# Option 4 as a 5G SA complement

## - Option 4 for smooth 5G NSA-SA migration -

## by NGMN Alliance

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# Abstract: Short introduction and purpose of the document

MNOs started the commercial introduction of 5G by deploying New Radio (NR) technology in their networks based on the so-called Non-Standalone NW architecture (NSA) which requires that LTE acts as the master technology, while also using the existing 4G core network (EPC).

The next step in network migration is the introduction of the 5G core network (5GC) allowing for a 5G Standalone NW architecture (SA) to realize the full set of 5G advantages. An Option 2 architecture, where customers' devices are supported exclusively by NR carriers, is proposed to support this migration.

However, the authors of this paper are convinced that the simple introduction of Option 2 risks the new 5G SA customers in many networks experiencing data rate performance levels below the level of existing NSA customers or even the "legacy" LTE customers. This may make the introduction of the 5GC unattractive for mainstream consumer use for several years until NR capable devices are penetrated into the device base to allow for sufficient spectrum to be refarmed.

To avoid this situation, this paper argues that SA network architecture should be complemented by the development of the Option 4 as an extension to Option 2 in order that 5G can quickly realizes its full potential in all networks.

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# 1 INTRODUCTION

The 5G New Radio (NR) radio interface brings significant improvements to mobile networks including improved spectrum usage possibilities and lower latency support. Nonetheless, the 5G specifications were created from the outset with LTE as an important 5G radio technology to be integrated alongside NR. Nowadays, bands below 3 GHz are mainly used for LTE, and therefore NR standalone (SA) deployments will struggle to compete with the data rates and/or coverage of LTE in many locations. In addition, operators have a high number of LTE customers with a really high penetration of LTE devices. Consequently, it will take time to refarm LTE bands to NR. It is important to note that the NR spectral efficiency performance in these low frequency bands is not significantly better than LTE, thus is neither a sufficient motivation for refarming specifically when costly nor does it allow to compensate for a large reduction in usable spectrum.

This integrated support of LTE as a 5G radio technology was seized upon to reduce the Time-to-Market of NR by concentrating first on a non-standalone (NSA) mode called Option 3. This architecture option uses LTE as the primary radio technology to provide an anchor carrier, with NR carriers deployed as extension carriers. This enabled a 5G launch without full development of all the basic NR procedures that would have been required in the development of a new standalone radio technology. To further ease the 5G NR introduction, this Option 3 NSA mode was designed to use the 4G EPC core network rather than the new 5G Core (5GC) network.

The Option 3 NSA mode of operation effectively means that NR is only a "booster" technology, enhancing the basic connectivity provided by LTE. Terminals camp on LTE, connect to LTE at initial access, access NR carriers based upon RRC decisions in LTE, and are directed by LTE to handover to a new LTE primary neighbour cell when required. This heavy dependency on the LTE technology to provide basic functionality was intended as a temporary option rapidly complemented with more future-proof architecture options.

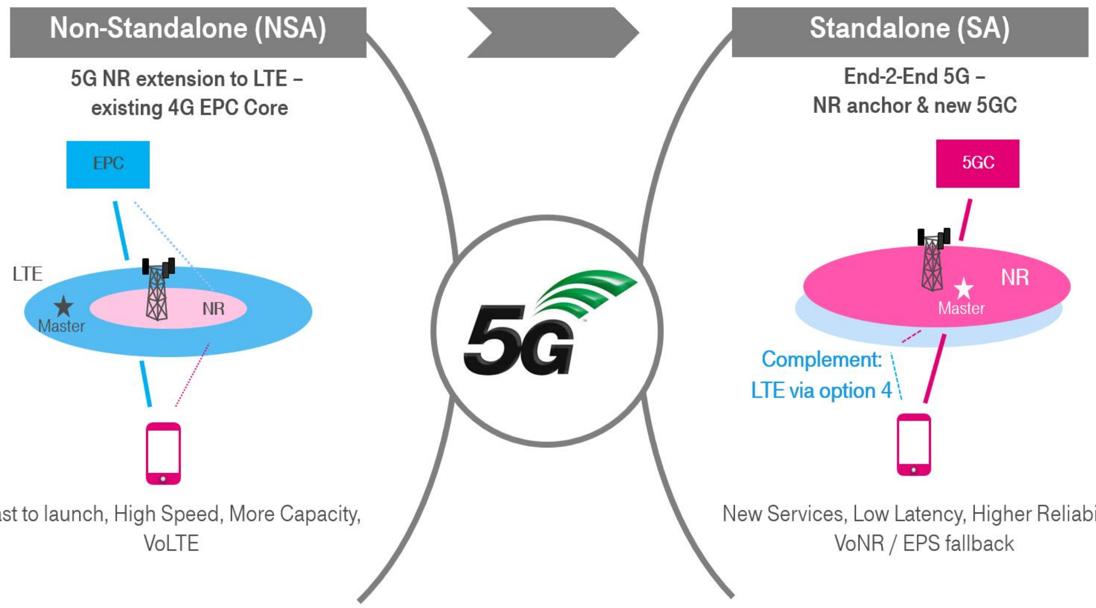


**Figure 1: 5G evolution from NSA to NR SA with complement Option 4**

Further 5G development is focussed on standalone Option 2, a major development step on top of NSA that connects 5G NR to the new 5GC, enabling an improved service evolution as shown in Figure 1. It also removes the dependency on LTE for baseline anchor carrier connectivity by adding all the other functions needed for NR to be a self-sufficient technology.

However, the authors of this document believe that Option 2 seems not in itself being sufficient to ensure a fast migration from NSA to SA using the new 5GC. While Option 2 transfers the master role from LTE to NR, it fails to make use of existing LTE assets as an added benefit to the NR connectivity.

3GPP has defined Option 4 to give the same benefits as Option 2, namely the connection to the 5GC and a transfer of the master technology from LTE to NR but in addition, it supports use of LTE as a “booster” technology to assist NR. This paper proposes a rapid development of Option 4 enabling an easier and faster NR SA migration from NSA.

Without Option 4, the 5GC with NR SA developments are at risk of near-term deployment due to the lack of sub 3 GHz NR spectrum for most operators, making NR SA uncompetitive compared to NSA in data rate performance in many locations. Therefore, Option 4 should be considered as a standalone complement to facilitate a near-term move towards NR SA deployments.

Note that in this paper, the usage of the term “Non-Standalone” is limited to Option 3.

## 2 BENEFIT OF STANDALONE AND NEW 5G CORE

The new 5G Core brings a number of benefits from a service and operational perspective:

- Cloud native design using a Service Based Architecture (SBA)
- Support for network slicing
- Improved security, including Integrity Protection on user plane data
- Fixed Mobile Convergence support using ATSSS
- Distributed UPF enabling local break-out for latency and capacity benefits

More details on the benefits and implementation of the 5GC can be found in [1].

5GC deployment is required in order to avoid the NSA dependence on LTE for the baseline connectivity. Avoiding a dependency on a legacy core is important in order to realise the full benefit of the new radio interface (NR), especially considering aspects relating to the master technology like the control plane latency. Without 5GC deployment, an increasing number of restrictions are likely to arise over time from the basic dependence on the older technology.

The deployment of Standalone is obviously an important evolution step that no operator can ignore. Most operators are expected to start with localized “campus” environments where there is no pre-existing LTE network to be connected.

However, it should also be noted that coupling of NR Standalone to 5GC deployment introduces risks to the 5GC development. The benefits arising from 5GC services for the wider consumer market are somewhat intangible and are probably not sufficient to justify significant extra costs or lower performance within a RAN. Considering that the RAN usually dominates the overall network cost, an operator that deploys Standalone on a wide area basis should have the secure knowledge that it achieves an equivalent performance and efficiency level to the existing NSA deployment. Otherwise, it risks that the investment is undermined by disadvantages that erode rather than enhance the operator’s competitiveness and efficiency.

## 3 WHY OPTION 4 IS NEEDED FOR COMPETITIVE STANDALONE

Unfortunately, a degradation of data rate performance is exactly the prospect that many operators will face when introducing Standalone without Option 4 support.

User data rates in mobile networks scale with the amount of spectrum that is aggregated together to support the connection. An illustrative example is given in Figure 2, where NR has been deployed in 2.1 GHz spectrum refarmed from 3G, in areas where 1.8 GHz and 2.6 GHz is already being used by LTE. In these scenarios, the use of Standalone with Option 2 restricts the spectrum available for a 5G connection, making the 5G Standalone data rate uncompetitive, not only compared to NSA which can aggregate the LTE and NR spectrum together, but also to LTE where carrier aggregation across two bands is already providing higher data rates than what can be achieved with 5G SA.

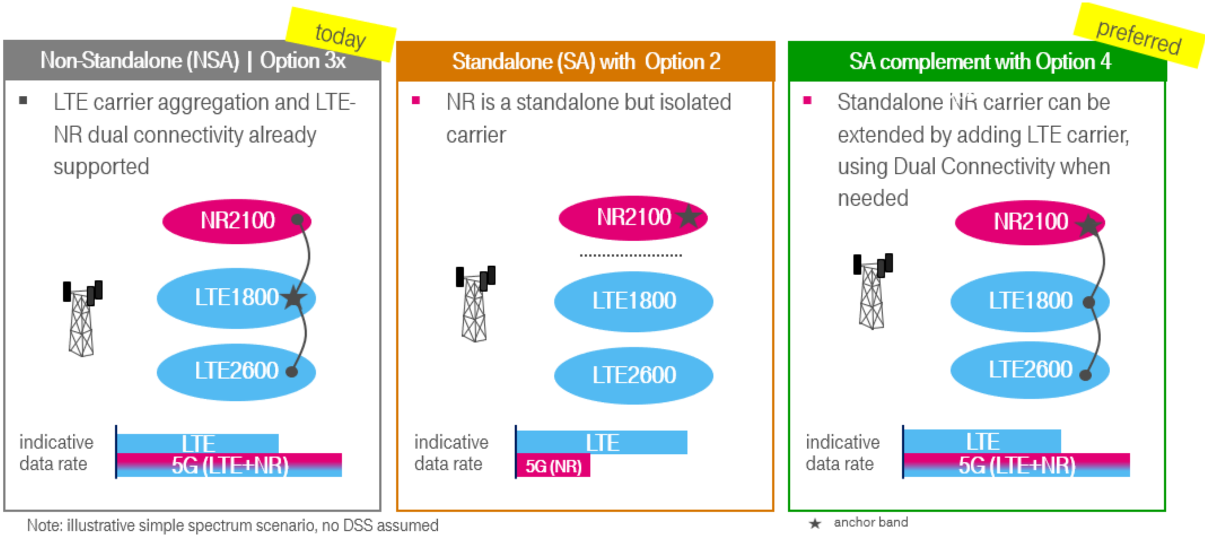


**Figure 2: Option 3x vs Option 2 vs Option 4**

Option 4 needed to maintain competitive user data rates in 5G on level similar to today

Option 4 can restore the data rate competitiveness of the SA customer to match an NSA customer while keeping the advantages of NR SA. With Option 4, NR becomes the master technology, so the benefits of SA are ensured, e.g. for low latency bearers. NR controls the (de)activation of dual connectivity therefore, LTE is only used when appropriate.

The data rates shown in Figure 2 above are somewhat simplistic as actual data rates depend not just upon the amount of spectrum, but also on utilization. Highly utilised carriers offer fewer spare resources, and so initially the data rate contribution from the more heavily utilised LTE bands, specifically in highly loaded cells and at peak times, will be less than that of NR bands at the beginning. In less loaded scenarios or with increasing usage of NR the superior performance of using the LTE bands will become obvious. So overall, LTE and NSA can claim higher peak data rates in general in scenarios where the NR carrier only holds a minority of the overall spectrum.

For a similar throughput among NR and LTE, a similar amount of dedicated spectrum is required. Otherwise, NR is not able to compete with existing LTE although it is more efficient than LTE. In current scenarios, most operators have most of their sub-3 GHz spectrum dedicated to LTE with a high number of subscribers. In consequence, Option

4 is the only way for most operators to transition to NR SA deployment in a competitive way compared with LTE or Option 3

If the industry cannot provide an Option 4 solution, operators have several alternatives but all of them have important drawbacks that need to be carefully analysed. One obvious way is to aggressively refarm spectrum from LTE to NR, but this has the unfortunate consequence of degrading the service to LTE-only customers, who are currently the large majority of customers, and therefore aggressively refarming a large amount of spectrum is an unrealistic option. A substantial refarming of spectrum could occur once the majority of terminals support NR SA, but this situation is not anticipated at least until 2025.

One other possibility is to use higher frequency spectrum where there are wider bandwidths available and which have typically not yet been used for LTE to overcome the spectrum shortfall with respect to LTE. Within the coverage of such higher frequency bands the data rate competitiveness is no longer an issue. However, a NR deployment in such spectrum bands to provide contiguous indoor coverage would become extremely costly. Therefore, NR deployments in these frequency bands are only expected to address localized capacity or service needs in particular locations. Wide area NR SA deployment will need to rely on low-to-mid bands for at least the next 5 years.

Overall, we conclude that most operators will face a considerable challenge in finding sufficient NR spectrum to provide competitive data rates for wide area NR SA without Option 4 or some other technology-based alternative.

In addition to Option 4, 3GPP defines two additional architecture options known as Option 5 and Option 7 that enable the use of LTE as well as NR with the 5GC. The development of all three options have been requested by operators, with statement issued by both NGMN [2] and 3GPP [3].

Unfortunately, major network and terminal suppliers have been unwilling to develop any of these options as the operators requested, and the lack of commonly agreed operator prioritization between the three options has hindered the development of any of them.

All the three options have valid deployment scenarios that justify their developments determined by the extent of the NR coverage in target networks:

- Option 5 is applicable in areas without any NR coverage but with LTE coverage.
- Option 7 is applicable in areas with limited NR coverage using higher frequency bands still requiring LTE as an anchor layer.
- Option 4 is applicable in areas where NR provides wide coverage and is overlaid by LTE, enabling use of NR as the master technology.

Option 4, Option 5 and Option 7 are complementary to Standalone Option 2 in supporting a faster adoption of the 5GC in a wider variety of deployments. Option 4 is the only one that makes NR the master technology and as NR spreads more widely, more and more network areas become suitable for Option 4 deployments. Option 4 removes the inherent NSA evolution constraint whereby NR is dependent on LTE to provide the anchor connection.

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Option 4 therefore encourages wide area NR as well as 5GC deployment, enabling a flexible long-term migration towards Option 2. For these reasons it is proposed to focus initially on Option 4 as the more strategic long-term option that addresses the main impediments to SA Option 2 deployment.

# 4 TECHNOLOGY ALTERNATIVES TO OPTION 4

Two technology alternatives have been proposed to mitigate the reduction in user data rates arising from use of SA without Option 4, Dynamic Spectrum Sharing (DSS) on all carriers and On-demand NSA fallback. Both alternatives are illustrated in **Figure 3**.

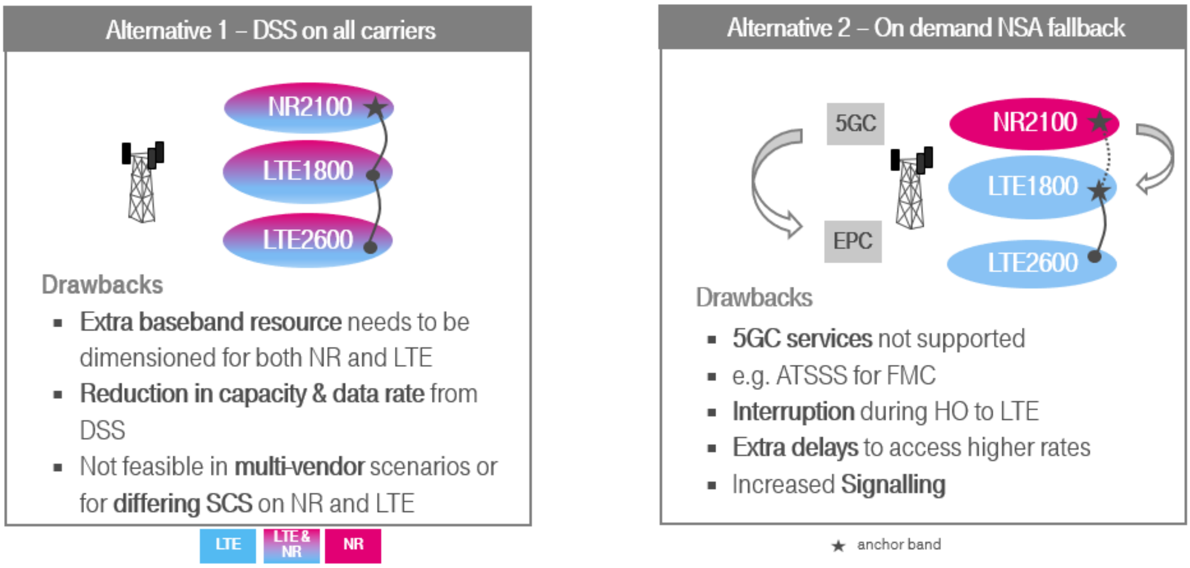


**Figure 3: Alternatives to Option 4**
Dynamic Spectrum Sharing and on-demand Option 3 fallback

## 4.1 Dynamic spectrum sharing (DSS)

Dynamic Spectrum Sharing (DSS) allows the introduction of NR on already existing carriers while maintaining LTE operation in a shared manner. DSS has been developed to enable faster, lower cost NR deployment through the reuse of existing antennas, radio units and spectrum assets.

By applying DSS on multiple carriers, it might be expected the SA performance shortfall of Option 2 compared to NSA could be eliminated as NR can then access all the LTE spectrum without denying the spectrum to LTE users.

However, the use of DSS typically requires new NR capable baseband resources, leading in many cases to the deployment of new or additional baseband hardware on top of those being in use for LTE. Besides, licensing costs are typically applied per technology which adds a substantial increase to the overall cost of an operator deploying DSS.

Furthermore, DSS brings performance reduction that reduces network capacity and user data rates. Support of both technologies on the same carrier requires a duplication of control channels and reference signals which increases the overheads (Extra Overhead in figure 4) and leaves less radio resource for user traffic. In this respect, the high fixed overhead from LTE CRS and PDCCH symbols is particularly detrimental for the NR performance. In more detail, NR capacity will be reduced by no less than 20 – 30 % compared to a common NR network configuration while the LTE capacity will be reduced by a minimum of 6 – 10 % due to the NR reference signals having been optimized.
But in addition to this overhead effect, if NR SA devices aren't able to eliminate the LTE CRS transmissions, those will cause additional (inter-site/inter-cell) interference that reduces the SINR, and hence the achievable data rate per

resource block. The relative degradation in data rate arising from DSS use is particularly marked for NR users on unloaded carriers where the CRS transmissions dominate the interference.

One of the motivations for deploying NR is the improvement in spectrum efficiency, largely arising from lower fixed overheads. But the use of DSS as currently implemented reverses this benefit as Figure 4 illustrates.

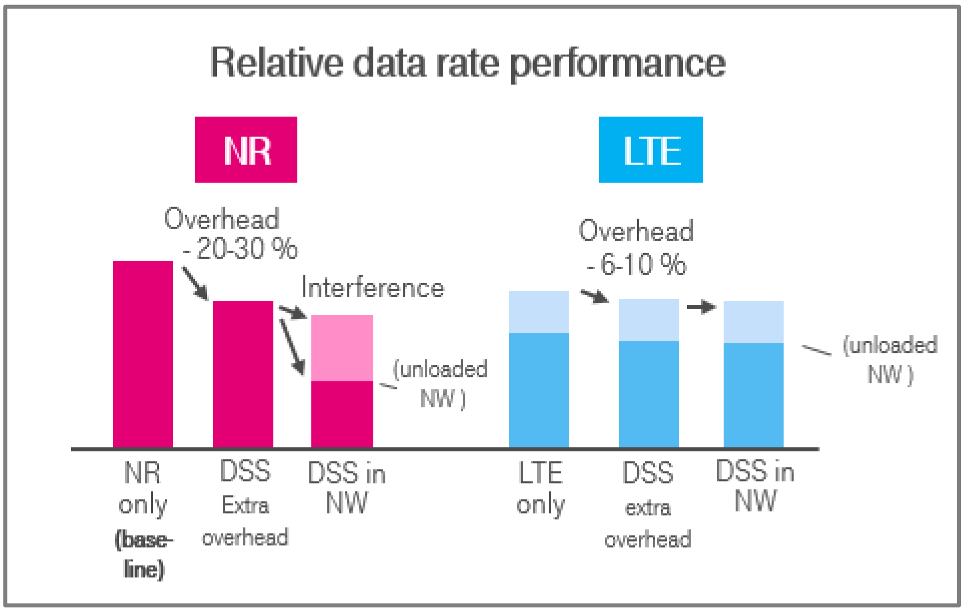


**Figure 4: Performance degradation in LTE and NR by DSS**

For LTE, Figure 4 shows a first reduction caused by NR overheads. On top of that, the fact that LTE devices have the required LTE CRS filters plus the control signal, the NR efficiency experiences further degradation. Note that the interference effects depend upon network load.

Interestingly however, LTE CRS filters for interference cancellation implemented in LTE devices aren't implemented in NR devices. That fact causes the high interference levels in NR devices which is an undesirable effect to be added to the overhead losses. Accordingly, the use of DSS even in unloaded networks will result in an unacceptable performance for NR UEs. Until LTE CRS filters are supported in the vast majority of NR devices, DSS is not a realistic option for operators to overcome the above shown performance shortfall..

Note that the relative performance between NR and LTE depends upon the network load and the relating contribution of CRS transmissions in the overall interference. Also note that the effectiveness of the CRS interference mitigation depends upon the number of interfering cells and the LTE synchronization.

DSS configuration limits the number of controls channel resources in LTE and in NR. That reduces the total number of end users that can be supported in each technology.

In conclusion, while DSS can be used as a valuable enabler for more rapid NR deployment on a restricted basis, it is not recommended as an alternative to Option 4 on a wider basis.

## 4.2 On-demand NSA fallback

The other alternative to Option 4 is to implement an On-demand fallback to NSA, using an inter-system handover whenever the higher data rate offered by NSA would be useful.

The obvious drawback is the loss of the service benefits of the new 5GC when falling back to the EPC. The advanced 5GC security, network slicing, FMC and local breakout features offered by the 5GC are compromised. In addition, the evolutionary case for deploying Standalone is compromised by the continued basic dependency on EPC/LTE whenever high data rates are needed.

Additionally, the On-demand NSA fallback involves an inter-frequency inter-technology handover with substantial delays also causing an interruption to the connectivity. For a 5G network aiming for high speed and low latency in packetized transmission these seems highly undesirable for a procedure that needs to take place as a condition for accessing higher data rates. In many instances the benefits of achieving a higher rate will never be realised due to the delay - or even worse, outweighed by the gap in transmission occurring at the time of handover to the EPC.

In summary, on-demand NSA fallback undermines the reasons to deploy SA and is not considered a realistic alternative to Option 4.

# 5 IMPLEMENTATION CONSIDERATIONS FOR OPTION 4

The complexity of implementing Option 4 is assumed to be similar to Option 3/3x, as though the development and testing effort involved simply scales with the number of options supported. In practice, Option 4 is a comparatively small extension to Option 2. Option 2 involves the development of all the idle mode and handover messaging and procedures needed to remove the dependence on LTE and, in addition, the support of an interface to the new CN (not considering the 5GC itself). Support of Option 4 on the other hand requires development of only a limited number of procedures like Secondary Node Addition and Secondary Node Removal, which control the use of dual connectivity which adds an LTE leg to that of NR.

Option 4 uses the same dual connectivity basis as NSA Option 3 and its variants, and therefore, the implementation of this variant of dual connectivity will be straightforward. Some changes are needed for the LTE lower layer to support QoS and network slicing on new NG-RAN bearers. But with a sensible mapping to existing QoS classes, it should be possible to keep such changes small by not mapping any elaborated QoS handling to the LTE side but treating LTE as an additional data pipe with simpler properties.

The LTE PDCP layer do not need to be adapted to provide an interface to the 5GC since it may reuse the ones defined for NR SA. Note that Option 4a (see figure 5) allowing SeNB bearer from LTE is not seen to be very useful and therefore is not targeted here.

From a device RF perspective, the implementation of a given EN-DC Option 3 band combination supporting NSA should implicitly support NE-DC Option 4, although a formal approval of the required NE-DC band combinations would be needed in 3GPP.

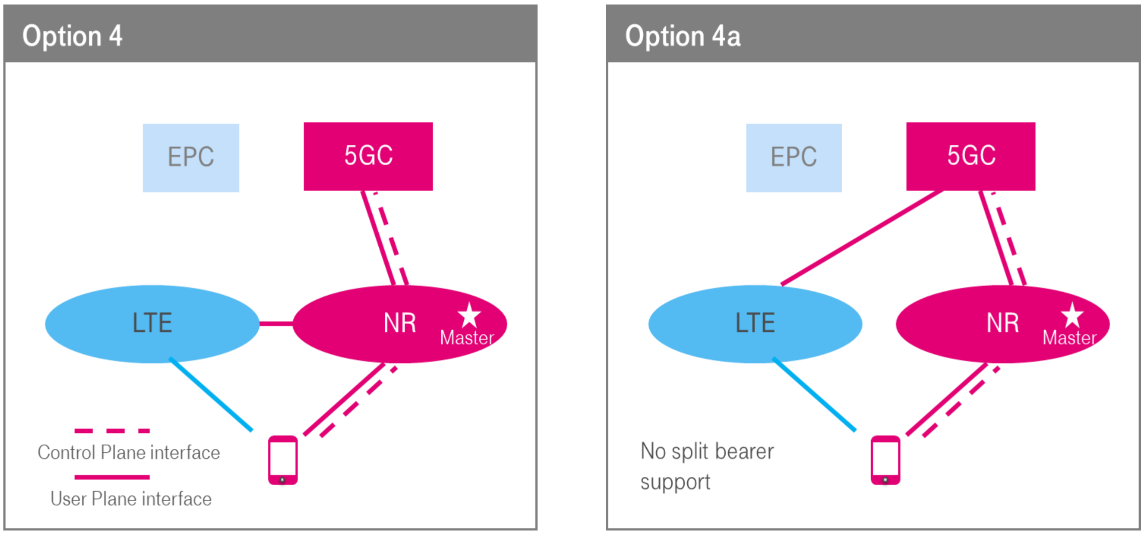


**Figure 5: Option 4 vs. Option 4a**

Option 4 should not add any hardware complexity in either the terminal or the base station. Implementation costs mainly relate to software development and testing, and while these are not negligible, they do not seem comparable to the costs arising from a widespread use of DSS as already outlined.

## 5.1 Option 2 vs Option 4

**The following**

Table 1 summarizes the pros and cons of Option 4 vs a future NR SA limited to Option 2 only.

| | **Option 2** | **Option 4** |
|---|---|---|
| Master Node | NR | NR |
| High data throughput | Only with large amount of NR supporting spectrum | Supported |
| Coverage | Based on NR bands | Same as Option 2, as Option 4 reverts to Option 2 at coverage limits |
| Capacity | Based on total NR spectrum | Same as Option 2 plus LTE spectrum |
| Impact in legacy LTE customers | High impact if aggressive refarming is required | No impact |
| Slicing | Supported | Supported |
| Low latency services | Supported | Supported |
| Enhanced security | Supported | Supported |
| Dual connectivity | Not required | Required |
| Enhanced UE power saving | Supported | Supported |
| Extra UE power consumption for DC | Not required | Required in short periods of time while Dual Connectivity (DC) is required. DC periods are shortened due to higher throughputs. |

**Table 1: Comparison between Option 2 and Option 4**

As elaborated in the previous chapters, Option 4 implementation would be a complement to Option 2. It allows for Dual Connectivity (NE-DC) to add LTE spectrum resources for the latest 5G NR SA customers but only optional and for short time periods when needed to achieve superior data rates. Without Option 4 and as long as significant spectrum resources cannot be refarmed to NR since still needed for the high number of LTE customers in the networks, the latest 5G NR SA customers will experience performance disadvantages.

### 5.2 Standardization in 3GPP

Option 4 is already standardized within the Release 15 core specifications. However the commercialization of Option 4 requires 3GPP to finalize work in two areas: test specifications and bands combinations.

3GPP RAN5 should complete its work to support all the required interoperability tests to validate Option 4 functionality in order to ensure the inter-vendor operability.

As has already been mentioned in the previous section, 3GPP RAN4 will need to incorporate any needed band combinations for NE-DC using the usual release independent process. It should be quite straightforward introducing pre-existing EN-DC combinations as NE-DC combinations as the RF design should be the same.

## 6 CONCLUSION

Realizing the full benefit of 5G requires the implementation of 5G Standalone architecture. That introduces new 5G technologies end-to-end, supporting new 5GC-based services and removing the dependency on the older LTE as an underlaid master technology.

Most operators will soon deploy a 5GC and offer Standalone service using Option 2. Some operators with large amounts of low frequency spectrum useable for NR might offer Standalone services on a wide area basis to all their customers, but mass market use in many countries will by hindered by uncompetitive data rates. The unavailability of new or free spectrum in high-coverage low-frequency bands limits the data rates which could be provided by NR alone. So, SA Option 2 implementations in the short term are expected to be mostly localized ones for vertical customers (“Campus”) rather than to become part of the public networks.

Option 4 eliminates performance shortfalls of NR SA, but unfortunately Option 4 is not yet being developed by most network and terminal suppliers.

A commonly proposed technology alternative to Option 4 is an extensive use of DSS on multiple carriers to increase the amount of NR usable spectrum or on-demand fallbacks of NR SA users to LTE and NSA. While DSS is a valuable enabler for more rapid NR deployment, it has been demonstrated that DSS degrades spectrum efficiency and it is costly to deploy. Recent measurements also show NR data rates on the same DSS carrier are worse than LTE due to lacking interference cancellation technology in NR devices. This turn means that DSS cannot fully address the competitiveness issue and therefore, an extensive use of DSS on multiple carriers is not recommended. With on-demand fallbacks an operator loses the 5GC benefits and therefore service continuity cannot be guaranteed.

There is consequently an urgent need for suppliers of network and terminal equipment to progress on Option 4 to enable a smooth path for Standalone introduction in all operators within the next few years. If the ecosystem continues to focus exclusively on Option 2 and Option 3, a medium term deployment of the 5GC for the mass market is likely to be delayed in many operators, probably until NR SA support is sufficiently well penetrated into the terminal population that most of the LTE spectrum can be refarmed to NR, enabling a competitive 5G SA performance level. Option 4 is needed so that the full NR SA ecosystem is not put at risk by denying NR technology the means to also exploit existing LTE assets.

Option 4 should be treated as a complementary extension to Option 2. The SW development and testing costs involved in developing Option 4 are significantly smaller than the investments made in NR SA and 5GC. No hardware impact is anticipated in either the network or the devices.

Finally, in the long term, Option 4 continues to be of value after SA introduction by boosting 5G performance for as long as there is spectrum dedicated to LTE. Option 4 also relaxes the pressure for LTE spectrum to be refarmed and thereby enables better performance for LTE customers for longer.

# 7 NEXT STEPS

NGMN requests network and chipset manufacturers and OEM suppliers to focus on the development of Option 4 and bring this functionality to a commercially usable state to have it in live networks in 2023 at the latest.

This NGMN project plans the first trial of Option 4 early 2021 to confirm benefits and promote a development of Option 4 within the ecosystem, assuming supporting suppliers can be found.

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