 2TDD) will be available as early as 2022. In addition, support for high-bands (>24 GHz) and mid-band bands can be combined, leading to downlink throughputs between 5 and 10 Gbps and

providing additional momentum to the potential of 5G in terms of achievable performance and innovative use cases. For uplink, 2CC NR Uplink CA (FDD+TDD) will be available too in the same timeframe.

Starting from this context, it is easy to expect in the following years (from 2024 onwards) new NR CA capabilities able to combine 4CC or even more bands. This potential set of radio capabilities will enable for the MNOs a wider range of choice regarding their re-farming policies.

3 NSA TO SA 5G MIGRATION PATH

Before analysing the possible NSA to SA migration paths that could be followed by MNOs, it is worth to introduce the frequency assets (LTE and NR) available to MNOs to manage in such a transition.
For the sake of simplicity, in this document only the Western Europe case has been examined; in the tables below the most common bands of this region have been reported.

Type	LTE		
	Operating band	Duplex-Mode	Frequency range
Low-bands (f < 1 GHz)	B28	FDD	Downlink: 758 – 803 MHz Uplink: 703 – 748 MHz
	B20	FDD	Downlink: 791 – 821 MHz Uplink: 832 – 862 MHz
	B8	FDD	Downlink: 925 – 960 MHz Uplink: 880 – 915 MHz
Mid-bands (1 GHz < f < 6 GHz)	B1	FDD	Downlink: 2110 – 2170 MHz Uplink: 1920 – 1980 MHz
	B3	FDD	Downlink: 1805 – 1880 MHz Uplink: 1710 – 1785 MHz
	B7	FDD	Downlink: 2620 – 2690 MHz Uplink: 2500 – 2570 MHz

Type	NR		
	Operating band	Duplex-Mode	Frequency range
FR1 - Mid-bands (1 GHz < f < 6 GHz)	n77	TDD	3300 – 4200 MHz
	n78 (subset of band n77)	TDD	3300 – 3800 MHz
FR2 - High-bands (f > 24 GHz)	n257	TDD	26.50 – 29.50 GHz
	n258	TDD	24.25 – 27.50 GHz

Table 2 – LTE and NR frequency assets in Western Europe region [6], [7], [8], [9], [10]

5G High-bands have not been considered as a key factor in the migration scenario as they are available only in some countries and are mainly intended for local coverage (small cells); specific

use cases of 5G in business and industry; Fixed Wireless Access; or Private Networks. From these premises, a possible migration timeline has been hypothesised: obviously, it is to be understood only as a logical sequence and the "Step 0" will depend for each country on the date of 5G auctions. All the following steps will be mainly affected by the local penetration of 5G devices and subscriptions. In this simulation, the 5G auction ended in 2019 and Option 3x for the first NSA deployment started from 2020.

The table 3 shows an overview of the migration steps identified and in the rest of the chapter each of them will be discussed. The percentages of 5G uptake in the table refer to the forecasted values at the end of each reference period.

Migration steps	Reference period	5G Smartphones	4G Smartphones	Deployment details
0	2019	< 5%	> 95%	Option 1 Full LTE (6 LTE bands FDD)
1	2020-2022	< 30%	> 70%	Option 3x (NSA) DSS on one Mid-band
2	2023-2025	~ 60%	~ 40%	Option 3x (NSA) + Option 2 (SA) DSS on one Low-band and on all Mid-bands
3	2026-2027	85-90%	10-15%	Option 3x (NSA) + Option 2 (SA) Static Re-farming of one low-band and two Mid-bands
4	2028-2029	> 95%	< 5%	Option 3x (NSA) + Option 2 (SA) Only one/two Low-bands left in DSS mode. All other bands statically re-farmed for 5G use

Table 3 – Overview of the NSA to SA migration path

STEP 0 (2019)

This is the initial step: the deployment is Option 1 with full use of all LTE FDD bands.

	LTE bands	DSS bands	NR bands
Low-bands	B28	-	-
	B20	-	-
	B8	-	-
Mid-bands	B1	-	-
	B3	-	-
	B7	-	-

Table 4 – Initial scenario (full-LTE)

STEP 1 (2020-2022)

In the step 1 the NSA 5G deployment is introduced with Option 3x.

In this configuration only one mid-band is enabled with DSS for two reasons: first, in the step 1 reference timeframe (2020-2022) there are no 5G Devices supporting NSA 3CC NR CA and second, DSS introduces an average performance degradation of 25-30%, and therefore of the overall spectral efficiency. Furthermore, in this phase the penetration of 5G devices is still quite limited (< 30%), so most of the traffic is still generated by 4G devices and it's not worth to enable DSS on all mid-bands.

	LTE bands	DSS bands	NR bands
Low-bands	B28	-	-
	B20	-	-
	B8	-	-
Mid-bands	B1	-	
	~~B3~~	B3/n3	-
	B7	-	-
	-	-	n78

Table 5 – Step 1 (2020-2022): DSS on one mid-band

STEP 2 (2023-2025)

The Step 2, placed in a hypothetical time frame 2023-2025, is the most challenging since it is in this range that the major changes will happen both on the device and the network side.
The 5G deployment is expected to be a mix of NSA + SA with the first Standalone commercial launches.
5G devices should become the majority (around 60%) at the end of the period and should be able to combine 4 or more NR bands. Accordingly, it is conceivable for the operators to enable DSS at least in a low-band for SA macro-coverage and in all mid-bands for 5G SA devices throughput boosting.
At the end of this timeframe the spectrum view could change as follows:

	LTE bands	DSS bands	NR bands
Low-bands	~~B28~~	B28/n28	-
	B20	-	-
	B8	-	-
Mid-bands	~~B1~~	B1/n1	-
	-	B3/n3	-
	~~B7~~	B7/n7	-
			n78

Table 6 – Step 2 (2023-2025): DSS on all Mid-bands and one Low-band

It is worth pointing out that the frequency assets reported in the "DSS bands" column must be intended as a superset of the actual supported band combinations by 5G devices and represent all the bands available on network side. These bands can be exploited for EN-DC by 5G Devices according to their own capabilities (2CC, 3CC, etc.), but some combinations may not be supported, e.g., due to intermodulation interferences; to avoid such issues, MNOs can also define traffic steering rules.
At this stage voice traffic is expected to be managed with VoLTE by legacy devices and via EPS Fallback by the new SA devices.
Since the use of Voice over New Radio (VoNR) is strictly related with the 5G coverage, its commercial launch will be available in this timeframe only for those operators who decide to

re-farm the low-band frequencies that provide wider coverage, or at least to use DSS in this band.

STEP 3 (2026-2027)

In the timeframe 2026-2027, it is expected that 5G devices will become dominant (between 80% and 90% at the end of the period) so MNOs should be free to start a static re-farming policy of the LTE bands to go one step further towards a full Standalone scenario.
At the end of this reference time, most of the LTE bands could be re-farmed as depicted in the Table 7, leaving only one dedicated band (B20 in this example) to ensure coverage for LTE legacy devices and IoT modules.
B8 and B7 have been hypothesised to be shared via DSS to still allow LTE Carrier Aggregation for the last 4G-only devices.

	LTE bands	DSS bands	NR bands
Low-bands	-	~~B28/n28~~ →	n28
	B20	-	-
	~~B8~~ →	B8/n8	-
Mid-bands	-	~~B1/n1~~ →	n1
	-	~~B3/n3~~ →	n3
	-	B7/n7	
			n78

Table 7 – Step 3 (2026-2027): Static refarming on one Low-band and two Mid-bands

In this phase 5G coverage is expected to be very extensive and the VoNR feature fully deployed.

STEP 4 (2028-2029)

The final step of the long NSA to SA migration path should happen in the last two years of the decade.
With almost all devices now 5G SA capable, the static re-farming policy can be completed. Only one or two bands will be maintained in DSS to keep IoT modules and the latest legacy devices (< 5%) running.

	LTE bands	DSS bands	NR bands
Low-bands	-	-	n28
	~~B20~~	B20/n20	-
	~~B8~~	B8/n8	-
Mid-bands	-	-	n1
	-	-	n3
	-	~~B7/n7~~	n7
			n78

Table 8 – Final Step (2028-2029): only one or two Low-bands left for LTE

4 ABBREVIATIONS

5GC	-	5G Core Network
CA	-	Carrier Aggregation
CC	-	Component Carrier
CN	-	Core Network
DSS	-	Dynamic Spectrum Sharing
EN-DC	-	EUTRA - NR - Dual Connectivity
EPS	-	Evolved Packet System
FR	-	Frequency Range
FDD	-	Frequency Division Duplex
gNB	-	gNodeB
LTE	-	Long Term Evolution
MNO	-	Mobile Network Operator
MoM	-	Month-over-Month
NAS	-	Non Access Stratum
NR	-	New Radio
NR-DC	-	New Radio Dual Connectivity
NSA	-	Non-Standalone
RAN	-	Radio Access Network
SA	-	Standalone
Sub-6	-	Sub-6 GHz
TDD	-	Time Division Duplex
VoLTE	-	Voice over LTE
VoNR	-	Voice over NR
UE	-	User Equipment

5 REFERENCES

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