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Nokia dynamic spectrum sharing for rapid 5G coverage rollout

White paper

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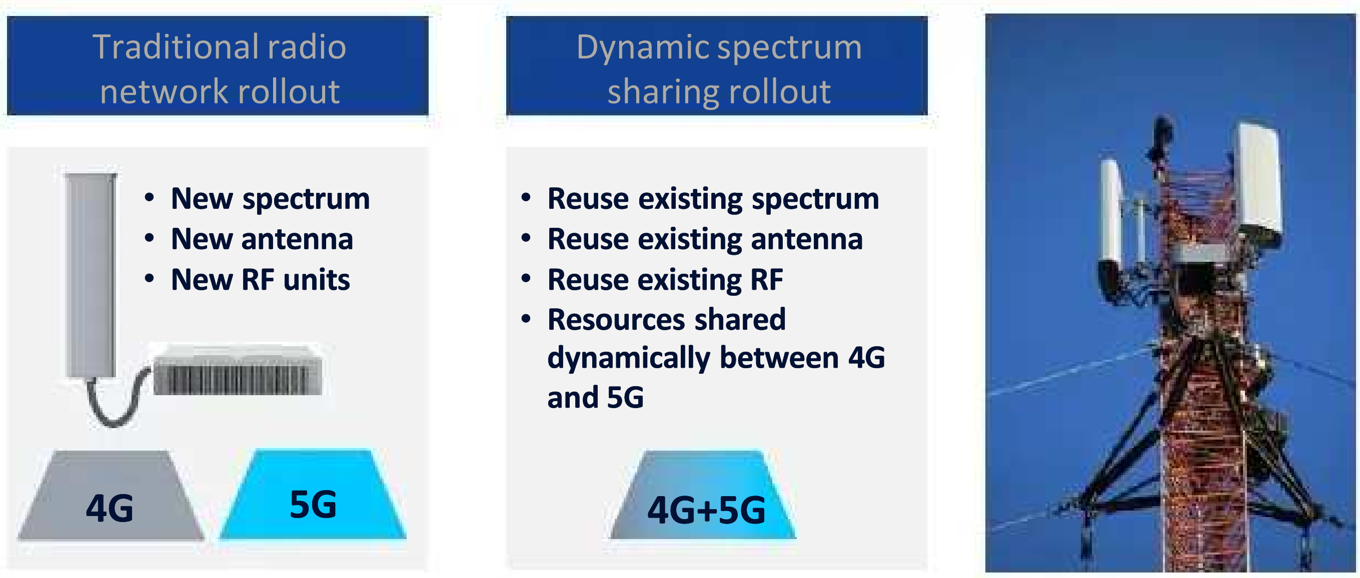
Executive summary

Dynamic spectrum sharing (DSS) technology allows spectrum resources to be shared dynamically between 4G (Long Term Evolution (LTE)) and 5G New Radio (NR) radios. 4G coverage rollout took several years without DSS, since new spectrum, new antennae and new Radio Frequency (RF) units were required. In contrast, communication service providers (CSPs) can build 5G coverage a lot faster because the spectrum, the antenna and the RF units can now be shared between existing 4G and emerging 5G deployments using DSS.

Figure 1 illustrates the DSS concept. This Nokia white paper outlines the DSS technology, Nokia's DSS solution and the practical aspects of deployment.

Figure 1. DSS concept allows fast 5G coverage rollout



DSS functionality was defined in 3GPP standardization and Nokia was a major contributor to that process. DSS capability has been built into Nokia's hardware and software, with AirScale baseband and AirScale and Flexi radio hardware platforms ready to support it. Millions of Nokia 4G RF units already in the field can be upgraded to support 5G, which enables fast rollout of 5G coverage and access to 5G services. Nokia's AirScale baseband software provides fast dynamic resource allocation between 4G and 5G to maximize the system efficiency.

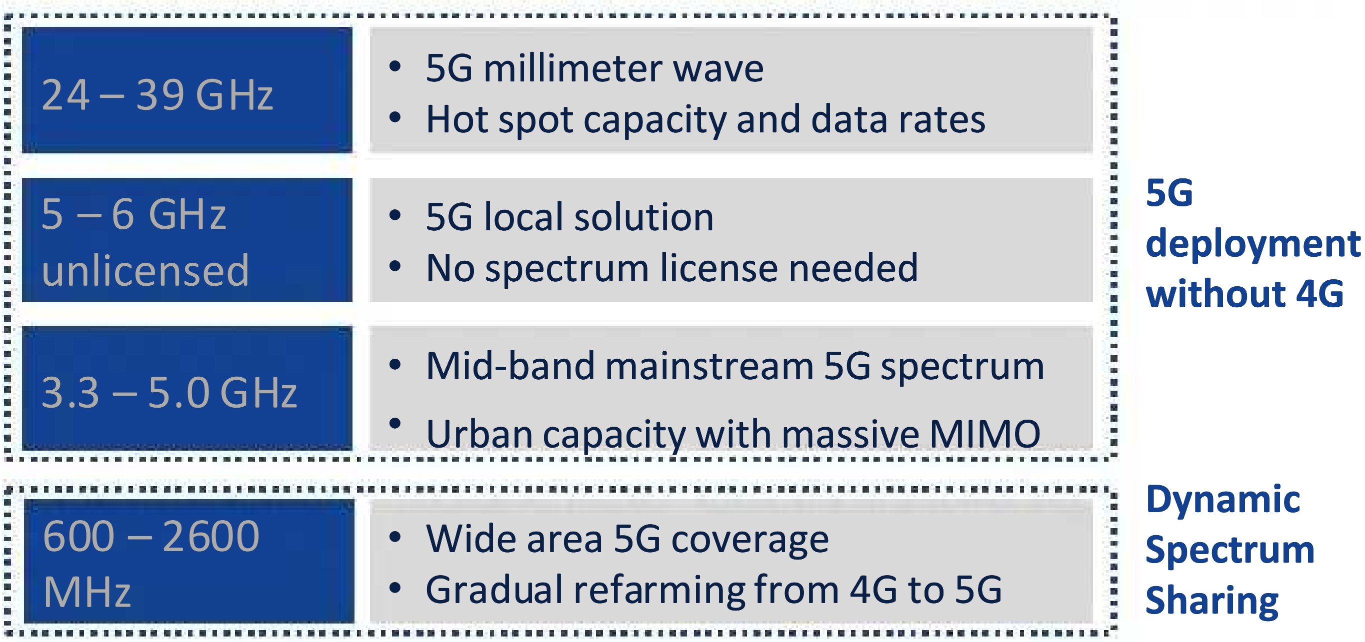
DSS with 5G carrier aggregation (CA) releases the full potential of the technology, especially when combined with standalone (SA) architecture. CA provides the highest data rates while SA maximizes low-band coverage and access to 5G services. DSS will be supported by a growing number of 5G devices from 2020 onwards, with widespread support for devices with DSS, SA and CA available during the course of 2021. The introduction of Nokia's DSS capability therefore aligns with the growing availability of devices.

Nokia's DSS solution extends beyond the 4G/5G transition to include dynamic sharing between 2G, 3G and 4G technologies. This enables a smoother evolution to 5G deployments.

5G spectrum overview and DSS

5G is the first ever mobile radio system that is designed to use any spectrum from below 1 GHz up to millimeter waves. 5G is also designed to be deployed in licensed, shared and unlicensed spectrum bands. 5G can use Frequency Division Duplex (FDD) technology for paired spectrum and Time Division Duplex (TDD) technology for unpaired spectrum. DSS technology is relevant for low-band FDD spectrum, where DSS can provide flexible refarming from LTE to 5G. Figure 2 is an overview of the 5G spectrum options.

Figure 2. DSS can be used for 600 – 2600 MHz band flexible refarming towards 5G



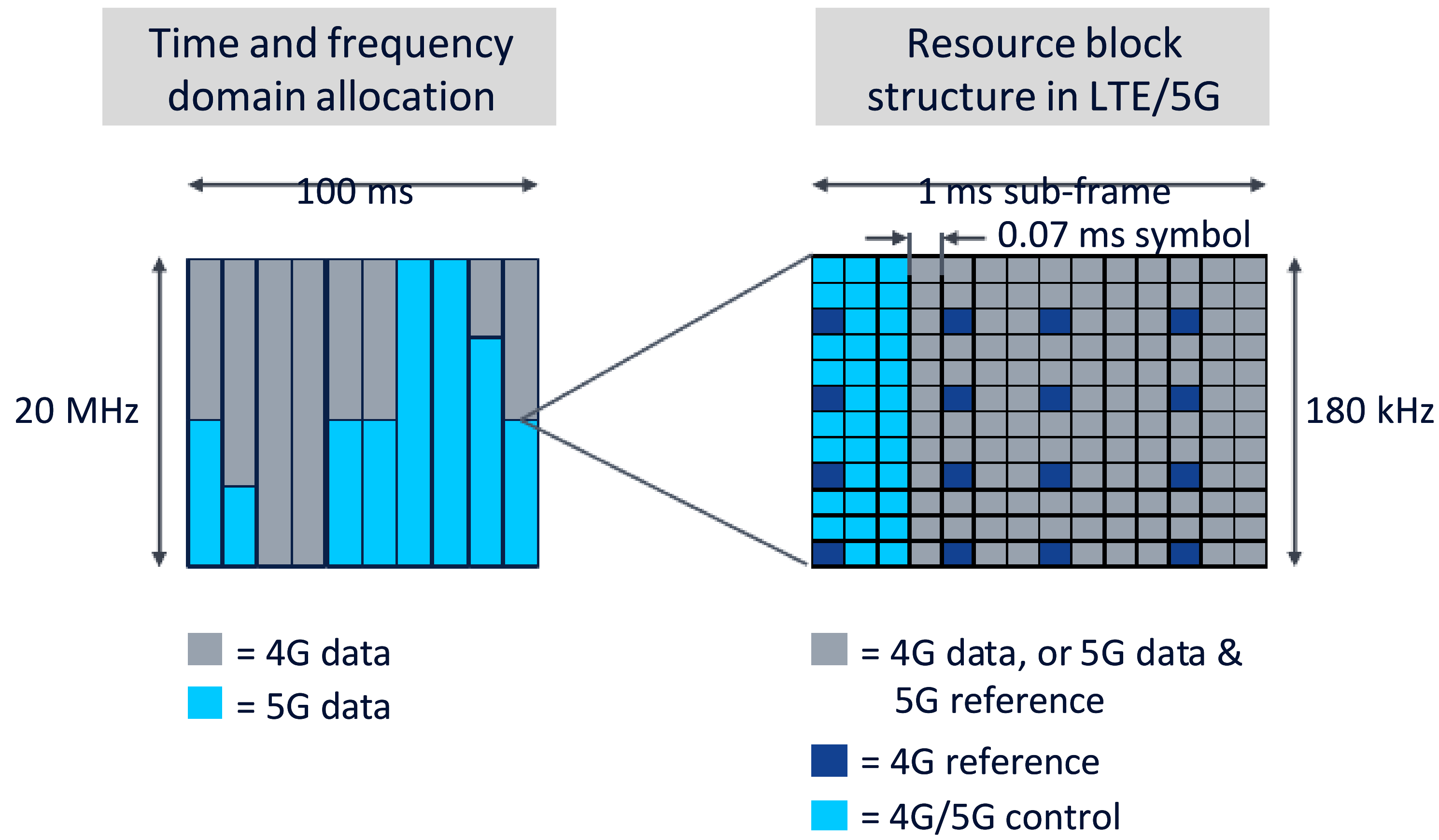
DSS in the physical layer

DSS allows CSPs to share resources dynamically between 4G and 5G in time and/or frequency domains, as shown on the left of Figure 3. It's a simple idea in principle, but we also need to consider the detailed structure at the level of the resource block in order to understand the resource allocations for the control channels and reference signals. A single resource block is shown on the right side of Figure 3.

The 5G physical layer is designed to be so similar to 4G in 3GPP that DSS becomes feasible with the same subcarrier spacing and similar time domain structure. DSS is designed to be backwards compatible with all existing LTE devices. CSPs therefore need to maintain LTE cell reference signal (CRS) transmission. 5G transmission is designed around LTE CRS in an approach called CRS rate matching.

5G uses demodulation reference signals (DMRS), which are only transmitted together with 5G data and so minimize any impact on LTE capacity. If all LTE devices support Transmission Mode 9 (TM9), then the shared carrier has lower overheads because less CRS transmission is required. The control channel transmission and the data transmission can be selected dynamically between LTE and 5G, depending on the instantaneous capacity requirements.

Figure 3. 4G and 5G resource sharing in time and frequency domain



DSS use cases with standalone architecture and carrier aggregation

DSS can provide full benefits for CSPs when deployed together with two other technologies: SA architecture with the 5G core network and CA in the devices. The optimum combination of DSS with SA architecture and CA depends on the operator-specific spectrum situation and on the 5G coverage targets.

Figure 4 illustrates the decision tree for DSS feature selection. If the target is to maximize 5G coverage then the combination of DSS and SA is preferred. If the CSP uses DSS with non-standalone (NSA) architecture then mid-band 4G is needed for the anchoring and it can limit the coverage. Typical devices are not able to support low-band 4G with low-band 5G. If the operator has mid-band (2.5 GHz or 3.5 GHz) 5G, the two 5G frequencies should be aggregated together, which calls for the support of DSS and 5G carrier aggregation. DSS on low frequency bands delivers 5G coverage. SA brings new 5G services and great coverage. 5G CA allows the CSP to combine low-band and mid-band resources together for high data rates. These key technologies are summarized in Figure 5. The relationship between the features is illustrated in more detail in the following sections.

Figure 4. Decision tree for DSS feature selection

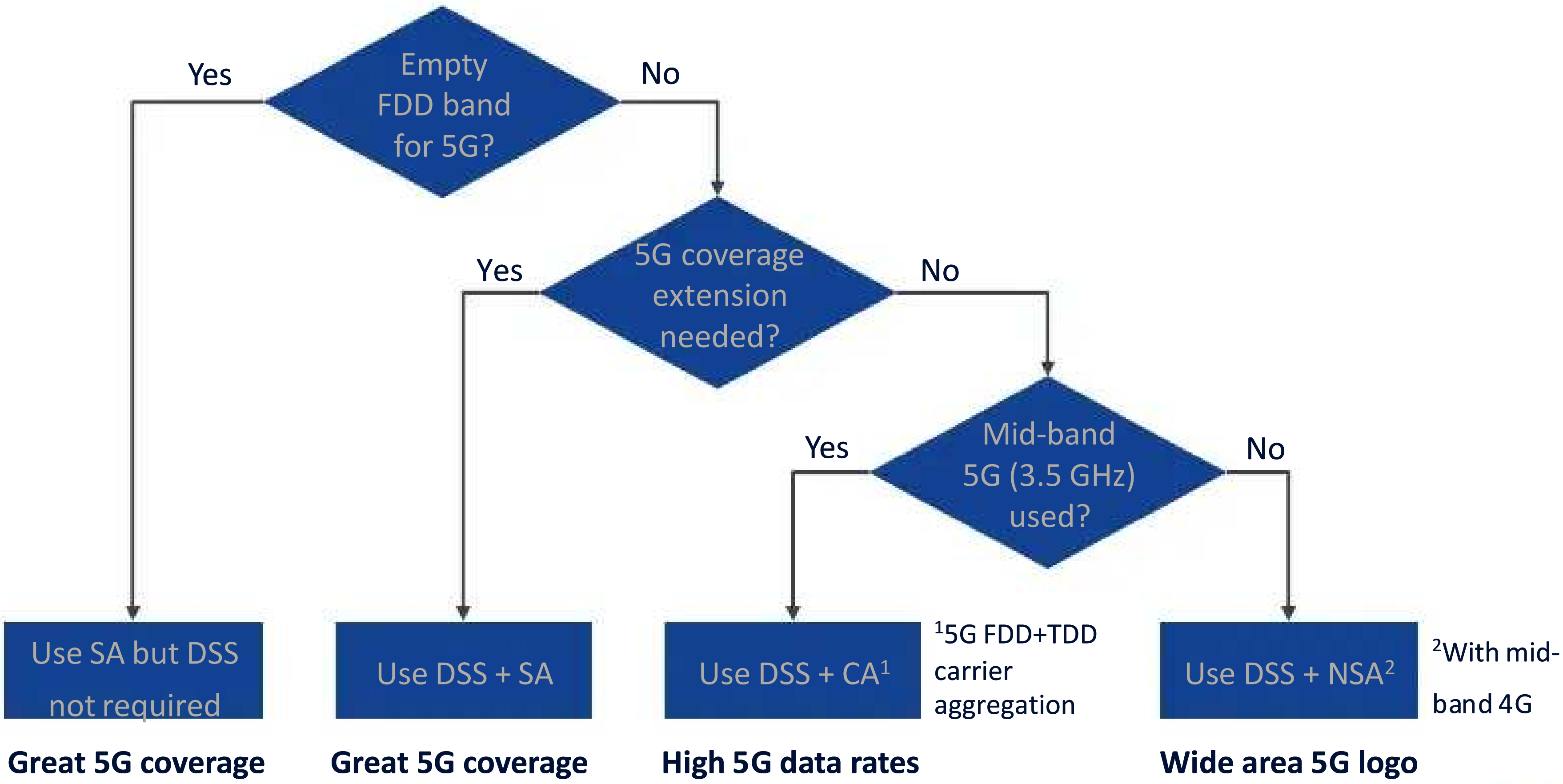
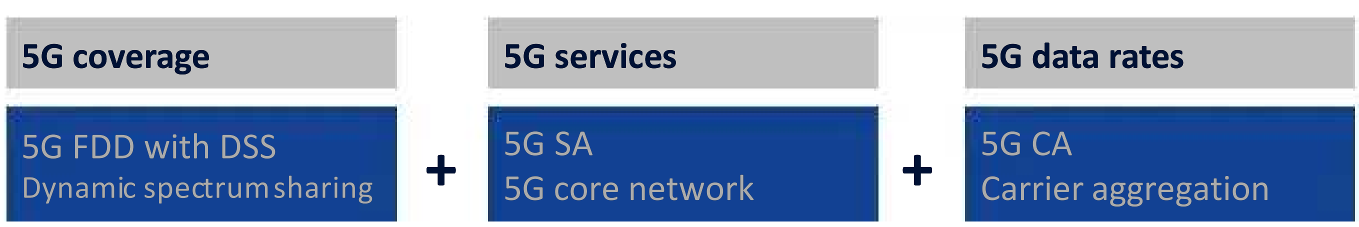


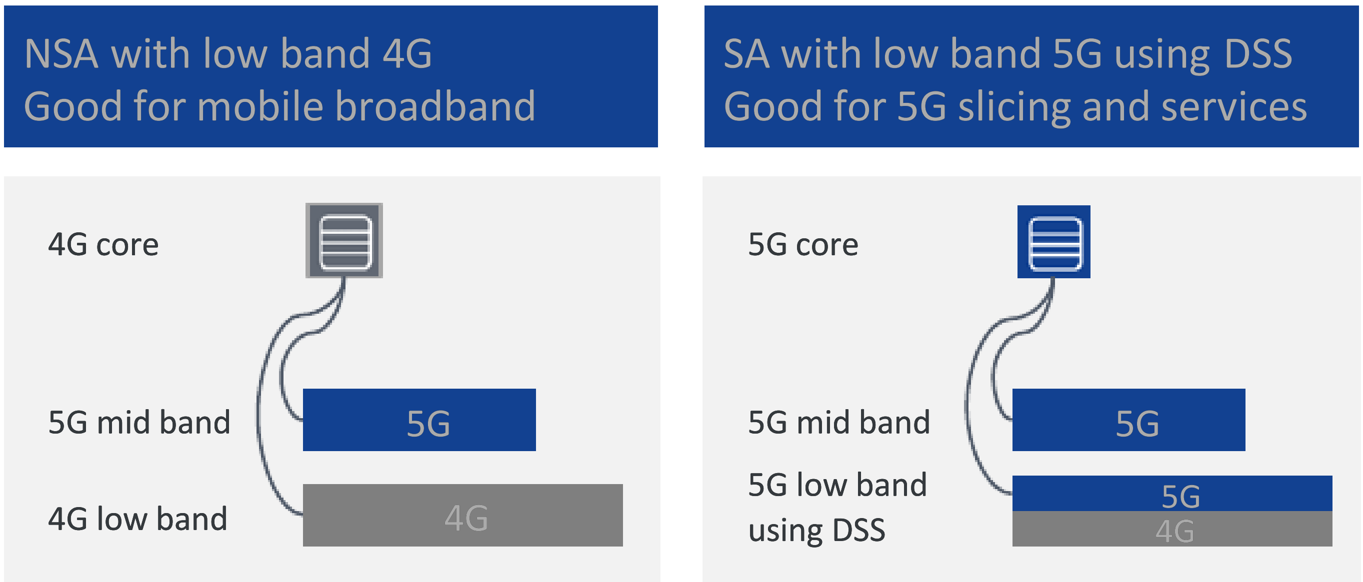
Figure 5. DSS with 5G core network and 5G carrier aggregation delivers the optimum set of 5G benefits



Standalone architecture with DSS

The first version of 5G is based on NSA architecture, where the 4G Evolved Packet Core (EPC) is used in the core network and 4G and 5G radios are used with dual connectivity (DC). In this way, NSA can be used to combine mid-band 5G with low-band 4G using dual connectivity for mobile broadband services (see left section of Figure 6). SA with the 5G core network brings new service opportunities thanks to its enhanced support for network slicing, with dynamic scalability and adaptability. SA, by definition, does not use DC in the radio since there is no connection to the 4G radio. It cannot therefore take advantage of low-band 4G. The solution is to use 5G with DSS in all or part of an existing 4G (low) band to boost 5G coverage, as shown in the right section of Figure 6.

Figure 6. 5G FDD operating in low bands (that are currently used for 4G services) is required for SA deployments since dual connectivity between mid-band 5G and 4G low bands is not available in SA



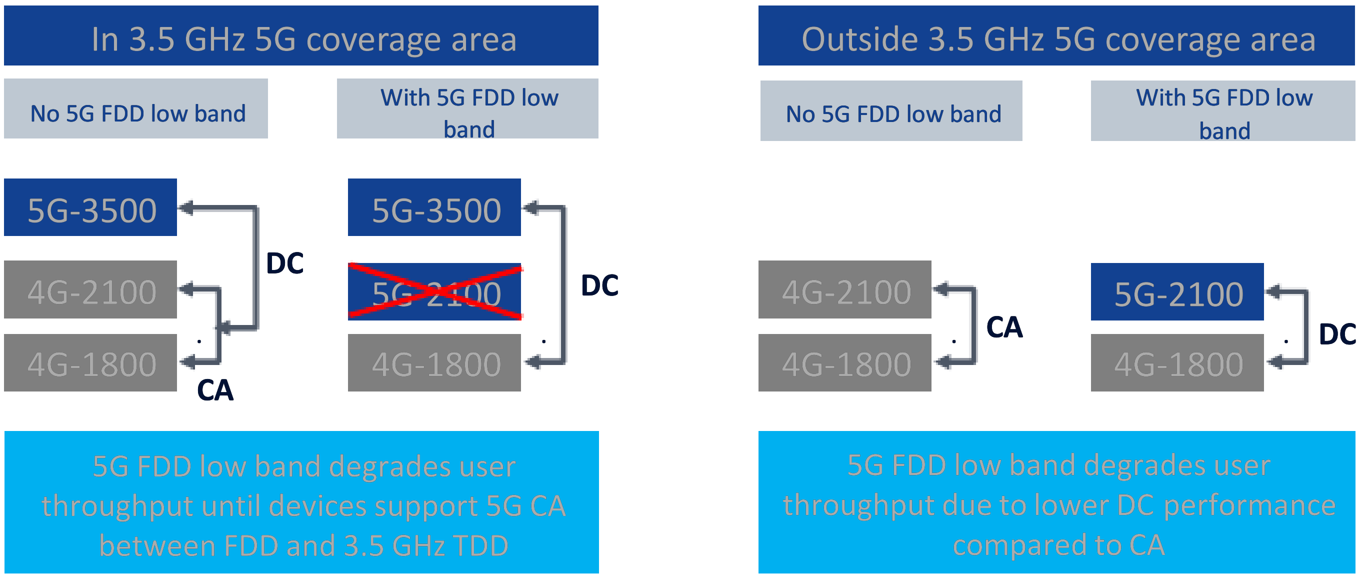
5G carrier aggregation with DSS

NSA can use 4G CA to combine the radio resources from multiple 4G bands to provide an additional capacity boost. 4G CA is a basic capability in 4G devices and in 5G NSA devices today. However, the 5G FDD devices available in the first part of 2020 only support a limited number of 5G FDD bands and no CA between 5G bands. This device limitation degrades the practical user performance because 5G FDD in a low band + 5G TDD at 3.5 GHz are not optimally utilized together. So, if a low band is converted from 4G to 5G usage, it is preferable to support 5G CA in order to maximize performance for the end user.

In addition to the above limitation, 5G FDD and 4G FDD bands are combined with DC instead of CA, resulting in 20-30% lower downlink throughput for two reasons. First, it does not allow for common scheduling, which would be possible with CA. Second, there will be a 3 dB coverage loss, because CA requires just one uplink whereas DC requires two separate uplinks.

Figure 7 illustrates the NSA case described above. It shows that low-band 5G without 5G CA degrades the end user performance by reducing the number of carriers that can be aggregated for each end user. Consequently, there is no merit in using DSS for such NSA deployments.

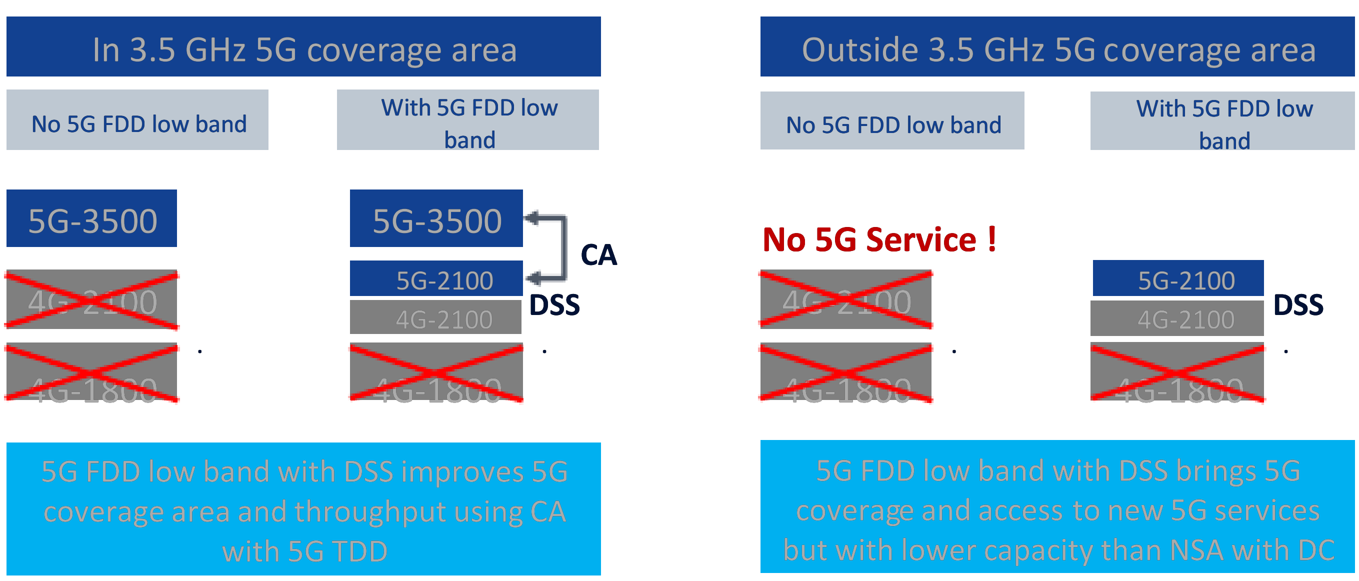
Figure 7. NSA case: 5G in FDD low bands degrades end user performance without 5G CA, resulting in no benefit for employing DSS.



CA = Carrier aggregation
DC = Dual connectivity

In contrast, the introduction of CA with 5G is a good reason to use DSS with SA, since it improves 5G coverage and access to the 5G core and associated new services, as depicted in Figure 8.

Figure 8. SA case: 5G FDD with CA and DSS provides clear benefits in 5G coverage



CA = Carrier aggregation

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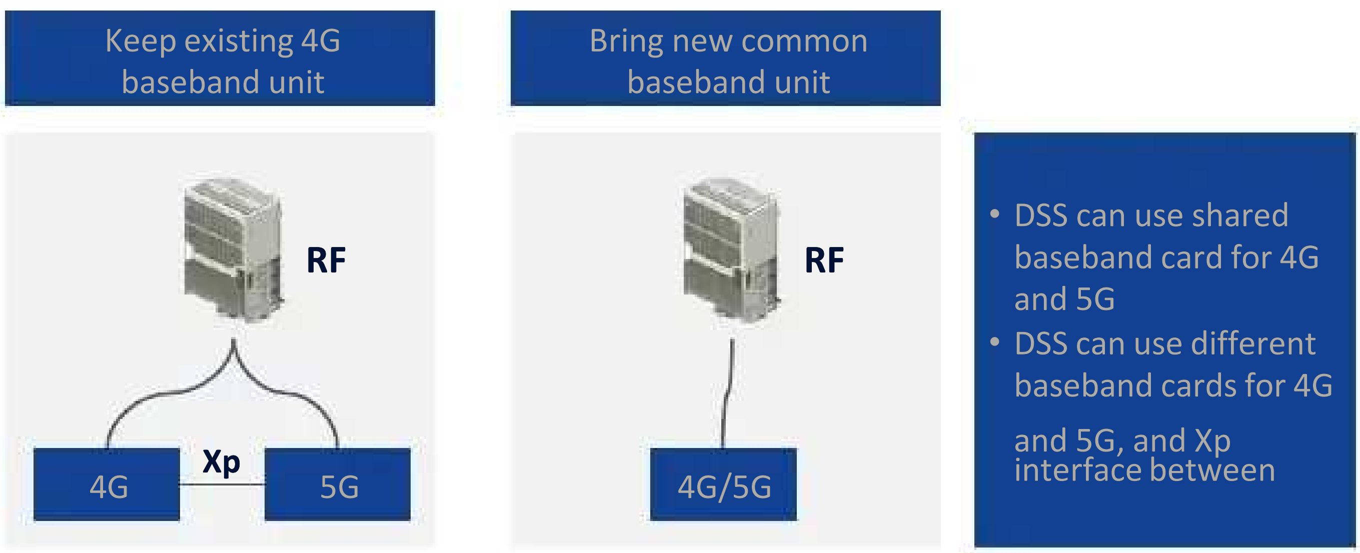
DSS technical solution specifics

One option is for DSS to use a single shared baseband card for 4G and for 5G, which obviously precludes a multi-vendor solution for 4G and 5G. The other option is to keep the existing 4G baseband and add a new 5G baseband. The scheduling between the two baseband functions is then based on a fast Xp interface between 4G and 5G. This interface is not open and works only for a single vendor, so CSPs must use the same vendor in 4G and 5G if they use DSS (Figure 9).

Figure 9. The two primary baseband options for DSS

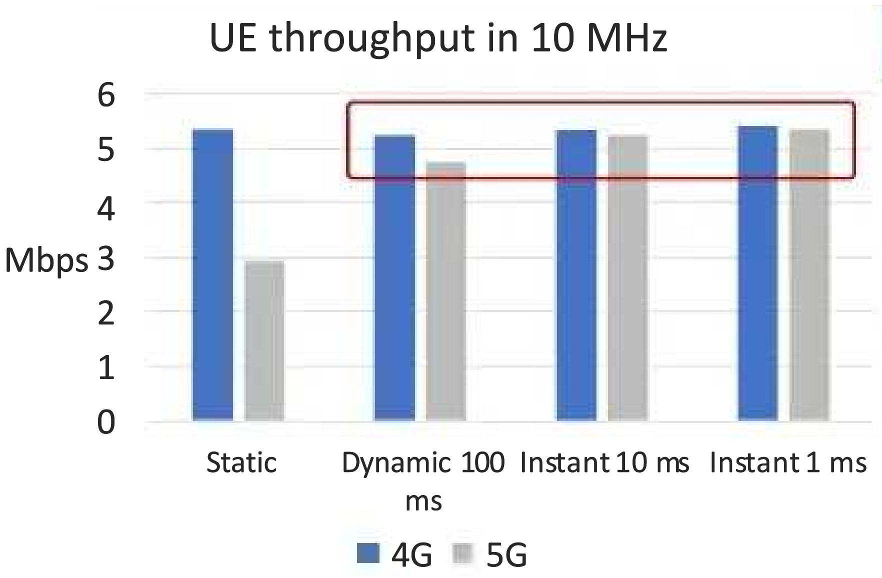


A primary performance consideration for DSS is the reconfiguration time. Figure 10 illustrates simulations for DSS with 100 ms, 10 ms and 1 ms coordination and a static split for reference. The simulations assume bursty 4 Mbit packet transmission, which is common for web browsing. Some 70% of devices are assumed to be 4G and 30% are 5G.

The results show that DSS provides a clear improvement in user data rates at all timescales compared to the fixed split. The majority of the gain is apparent using 100 ms DSS, with 10 ms DSS only providing an extra 5% gain and 1 ms DSS a further 2% gain. The results can be explained as follows: Feedback loops and allocation cycles in 4G (Physical Downlink Control Channel (PDCCH), Channel Quality Indicator (CQI), Rank Indicator (RI), Automatic Repeat Request (ARQ)) run on an approximate 10 ms cycle, so that DSS with less than a 10 ms period provides no material gains. Furthermore, in terms of usage patterns, the following is true:

- If there is just one or a few bursty users that might motivate a fast reconfiguration, this is not an issue because the dynamic capacity is not fully utilized.
- If there are a lot of bursty users, the full data capacity can be used with the 100 ms allocation time.
- If there are 5G speed tests being performed, these take several seconds and, again, the 100 ms reconfiguration time is more than adequate.

Figure 10. The relative impact of DSS reconfiguration time on user throughput



DSS for 2G, 3G and 4G technologies

DSS can also be implemented between 2G, 3G and 4G radios, enabling legacy technologies to support existing devices while maximizing the use of spectrum for 5G. This is important because most CSPs still run these technologies as they deploy 5G.

With much spectrum having previously been refarmed to 4G, it is vital to achieve the highest efficiency when applying spectrum sharing to the relatively small amount of remaining 2G and 3G bandwidth. 4G-5G DSS builds on the common numerology of LTE and NR. DSS for 2G and 3G uses different dynamic sharing mechanisms. Applying DSS on 2G-3G, 2G-4G, 3G-4G and 4G-5G on distinct carriers reduces signaling overheads and maximizes overall efficiency.

DSS aligns with the patterns of subscription and traffic migration from one radio access technology to another, which is typically governed by the affordability of devices. Enabling large numbers of 4G users to dynamically tap into the resource pool previously dedicated to 2G and 3G frees resources for the growing number of 5G users on the 4G-5G DSS carrier. This also protects 2G, 3G and 4G performance.

Nokia's DSS features and the schedule is summarized in Table 1.

Table 1. Nokia multi-technology DSS solutions

DSS features	Nokia support
2G – 3G DSS	**Yes, 2019**
2G – 4G DSS	**Yes, 2019**
3G – 4G DSS	**Yes, 2020**
4G – 5G DSS	**Yes, 2020**

Q&A

DSS technology impacts on devices and existing network deployments, which raises a number of questions about the technology. The main questions and answers regarding DSS technology are summarized in Figure 11.

Figure 11. The primary questions and answers on DSS usage

Is there any specific device needed for DSS?	All LTE devices support DSS (backwards compatible). All 5G devices will support DSS during 2020
When will devices support FDD + SA + CA?	Devices will support this set of features more widely in 2021
How fast DSS is needed?	Dynamic allocation with 100 ms cycle provides the vast majority of the DSS benefits
Is common LTE & 5G baseband needed for DSS?	No, a DSS solution can use two separate baseband cards with fast Xp interface between the two basebands
Is multivendor LTE – 5G DSS feasible?	No, DSS must use the same vendor in LTE and in 5G
What is the minimum LTE capacity loss caused by DSS?	5G broadcast takes 1 ms of 20 ms impacting LTE capacity up to 5%. Other controls can increase the impact.
Is DSS feasible for 2G and 3G refarming?	Nokia has DSS solution for all technology refarming for 2G, 3G, 4G and 5G.

Conclusions

DSS is a handy solution for flexibly refarming spectrum to 5G. Nokia supports DSS between all technologies from 2G to 5G. The most advanced DSS solution is available between 4G and 5G, where spectrum sharing is already specified as an option by 3GPP. DSS provides full benefits when combined with SA architecture for maximum coverage and new 5G services, and with CA for maximum 5G data rates. The combination of these technologies will be available in devices towards the end of 2020. Nokia's radio products are designed to support DSS, so millions of existing RF units can be upgraded to support 5G and DSS. Similarly, existing LTE baseband modules can be used for DSS with 5G.

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Abbreviations

ARQ	Automatic Repeat Request
CA	Carrier Aggregation
CRS	Call Reference Signal
CSP	Communication Service Provider
CQI	Channel Quality Indicator
DMRS	Demodulation Reference Signals
DSS	Dynamic Spectrum Sharing
DC	Dual Connectivity
EPC	Evolved Packet Core
FDD	Frequency Division Duplex
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
NR	New Radio
NSA	Non-standalone
PDCCH	Physical Downlink Control Channel
RF	Radio Frequency
RI	Rank Indicator
SA	Standalone
TDD	Time Division Duplex
TM9	Transmission Mode 9
UE	User Equipment

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Document code: SR2003042300EN (April) CID207265