5G New Radio for spectrum allocations below 5 MHz

Enabling 5G-based mission-critical networks

White paper

Since its introduction, 5G New Radio (NR) has been a great success story, especially in consumer markets. There are also specialized networks serving industry verticals that will benefit from the 5G NR capabilities. 5G NR offers low communication latency, high reliability, flexibility and efficiency that enable mission-critical applications to be modernized and enhanced to meet the challenges of the future. Key use cases include communications for critical infrastructure such as railways, smart electrical power distribution grids and public safety. These networks often use dedicated spectrum allocations that are narrower than the original minimum operating bandwidth of 5 MHz for 5G NR.

This paper describes how new flexibility is being introduced to the 5G NR design as part of 5G-Advanced to allow operation in these dedicated spectrum allocations with bandwidths between 3 and 5 MHz.

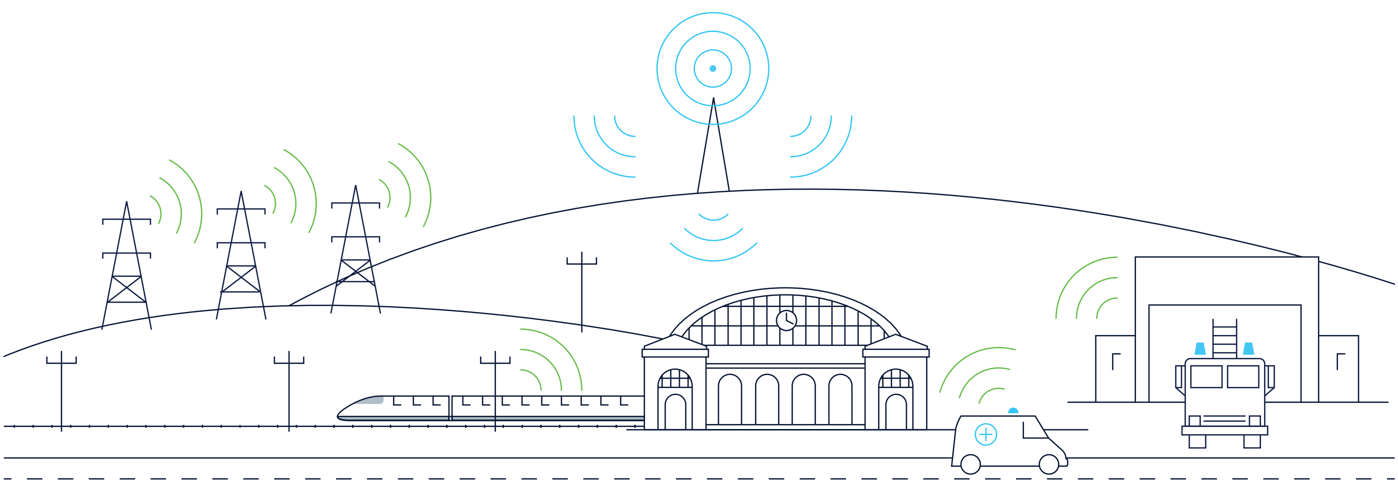
Contents

Why such narrow bandwidths?

5G New Radio (NR) can flexibly support a wide range of bandwidths, but it was originally designed on the assumption that 5 MHz would be a reasonable minimum bandwidth for a broadband system. Why should we now extend 5G NR's capabilities to enable it to operate in bandwidths below 5 MHz?

Specialized mobile networks are used to provide mission-critical communications for industry verticals such as smart energy and infrastructure, public safety, and railway communications. These networks would benefit not only from the high spectral efficiency of 5G NR but also from its ultra-reliability and low latency communication and control capabilities. The enhancements provided by 5G NR can facilitate further digitalization and automation of mission-critical applications, paving the way for improvements in the reliability of applications and the efficient use of resources related to the industry vertical. These specialized networks often operate in dedicated spectrum allocations that are narrower than the typical allocations for public broadband networks. Some dedicated allocations span 3 MHz, while the upgrading of railway communications from 2G to 5G will necessitate parallel operation of the legacy and 5G systems within a bandwidth only slightly greater than 5 MHz for a decade of gradual migration, during which time, 5G NR will have to operate in significantly less than 5 MHz bandwidth.

Figure 1. Examples of mission-critical communications



Several design changes are needed before 5G NR can be deployed in spectrum narrower than 5 MHz, but these changes should be minimized so that the established 5G NR ecosystem of devices and infrastructure can be efficiently leveraged without major changes in implementation. It is worth noting that this is a very different set of requirements from 3GPP's efforts to support devices with reduced capabilities, known as RedCap devices: for RedCap devices, the feasible cost, complexity and size of the devices is heavily constrained, whereas devices for mission-critical purposes are typically fully capable, sophisticated terminals.

3GPP has recognized the importance of supporting these valuable spectrum-constrained mission-critical networks with 5G NR, and the required design work will be introduced in the Release 18 (Rel-18) specifications of 5G NR under Nokia's rapporteurship and with support from numerous companies including several UE chip vendors [1].

Rel-18 is due to be ready in 2024 and is the first release of the 5G-Advanced era, which will provide a large set of innovations offering a plethora of benefits for network and system operators, end-users and verticals. Evolving the 5G system to its fullest capabilities, Rel-18 content can be grouped into four areas: Experience (providing a new level of experience), Extension (extending the network into new areas), Expansion (expanding the mobile network beyond connectivity) and Excellence (providing excellent operational support). Providing support for dedicated networks utilizing less than 5 MHz spectrum will be an important part of the Extension block of features. This will not only make the 5G-Advanced network expand its reach to new geographic areas but, as in this case, also to new service areas. A full introduction to 5G-Advanced can be found in [2].

In this paper, we explain in detail the changes required to enable NR operation in less than 5MHz bandwidth and discuss how they can be made efficiently.

Figure 2. 5G-Advanced Rel-18

Mission-critical networks with below 5 MHz bandwidth

There are several critical industry use cases that have dedicated spectrum allocations spanning less than 5 MHz, and the main frequency bands of relevance are summarized in Table 1 with an example of a related industry vertical.

Table 1. Frequency bands with below 5 MHz channels

3GPP band designation	Duplex mode	Uplink	Downlink	Example of vertical
n8	FDD	880 – 915 MHz	925 – 960 MHz	Power distribution
n26	FDD	814 – 849 MHz	859 – 894 MHz	Power distribution
n28	FDD	703 – 748 MHz	758 – 803 MHz	Public safety
n100	FDD	874.4 – 880 MHz	919.4 – 925 MHz	Railway

In the USA, smart electrical power distribution grids can use 2 x 3 MHz FDD channels in bands n26 and n8 in the 800 – 900 MHz frequency range. For these use cases, the ultra-reliability and low latency provided by 5G NR allows critical functions to be automated with low deployment costs and a high degree of flexibility.

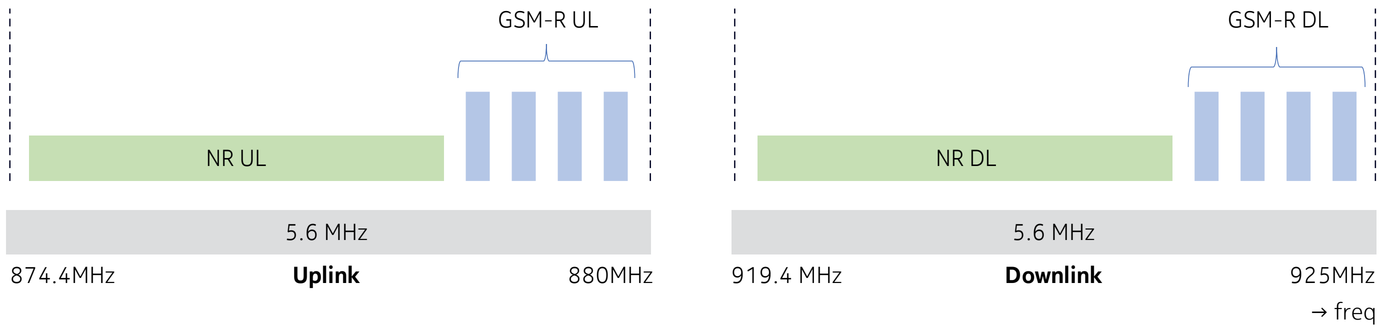
For public safety, 2 x 3 MHz FDD channels have been allocated in Europe for Public Protection and Disaster Relief (PPDR) communications in band n28 in the 700 MHz frequency range.

Railway communications are critical for ensuring safe and efficient rail operations. GSM-R has been hugely successful in bringing railway communications into the digital era in around 40 countries worldwide over the last two decades. Now the time has come to modernize these systems with the state-of-the-art performance of 5G NR, which has already been selected in Europe as the technology for the Future Railway Mobile Communication System (FRMCS)[1] which will replace GSM-R.

Railway communications in Europe have access to 2 x 5.6 MHz of FDD spectrum in band n100 in the 900 MHz frequency range. During the migration from GSM-R to 5G NR, both GSM-R and FRMCS networks will have to be operated in parallel to ensure full serviceability of both old and new rolling stock. The upgrade timeframes of the rail industry are expected to last at least 10 years (from around 2025 to 2035), therefore, the ability to deploy 5G NR on bandwidths from around 3 MHz to 5 MHz will be critical. A typical migration scenario for railway communications might involve sharing the 5.6 MHz of spectrum with eight 200 kHz GSM-R channels, leaving approximately 4 MHz for NR, as shown in Figure 3. In the frequency domain, on the other hand, an extreme case of sharing the 5.6 MHz of spectrum with 14 GSM-R channels would only leave 2.8 MHz for NR. The exact bandwidth available for 5G NR will depend on the number of narrowband GSM-R channels in operation, thus a high degree of flexibility is required for 5G NR in this scenario.

1 For more information on FRMCS, please read Nokia 5G for Railways White Paper

Figure 3. GSM-R and NR co-existence during soft migration from GSM-R to NR



Required 5G New Radio enhancements

The goal is to adapt the 5G NR physical layer to the available bandwidth, ranging from approximately 3 MHz up to 5 MHz, while building on the existing NR ecosystem. To make the scenario attractive for both user equipment (UE) and network vendors, as well as being economically compelling for network operators, it makes sense to minimize the changes to the existing standardized versions of 5G NR (Rel-15 to 17). The changes focus on the physical layer and RF parts of NR while no, or only limited, changes are expected on the higher layers. Existing NR functionalities are sufficient, for example, for the Doppler and mobility facets of high-speed trains.

In the frequency domain, NR data transmission is designed to operate in units of 12 subcarriers, known as physical resource blocks (PRBs). A single PRB occupies 180 kHz with 15 kHz subcarrier spacing (SCS) that will be used to support NR bandwidths below 5 MHz. After allowing for reasonable guard bands, 4 MHz of spectrum might, therefore, be expected to permit approximately 20 PRBs. In the case of a 3 MHz channel, available for critical infrastructure and public safety, only 15 PRBs may be supported when appropriate guard bands are taken into account.

Most of the changes that are required in 5G NR are for signaling that is used before a UE has acquired sufficient system information. Otherwise, the existing NR flexibility can be utilized to provide configurations limiting the bandwidth to less than 5 MHz. For example, according to the current NR design, the minimum transmission bandwidth of the physical broadcast channel (PBCH) is 3.6 MHz, or 20 PRBs. Thus, it is clear that some changes need to be made to fit the current PBCH into the narrowest of the spectrum availabilities (between 2.8 and 4 MHz).

In the subsequent sections, we provide some more detailed examples of the necessary changes, as well as explaining potential ways to avoid or mitigate related performance degradation while keeping the UE impact reasonable. We will first discuss the changes expected to RF requirements to meet the aforementioned target of below 5MHz operation, followed by considerations on the impact of restricted bandwidth to other NR signals and channels, including PBCH and the physical downlink control channel (PDCCH).

RF requirements for below 5 MHz channel bandwidth

Achieving maximum utilization of the existing ecosystem applies to all aspects of the standardization work. 3GPP will therefore define only one new channel bandwidth, namely 3 MHz. It is expected that the current RF requirements defined for LTE 3 MHz bandwidth can be largely reused for the NR 3 MHz channel. This could mean, for example, that the 3 MHz channel utilizes at most 15 PRBs with 15 kHz SCS, which corresponds to a spectrum utilization of 90%.

The 3GPP work item assumes that the existing RF requirements defined for the NR 5 MHz channel bandwidth can be reused for FRMCS scenarios involving transmission bandwidths between 14 and 25 PRBs. In these scenarios, the interference from GSM-R can be mitigated by the NR base station implementation, facilitated by the assumption that the NR and GSM-R base stations are co-located and managed by the same operator. Examples for the NR base station implementation-based solutions include scheduling constraints, reservation of a suitable guard band and filtering solutions.

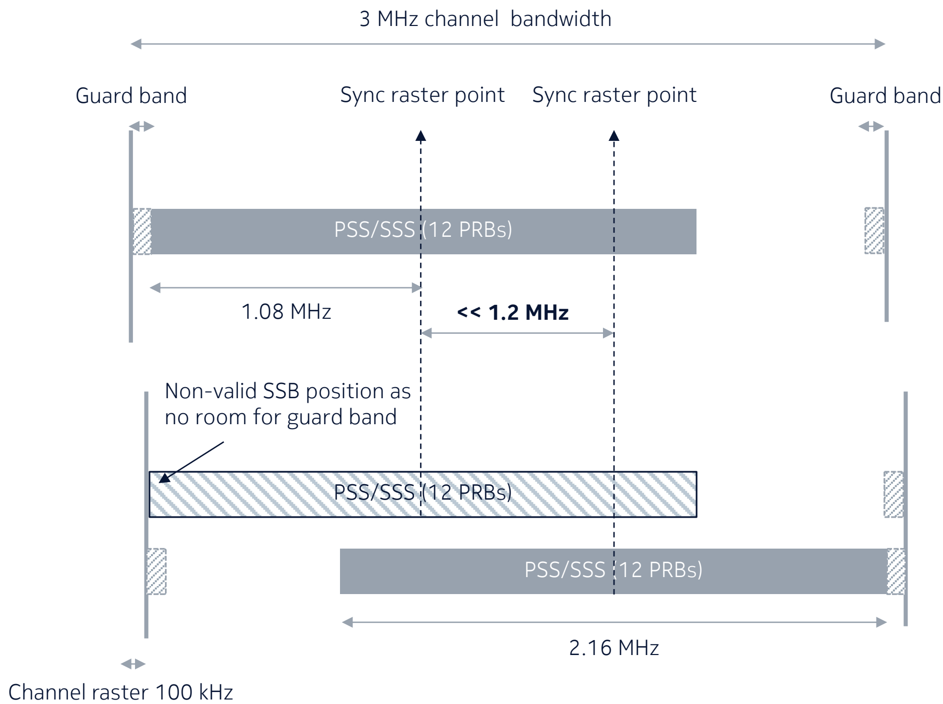
Broadcast channel

Synchronization signal/PBCH block (SSB) is a core building block of the NR system. The SSB is used for initial cell search and selection, beam and cell measurements, radio link monitoring and new beam identification in the beam recovery procedure. The block consists of the primary synchronization signal (PSS), secondary synchronization signal (SSS) and PBCH with the related demodulation reference signal (DMRS) for PBCH demodulation. Two challenges related to SSB can be identified: PBCH occupies bandwidth of 3.6 MHz, or 20 PRBs, and the set of possible frequency positions for SSB is rather coarse for bandwidths below 5 MHz. PBCH needs to be narrowed down to the desired transmission bandwidth, preferably by means of puncturing, and the set of possible SSB frequency positions needs to be redesigned to support NR bandwidths below 5 MHz, as discussed in more detail in the following.

In the cell search procedure, the UE acquires time and frequency synchronization to a cell and determines the physical layer cell ID. The UE does this by searching for the PSS and SSS and decoding the PBCH. The 3GPP work item assumes that the current PSS/SSS design is reused without puncturing, which is possible as its bandwidth is narrower than the narrowest channel bandwidth that needs to be supported.

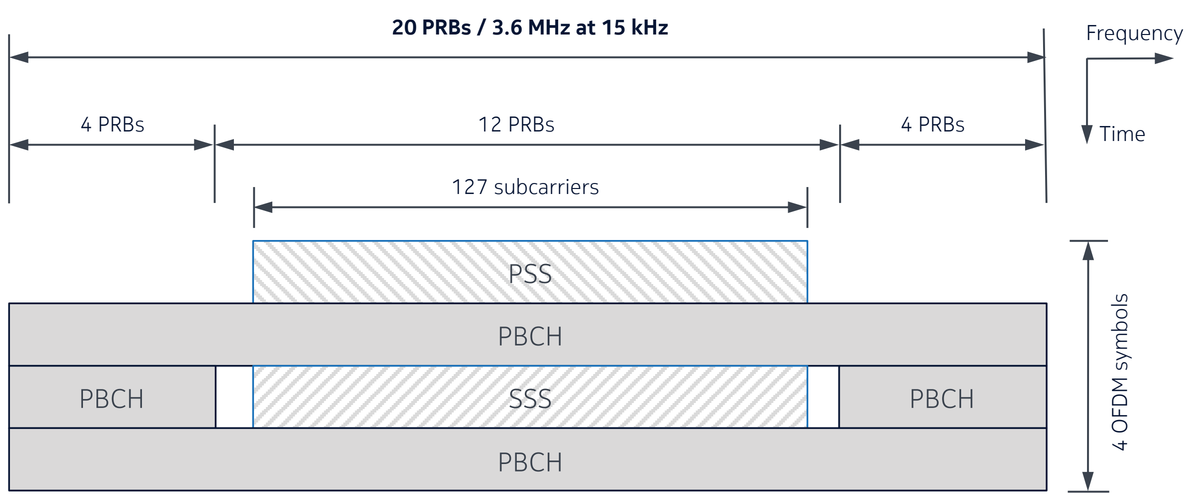
The synchronization raster defines the set of frequency positions at which the SSB may be located, thereby setting the frequency positions that need to be searched by the UE for initial cell search. To expedite cell search, the synchronization raster is much sparser than the set of frequency positions on which the carrier may be centered, which is known as the channel raster. In the relevant range of FR1 frequencies below 7 GHz, the channel raster typically has a 100 kHz spacing, but the synchronization raster has a cluster of three raster positions every 1.2 MHz, with the raster offsets in each cluster being 50, 150 and 250 kHz. For an allowed bandwidth of, for example, 3 MHz, and with the principle of not modifying PSS and SSS, the clusters of synchronization raster points need to be separated less than 1.2 MHz, as shown in Figure 4. In this figure, two channels of 3 MHz bandwidth separated by 100 kHz are shown. The synchronization raster will therefore need redesigning for narrowband NR operation.

Figure 4. Synchronization raster consideration for 3 MHz bandwidth



Further modifications will be needed for the PBCH, as it occupies 20 PRBs corresponding to 3.6 MHz bandwidth at 15kHz sub-carrier spacing, as illustrated in Figure 5.

Figure 5. SSB structure at 15 kHz subcarrier spacing



Puncturing of the transmitted signal is considered as a solution to narrow down the transmission bandwidth with minimum change. In the puncturing operation, the NR base station just blanks the signal mapped on certain predefined PRBs that fall outside the desired transmission bandwidth (i.e., it does not transmit them), but otherwise the NR base station's encoding and transmit processing can be kept unchanged. When the UE receives the transmission with punctured PRBs, it may just null the punctured PRBs at the receiver (e.g., setting the log-likelihood ratios (LLRs) to zero in the channel decoder). Otherwise, the UE's receiver processing can be kept unchanged.

To limit the impact to other UE procedures such as channel estimation, it is seen as preferable to perform puncturing with PRB granularity and avoid puncturing of PRB fractions. One possible way for the UE to ascertain which PRBs are punctured is to define a relationship between the synchronization raster position and the puncturing. Consequently, the case of railway communications, where puncturing may change over the gradual migration to FRMCS, can also be supported.

As mentioned above, a 3 MHz spectrum allocation to NR would result in a 15 PRB channel bandwidth with 15 kHz sub-carrier spacing when 90% spectrum utilization is assumed. For the PBCH, this would mean five PRBs needing to be punctured. To avoid affecting the PSS/SSS, at most four PRBs of the PBCH can be punctured on either side of the SSB, requiring both sides of the PBCH to be punctured to a certain extent to reach the 3 MHz bandwidth. To meet the desired bandwidth of 15 PRBs, for example, the puncturing could be done in PRB granularity and in asymmetric manner by, for instance, puncturing three PRBs from one side of the SSB and two PRBs from the other side.

When considering puncturing the transmitted signal to limit the bandwidth, it is evident that the detection performance will degrade compared to the non-punctured case. The performance impact of the puncturing can be limited, however, if the UE can determine which PRBs are punctured before trying to decode the PBCH. In this way, the UE can avoid the noise and potential interference from punctured PRBs.

Table 2 compares the simulated PBCH performance[2] for different transmission bandwidths as well as for UEs with and without knowledge of the punctured PBCH PRBs. In the table, a change in maximum coupling loss (MCL) is shown when punctured PBCH performance is compared to unpunctured, 3.6 MHz PBCH performance. The MCL change reflects the potential change in coverage when no other changes are made. Note that in the case of 15 PRB PBCH, for example, there is a 1.2 dB difference in detection performance depending on whether the UE is aware of the punctured PRBs. This difference can be dramatically larger if the UE receives interference from, for example, GSM-R on the punctured PBRs. Hence, it is important for reasonable PBCH performance that the UE has knowledge of punctured PBCH PRBs prior to the PBCH decoding. The results show that approximately a 1.4 dB loss may be seen when comparing detection of punctured 15 PRB PBCH against non-punctured 20 PRB PBCH detection.

Table 2. PBCH detection loss due to puncturing [dB] @ 1% BLER (compared to 20 PRB PBCH). Change in maximum coupling loss is reported.

	PBCH size in frequency		
	18 PRBs	**15 PRBs**	**12 PRBs**
Change in MCL - UE unaware of PRBs punctured [dB]	-0.7	-2.6	-5.6
Change in MCL - UE aware of PRBs punctured [dB]	-0.5	-1.4	-3.7

Nevertheless, even with knowledge of the puncturing, the reduced coding gain will mean that the detection performance for the punctured transmission of the PBCH will not be equal to the performance without any puncturing.

2 The link simulations are done with a 3GPP-compliant simulator with two transmit and two receiving antennas.

Hence, 3GPP may need to consider how to recover the performance degradation, at least partially, to maintain NR functional performance. But this needs to be done based on a careful trade-off between the required UE changes and performance. For example, the current 3GPP work item states that in addition to PSS/SSS specification re-use, the PBCH needs to be "based on" the current design. This means that PBCH redesign involving PRB remapping cannot be part of the 3GPP outcome.

Some coverage compensation may also be possible based on implementation, for example, improved receiver noise figure or antenna gain for train or vehicle mounted UEs with rooftop antennas.

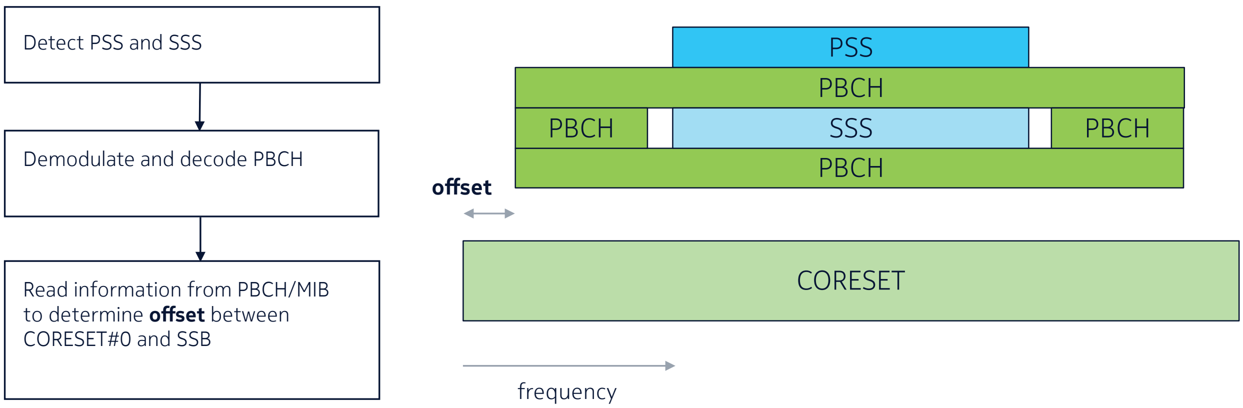
Physical downlink control channel

The physical downlink control channel (PDCCH) is the control channel on which the UE receives fundamental scheduling and control information from the NR base station. For the PDCCH, 3GPP aims to identify and specify necessary minimum changes for functional support based on the existing design, without optimization. During system information acquisition, the UE monitors PDCCH on resources spanning at least 4.32 MHz. The PDCCH changes that are necessary to support NR in narrow spectrum allocations are therefore focused on these PDCCH resources. In the following, we discuss two alternatives for the changes: use of non-interleaved PDCCH with minor puncturing or solely relying on PDCCH puncturing when scheduling DL transmission for system information, from which the non-interleaved PDCCH approach is preferred. Another aspect requiring attention is the PDCCH frequency domain location with respect to SSB.

The PDCCH is mapped to sets of physical resources known as a CORESET (control resource set). A CORESET is comprised of control channel elements (CCEs) that are the basic unit of time-frequency resources that can be aggregated for the transmission of a PDCCH message. Multiple CCEs can be aggregated to carry a single PDCCH depending on the coverage requirement. CORESETs can be flexibly configured to the UE after the initial access. However, there are limited configuration options for the CORESET that is used for the PDCCH scheduling the transmission of system information block 1 (SIB1), known as CORESET#0 and Type0-PDCCH respectively.

First, we consider the CORESET#0 frequency domain location with respect to SSB. After the UE has detected PSS and SSS and demodulated the PBCH, the UE has acquired the master information block (MIB) on the PBCH. Next, the UE needs to acquire the remaining minimum system information carried by the SIB1. The UE reads the CORESET#0 configuration index from the MIB on the PBCH, which indicates certain time and frequency resource allocation parameters for the CORESET. One of the parameters defines the frequency domain offset between the first PRB in which the SSB is located and the first PRB of CORESET#0. This procedure is illustrated in Figure 6.

Figure 6. CORESET#0 frequency domain resource allocation signaling



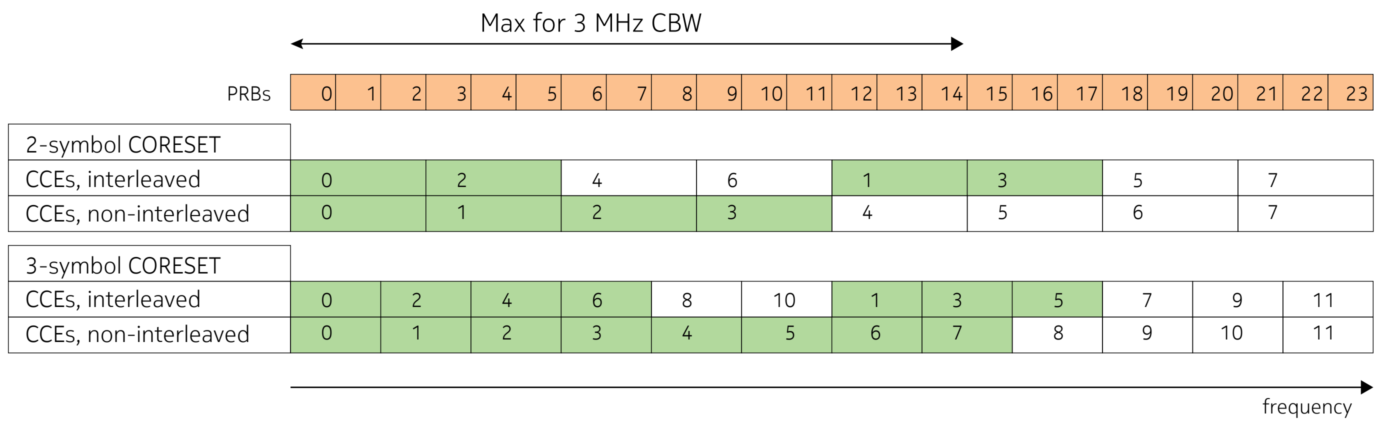
Similar to the PBCH transmission, puncturing may be needed to constrain CORESET#0 within the available spectrum. This may lead to a situation where the normal resources of the CORESET#0 contain some partial CCEs. Because the CCE is used as the basic resource unit in channel estimation, partial CCEs can complicate and degrade channel estimation. Thus, the CORESET#0 frequency domain allocation may require re-consideration to keep CORESET#0 aligned at the CCE level with the non-punctured PRBs of the SSB.

Next, we consider how to fit Type0-PDCCH to a narrower bandwidth than earlier. CORESET#0 spans at least 24 PRBs (i.e., 4.32 MHz) with 15 kHz subcarrier spacing. Hence, the CORESET#0 needs to be reduced by nine PRBs to, for example, reach 3 MHz bandwidth. Figure 5 shows the normal CCE indices for two and three OFDM symbol durations. Two CCE mappings are defined in NR: interleaved and non-interleaved CCE. According to the current NR specification, CORESET#0 always utilizes the interleaved CCE mapping, while other CORESETs that are read later by the UE can use either interleaved or non-interleaved CCE mapping.

It can be observed from Figure 7 that the CCEs available for PDCCH transmission will be limited in a narrow bandwidth scenario. For example, for a 3 MHz carrier with only 15 available PRBs, the maximum number of CCEs that can be used for PDCCH in the non-interleaved mapping with a two-symbol CORESET duration is five. If the PDCCH coverage requires more CCEs, then the CORESET would have to be extended to a third symbol, allowing up to seven full CCEs.

With the interleaved mapping, the maximum number of full CCEs would be five assuming PDCCH punctured from aggregation level eight. On the other hand, with non-interleaved CCE mapping and three-symbol CORESET, CCE puncturing is hardly needed. Hence, the simplest, and preferred, way to maximize the PDCCH coverage for Type0-PDCCH in bandwidths below 5 MHz is to introduce non-interleaved CCE mapping to CORESET#0 with the necessary minor puncturing. The drawback is reduced PDSCH capacity due to use of three-symbol CORESET and of course the total PDCCH capacity is reduced compared to the 5 MHz case.

Figure 7. Different PDCCH scenarios with interleaved and non-interleaved CCEs. PDCCH candidates with AL4 (two-symbol CORESET) and AL8 (three-symbol CORESET) are highlighted



Next, we study the PDCCH link performance with CCE puncturing. As mentioned, the need for puncturing varies according to the bandwidth available, interleaving configuration and the number of OFDM symbols in the CORESET. To see the performance limits for CCE puncturing we consider the scenario relying solely on CCE puncturing. Table 3 compares the simulated PDCCH link performance for Type0-PDCCH with different transmission bandwidths, for a two-symbol CORESET with interleaved mapping. In all cases, the Type0-PDCCH is sized to fit to eight CCEs (within a 24-PRB CORESET) but some of the PRBs are not transmitted. This results in PDCCH transmission bandwidths of six CCEs (18 PRBs), five CCEs (15 PRBs) and four CCEs (12 PRBs), respectively. In the table, a change in MCL is shown when punctured PDCCH performance is compared against the unmodified NR PDCCH with 5 MHz channel bandwidth and eight aggregated CCEs. The results show that puncturing an eight-CCE PDCCH down to five CCEs (i.e., 15 PRBs) will cause a 0.9 dB loss in MCL when compared to the non-punctured case. In order to keep the PDCCH performance degradation at a manageable level it is important that the UE knows the punctured PRBs in advance.

Table 3. PDCCH detection loss due to puncturing [dB] @ 1% BLER (compared to aggregation of eight CCEs). Change in maximum coupling loss is reported.

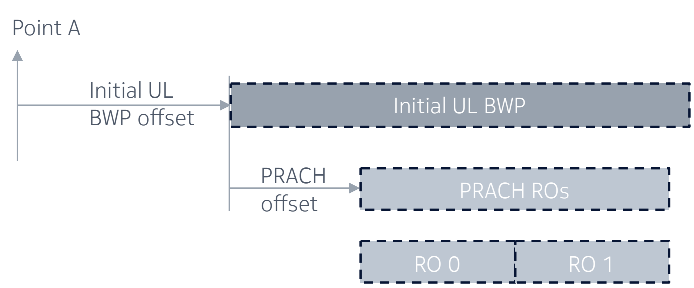
	CORESET#0 size in frequency		
Factor	**18 PRBs**	**15 PRBs**	**12 PRBs**
Change in MCL [dB]	-0.7	-0.9	-2.0

Other considerations

There are few other NR channels and signals having wide bandwidth or limitations on the flexibility of frequency domain allocation. These are physical random-access channel (PRACH), physical uplink control channel (PUCCH), and channel state information reference signal (CSI-RS). In the following, we briefly consider these signals and channels and conclude that they do not impose any relevant challenges when supporting bandwidths from 3 to 5 MHz.

To gain access to the cell, the UE initiates the random-access procedure by transmitting a preamble on PRACH. Before initiating the random-access procedure, the UE reads the remaining minimum system information in SIB1. From the system information, the UE determines the initial UL BWP configuration used in the cell. Since the network can configure initial UL BWP and can flexibly allocate random access occasions (ROs) in frequency in the initial UL BWP, the current PRACH configuration also allows sufficient flexibility for narrowband NR operation. Thus, it can be used as is. This is illustrated in Figure 8 where two ROs are configured within the configured initial UL BWP. Point A is an absolute reference frequency point that is used to configure BWPs.

Figure 8. PRACH configuration



PRACH offset: Offset within BWP to the start of the first RO.
Given by higher layer parameter msg-1FrequencyStart.

NR defines a set of PRACH preamble formats: four long and nine short preamble formats. Long preambles are based on a sequence length L=839 and subcarrier spacing for long preambles can be either 1.25 kHz or 5 kHz. Short preambles are based on a sequence length L=139 and subcarrier spacing for short preambles is the same as for other NR uplink channels. For example, in the relevant range of frequencies below 7 GHz the subcarrier spacing can be 15 or 30 kHz. Different formats are targeted to different use cases and different coverage requirements. All the preamble formats except one long format (Format 3) are designed for high-speed users to fit into bandwidths of even 3 MHz. It is further noted that, for instance, another long format (Format 0) can support high UE speeds at 1 GHz carrier frequency with only about 1.7 dB reduction in sensitivity compared to Format 3. Thus, no changes are needed for PRACH formats other than restricting the use of Format 3 from the NR operation in spectrum allocations down to 3 MHz.

The UE transmits physical layer control information to the NR base station on the PUCCH. For example, the UE may indicate a need for a data retransmission or request uplink scheduling through the PUCCH. During the UE's initial access to the cell, it uses PUCCH resources that are determined with four bits only. However, the frequency domain allocation is relative to the initial UL BWP, which can be flexibly configured in the SIB1, as discussed earlier. After the initial access, the UE can use PUCCH resources that are flexibly configured to the UE according to the available bandwidth. As NR already provides sufficient configuration flexibility for the PUCCH, NR PUCCH can be used as it is, without need for modifications.

In NR, CSI-RS is used for different purposes such as for time and frequency tracking, channel state information acquisition, beam measurements and mobility measurements. The CSI-RS is configured with frequency domain allocation granularity of four RBs, which is rather coarse for a bandwidth of, as an example, 15 PBRs. However, the CSI-RS can be allocated entirely upon bandwidth parts having sizes that are not integer multiple of four RBs. That can be accomplished by configuring the CSI-RS allocation to be wider in frequency domain than the configured bandwidth part. Thus, in general CSI-RS can support narrowband NR operations where the configured bandwidth part, for instance, has a bandwidth of 3 MHz or 3.6 MHz.

Summary on necessary enhancements

From the above analysis, it is seen that the key signals and channels of 5G NR (SSB, PDCCH, CSI-RS, PUCCH and PRACH) can be adapted to fit within the narrow spectrum allocations available for critical communications systems with relatively minor changes in the implementation and minimal performance impact.

The minor number of required changes should simplify the development of suitable devices for use with these systems, with only limited modifications needed to the designs already widespread in the established 5G NR ecosystem. This facilitates timely availability of full-capability terminals for the mission-critical communication systems.

Conclusion

5G New Radio services will be extended to specialized vertical use cases that require the ability to operate in dedicated spectrum allocations narrower than 5 MHz. These use cases include communications for critical infrastructure such as smart energy grids and public safety, as well as soft migration of railway communications from GSM-R to FRMCS utilizing 5G NR and 5G Core.

To achieve this new flexibility for 5G NR, support for bandwidths ranging from about 3 MHz to 5 MHz will be introduced in 3GPP Rel-18. This will be achieved with a set of rather modest changes, such as puncturing of PBCH transmitted bandwidth and PDCCH modifications during initial access. By keeping the changes minimal, the existing wide ecosystem of 5G NR devices and infrastructure as well as 5G Core network functions can be leveraged with only modest changes in the implementation. This will pave the way for further digitalization and automation of mission-critical operations in several vertical industries.

Nokia, with its extensive experience in 5G NR and 5G Core, railway communications, critical communications, public safety infrastructure and private networks, is well prepared to support the introduction of 5G NR in spectrum allocations narrower than 5 MHz, thus serving critical infrastructure communications for years to come.

Abbreviations

AL	Aggregation Level
BWP	Bandwidth Part
CCE	Control Channel Element
CORESET	Control Resource Set
CSI-RS	Channel State Information Reference Signal
DMRS	Demodulation Reference Signal
GSM-R	Global System for Mobile Communication – Railway
FDD	Frequency-Division Duplexing
FR1	Frequency Range 1
FRMCS	Future Railway Mobile Communication System
MIB	Master Information Block
NR	New Radio
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PPDR	Public Protection and Disaster Relief
PRB	Physical Resource Blocks
PRACH	Physical Random Access Channel
PSS	Primary Synchronization Signal
PUCCH	Physical Uplink Control Channel
RO	Random Access Occasion
SCS	Sub-Carrier Spacing
SIB1	System Information Block 1
SSB	Synchronization Signal/PBCH block
SSS	Secondary Synchronization Signal
UE	User Equipment

References

1. RP-213603, "New WI: NR support for dedicated spectrum less than 5MHz for FR1", Nokia, UIC, Anterix, Qualcomm, www.3gpp.org
2. "5G-Advanced: Expanding 5G for the connected world", Nokia White Paper, https://onestore.nokia.com/asset/210984

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