**3GPP TSG RAN WG1 Meeting #103-e R1-2009403**

**e-Meeting, October 26 – November 13, 2020**

**Source: Moderator (Intel Corporation)**

**Title: [103-e-NR-52-71-Waveform-Changes] Discussions Summary #2**

**Agenda item: 8.2.1**

**Document for: Discussion**

# Introduction

In this contribution, we summarize the email reflector discussions for • [103-e-NR-52-71-Waveform-Changes]. Chairman has approved the following email discussion:

* [103-e-NR-52-71-Waveform-Changes] Email discussion/approval on required changes to NR using existing DL/UL NR waveform until 11/2; address any remaining aspects by 11/10 – Daewon (Intel)

# Summary of issues and discussions

## 2.1 Numerology (SCS and CP Length)

### 2.1.1 Observations and Proposals from Contributions

* From [1]:
	+ Proposal 1: The decision of adding an additional SCS numerology to NR for 60 GHz band should be based on a careful compromise between receiver complexity necessary to keep the existing SCS (240kHz) and the amount of necessary changes to the existing design for the addition a new numerology (480kHz or 960 kHz) including a possible loss in spectrum efficiency.
	+ Proposal 2: For the maximum carrier bandwidth choice for the operation between 52.6 GHz and 71 GHz NR should support the largest bandwidth for the FFT size and sampling rate with minimum impact to existing design, for 120, 240, 480, 960 kHz, maximum supported BW of 400, 800, 1600, 3200 MHz, respectively.
* From [2]:
	+ Proposal 1: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, higher subcarrier spacing (numerologies) than 120 kHz should be adopted only if there is a significant performance gain in terms of phase noise reduction in comparison to existing subcarrier spacing (numerologies).
	+ Proposal 2: For supporting NR operation between 52.6GHz and 71GHz in Rel. 17, if 480kHz SCS is agreed to be supported, then only normal cyclic prefix is sufficient
	+ Proposal 3: For supporting single carrier bandwidth of ~2GHz for NR operation between 52.6GHz and 71GHz in Rel. 17, subcarrier spacing of 960kHz with normal cyclic prefix can be supported and higher subcarrier spacing value should not be further considered in NR Rel. 17.
	+ Observation 16: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then the selection of SCS value should not limited based on the frequency range .Other factors of channel conditions such as phase noise, ICI, Doppler, CQI, etc. plays an important role in determining the SCS value:
		- For DL channel, UE has all the required estimates related to channel, receiver phase noise and other impairments, etc.
	+ Proposal 12: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then UE assistance for SCS/BWP selection could be considered to take in to account all the channel measurements and receiver impairments that are more prominent at higher frequency range.
* From [3]:
	+ Proposal 5: If the existing FR2 SCSs are adopted for above 52.6 GHz, the physical layer design of FR2 should be reused for the licensed band and used as a baseline for the unlicensed band with possible modifications due to the regulatory requirements such as LBT and OCB.
* From [4]:
	+ Proposal 1: 240 KHz SCS for SSB can be an option for unlicensed band above 52.6GHz.
* From [5]:
	+ Observation 5: (960K, NCP) could achieve the highest peak data rate which is more than 7 times as that of (120K, NCP).
	+ Proposal 1: For BWP numerology, (960K, NCP) is preferred for scenarios targeting high peak data rate and (120K, NCP) is preferred with no spec impact for scenarios targeting large coverage.
	+ Proposal 13: Timeline definition, basic time unit and super long CP per half frame should be discussed for new defined numerology such as (960K, NCP).
* From [7]:
	+ Observation 1: Larger subcarrier spacings such as 480 kHz and 960 kHz mitigate the RF impairments in higher frequency especially for higher modulation order.
	+ Observation 2: Limiting subcarrier spacing choices to keep the maximum FFT size as in Rel-15/16 can reduce implementation burden for redesigning FFT engine.
	+ Proposal 3: The candidate new subcarrier spacing is limited to the subcarrier spacing that is within minimum and maximum FFT sizes in Rel-15.
	+ Proposal 4: Considering the available spectrum, corresponding maximum channel bandwidth and the coexistence, 960 kHz should be considered for the specification support.
	+ Proposal 5: Considering the different amounts of RMS delay spreads for possible scenarios, supporting multiple subcarrier spacings for higher frequencies would be beneficial.
* From [8]:
	+ Proposal 2: SCS 480 KHz is supported for control and data channels for the maximum system bandwidth up to 1.6 GHz in NR operation up to 71 GHz.
	+ Proposal 3: For NR operation on above 52.6GHz and up to 71GHz, the CP length of 240 kHz SCS for both data and control channels are sufficient to cover both indoor office and outdoor UMi Street-canyon deployment scenarios for battling of ISI. The CP length of 480 kHz SCS for both data and control channels are sufficient to cover indoor office deployment scenarios for battling of ISI.
	+ Proposal 4: The system complexity and benefit of introducing the larger SCS more than 480 KHz for phase noise mitigation shall be carefully analyzed.
	+ Proposal 5: Introducing larger SCS, such as 960 kHz is not essential for the mitigation of ICI caused by large phase noise.
* From [10]:
	+ Observation 1: Considering outdoor deployment scenario, and close to zero specification effort, it seems that subcarrier spacing (µ=3) for physical data channels is valid option for 60 GHz scenario.
	+ Observation 2: Considering indoor deployment scenario from specification effort, coexistence with WiGig, low delay spread, and low implementation complexity, it seems that only one additional subcarrier spacing, particularly value of (µ=6) for physical data channels would be sufficient for 60 GHz scenario.
	+ Proposal 6: Support 960kHz for CP-OFDM to enable use of high-order modulations with low complexity CPE compensation.
	+ Proposal 8: Support 960kHz SCS for DFT-s-OFDM to robustly enable all MCSs.
	+ Proposal 10: Prioritize NCP in 60 GHz studies. ECP can be considered later, if needed.
	+ Observation 24: RAN1 shall agree on which new SCS are supported, if any.
* From [13]:
	+ Observation 2: The selection of SCSs for Rel-17 NR above 52.6 GHz needs to consider the impacts of frequency band, bandwidth, phase noise, CP overhead and multi-path delay.
	+ Proposal 3: Numerology (SCS as well as CP) of NR above 52.6 GHz can be scaled by an integral multiple of current numerology supported by Rel-15/16 NR, i.e. Δf = 2μ × 15 kHz (μ can be set as 3, 4, 5, 6).
	+ Proposal 4: 960 kHz can be defined as the SCS for 2.16 GHz channel bandwidth if it is supported for Rel-17 NR beyond 52.6 GHz.
	+ Observation 3: If SCSs larger than 240 kHz are supported, the short CP may be not enough to cover delay spread, beam switching time and possible timing errors.
* From [14]:
	+ Consider sub-carrier spacings up to 480 kHz for NR operation in 52.6 to 71 GHz.
	+ For selection of suitable SCS for the 52.6 – 71 GHz frequency range, it is important to perform link level evaluations with sufficiently large post-beamforming RMS delay spreads that are representative of a suitable range of deployment scenarios including the indoor factory scenario analyzed above (e.g., up to at least 40 ns using the agreed TDL-A model). It is important to consider the margin left over for other sources of time synchronization error such as initial timing error, timing advance setting, timing advance adjustment granularity, and timing differences expected in multi-TRP deployments.
	+ Extended CP is not to be considered further for NR operation in 52.6 to 71 GHz.
	+ A higher UL SCS puts tighter requirements on UE initial UL timing accuracy.
	+ Capture the following observation in TR 38.808: To avoid further tightening the UE requirement on UL timing error in relation to 1/SCSSSB compared to current specifications, the UL SCS should not be more than twice that of the SSB SCS. Using existing Rel-16 specifications for SSB, this can be achieved with 240 kHz SCS for SSB and 480 kHz for UL SCS.
	+ A higher UL SCS puts tighter requirements on the absolute UE UL timing advance adjustment accuracy.
	+ Capture the following observation in TR 38.808: For 960 kHz, maintaining UL timing within the CP becomes very challenging even without taking multi-TRP deployments into account. When taking multi-TRP deployments into account, it becomes practically infeasible.
	+ Capture the following observation in TR 38.808: A higher UL SCS puts tighter requirements on UE UL timing and thus it is essential that the SCS selection and UE UL timing requirements are discussed jointly.
* From [15]:
	+ Proposal #1: Consider the followings as candidate numerologies to support NR in FR-X band by taking frequency utilization efficiency, unlicensed band operation, the ICI mitigation, and the UE implementation into account.
	+ SCS for other channels/signals
		- Introduce new value as 240 kHz and 480 kHz (and/or 120 kHz)
	+ Study further on potential impacts (and relevant handling) due to the shortening of OFDM symbol duration and CP length by adopting larger SCS value.
		- Whether/how to handle impact to cell coverage and/or beam switching time (e.g. by employing the extended CP, grouping multiple OFDM symbols as a unit, and/or putting symbol gap between consecutive DL/UL signals/channels)
* From [16]:
	+ Proposal 1: It is proposed to consider up to 480KHz SCS for 52.6GHz~71GHz.
* From [17]:
	+ Proposal 1: The subcarrier spacing should be discussed and decided with higher priority.
	+ Proposal 2: Support data transmission for 240 KHz for NR above 52.6 GHz to 71 GHz.
	+ Proposal 3: Support new subcarrier spacing of 480 KHz and 960 KHz for NR above 52.6 GHz to 71 GHz.
* From [20]:
	+ Observation 3: Wider SCS has robustness to frequency offset and phase noise, but impacts on CP duration.
	+ Proposal 2: Support up to 960 kHz SCS, in order to support 2.16 GHz bandwidth by single carrier.
* From [21]:
	+ Observation 4: the delay spread to be supported sets a lower limit on the SCS.
	+ Observation 7: A maximum SCS of 480 kHz has been used for multiple elements of the Rel-15/Rel-16 specification. The use of SCS > 480 kHz should be justified to reduce the specification impact.
	+ Proposal 4: Select 120 kHz, 240 kHz and 480 kHz as SCS candidates for NR operation between 52.6 GHz and 71 GHz.
	+ Proposal 5: RAN1 to study the need for selecting 960 kHz as an SCS candidate considering specification impact and possible phase noise model changes from RAN4.
* From [22]:
	+ Proposal 1: 240kHz SCS should be supported for 52.6-71GHz. 480kHz SCS is FFS.
* From [24]:
	+ Proposal 1. The support of extended CP for large numerology or SCS like 480 KHz and above should be studied for NR operation from 52.6 to 71 GHz.
* From [26]:
	+ Proposal 4: The study for the high frequency regime should prioritize NCP.
* From [29]:
	+ Observation 6: MIMO timing alignment error (TAE) should be considered during the selection of supported subcarrier spacing set for NR in 52.6–71GHz.
	+ Proposal 2: Support 480 kHz and 960 kHz SCS for NR operating in 52.6 – 71GHz.
	+ Observation 10: Extended CP may not be needed for NR in 52.6–71GHz if MIMO TAE requirement less than 65ns is defined.
	+ Observation 11: Advanced phase noise compensation methods, such as direct de-ICI compensation method, may not be suitable for NR operating in 52.6 GHz to 71 GHz.
* From [30]:
	+ The following two combinations of maximum channel bandwidth and numerology shall be supported:
		- Maximum carrier bandwidth of 2.16 GHz with SCS of 960 kHz;
		- Maximum carrier bandwidth of 400 MHz with SCS of 120 kHz.
		- Further study whether ECP is needed for 960 kHz SCS.
		- Further study whether the support of other SCS is needed.
		- Further study whether mixed numerology is needed.
* From [31]:
	+ Proposal 1: For numerology, at least one higher SCS than 120 kHz should be introduced for 52.6 – 71 GHz NR.
		- The number of SCSs to be newly supported for 52.6 – 71 GHz should be minimized
		- For 960 kHz SCS if supported for 52.6 – 71 GHz, extended CP should be considered

### 2.1.2 Discussion

##### Moderator Summary of observations and proposals from Contributions:

* Companies views are somewhat diverse and there seems to be few sub issues, (1) supporting a single SCS or multiple SCS, (2) CP length, (3) supported SCS (for channels/signals other than SSB and PRACH)
	+ Many companies seem to hint at supporting multiple SCS, although always not explicitly mentioned.
	+ Many companies are gravitating towards use of NCP and FSS on ECP usage.
	+ Companies has diverse view on supported SCS, ranging from 120 kHz to 960 kHz.
* Given that SCS and CP length are fundamental aspects needed for further progress on physical layer aspects, try to see we can come to a conclusion (if possible).

##### 1st round of Discussion:

Chairman has suggested to gather input from companies on various aspects related to numerology. Please provide comments and input for each of the topics. The moderator will try to collect the inputs from the companies and summarize them.

* Number of numerologies
* Specification impacts of numerologies
* Whether design can operate with a single numerology
* Maximum supported numerology
* NCP/ECP
* Observations on performance from evaluations
* Implementation Complexity
* Scenarios enabled by different SCS

##### Company comments on number of supported numerologies:

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|  **Company** | **Comments** |
| Futurewei | The numerology selection should be based on few basic principles such as performance, complexity of implementation , impact on the existing specification. Moreover, in the 60 GHz unlicensed band one should consider the abundence of spectrum and the almost inexistent incumbent deployments. Based on the link evaluations we observed that SCS 240 MHz is a very good compromise of the above criteria. It offers minimal changes to the existing specifications, it operates very well in channel of relative larger delay spread, and with a reduced ICI filtering, it performs very well at lower and high MCS.  |
| LG Electronics | Taking into account issues such as implementation complexity, specification impact, and so on, it might be beneficial to minimize the number of numerologies that will be supported for NR above 52.6 GHz. However, how many numerologies are to be supported will be influenced by other aspects (e.g., performance) as well. Therefore, the necessity of each candidate numerology should be justied first. |
| Ericsson | Agree that number of numerologies needs to be limited, e.g., to two. 120 kHz is a natural candidate due to existing FR2 implementations. The value for a (single) larger candidate numerology must be justified considering performance, implementation complexity, and specification impact. It is vital to have a firm view on feasible UE processing timelines and UE and BS timing error tolderances with respect to CP duration, otherwise high performance, and low latency cannot be achieved. Timing error tolerances, while in RAN4 purview, need to be understood in RAN1 before numerology can be decided. Furthermore, SCS and maximum channel BW needs to be selected together (see below for comments on max channel BW). |
| Nokia, NSB | We prefer to minimize the number of newly introduced SCS, this to minimize the specification effort. Based on our analysis, only one additional subcarrier spacing, particularly value of (µ=6) for physical data channels would be sufficient for 60 GHz scenario. Up to two new SCS values could be an acceptable compromise for us. As we already re-iterated, different SCS are suitable for different types of deployments, in terms of delay spread, coverage and ISD determining the required timing tolerances.  |
| NTT DOCOMO | In our understanding the point here would be only one numerology or multiple numerologies are supported, regardless of the exact SCS value(s) (i.e. regardless of whether to support higher SCS than FR2). Our view is at least two SCS values are necessary, one is to achieve wider BW which would be necessary for 3GPP to be competitive against 11ad/ay (of cource the exact BW will be discussed in section 2.2, but we assume at least larger BW than FR2 should be supported), and the other is to reuse the existing NR. It would be hard for only a single SCS to achieve these two goals in our view. In this sense, given carrier bandwidth, the numerology can be unique. Multiple numerologies are used to support different carrier bandwidth. |
| Lenovo/Motorola Mobility | We suggest to consider the requirements for different use cases that need to be supported and identify if one or more numerologies are needed to satisfy those requirements. Then further consideration is needed on the specification impact, UE capability, implementation complexity and performance gap with those numerologies would be needed.  |
| ZTE, Sanechips | We agree to limit the number of numerologies in 60GHz considering the spec impact. The required numerologies should be associated with the supported channel bandwidth, e.g. 120kHz with 400MHz channel bandwidth, and if the maximum supported channel bandwidth goes up to 1.6GHz, it’s clear that at least 480kHz should be supported accordingly due to the maximum FFT size limitation. So we suggest to consider the combination of supported numerologies and channel bandwidth, and at least support 2 candidate numerologies for different channel bandwidth. |
| Huawei, HiSilicon | The choice of numerology(ies) should follow from the observations on performance evaluations, adequate support of targeted use cases and scenarios including aspects such as coverage, feasibility, and specification effort. Our observations point toward supporting at least one of 120 kHz or 240 kHz SCS for scenarios maximizing coverage, including the support of bandwidths smaller than the maximum supported bandwidth, and requiring multiple channels for sharing regulated spectrum block sizes either licensed (e.g. with 4 operators) or unlicensed (with channel selection e.g. based on sensing and avoiding). Additionally supporting a larger SCS in the specifications can be considered if it is justified by a relevant use case and scenario. |
| Samsung | RAN1 shall strive minimum number of numerologies supported. The discussion can start from single numerology to be supported, and investigate whether it is suitable for all the development scenarios. If not, naturally we should consider multiple numerologies to support.  |
| vivo | Not sure that the number of supported numerologies is the total number for all channels including channels other than SSB and PRACH. Actually, the total number of numerologies are different for different channels in FR1/FR2, e.g. 1.25k/5k/15k/30k is supported for PRACH. From our point of view, to minimize implementation effort, support up to 2 numerologies for each of the above channel is preferred.  |
| InterDigital | We also sympathize that we need to limit the number of new SCSs as much as possible, however, the selections should be based on evaluation results. According to our evaluation results as well as others, Supporting up to two SCSs seems beneficial considering scenarios, delay spreads, coverage and so on.  |
| Qualcomm | We share the same view that the number of supported numerologies should be kept to minimum to minimize the specification load. Thus, an existing FR2 numerology, 120kHz, is the natural starting point. However, as many companies already pointed out, a single SCS is not versatile enough to support various applications and deployment scenarios envisioned for the 60GHz band. Thus, one additional SCS higher than 120kHz, i.e., two numerologies in total, would be enough. |
| MediaTek | Existing FR2 numerology of 120 KHz SCS should be supported and serve as the baseline. Based on evaluation results from multiple companies, the setting allows proper operation @ 60GHz (with performance degradation for high MCS cases due to PN). An additional numerology (e.g., SCS of 960KHz) could be supported if evaluation results show significant performance enhancements compared to the baseline. |
| CATT | The principle of numerology for NR operation in 52.6-71 GHz is to reuse most of current specifications for FR2 with required enhancement by introducing new numerology. The introduced of additional numerology needs to have strong justification with minimum specification impacts and implementation complexity.  |
| Sony | From the perspective of co-existence with 802.11ad/ay, we believe at least 960kHz SCS is necessary to achieve 2.16GHz with a single carrier. In addition, it has been shown in multiple LLS results that the 960kHz SCS can provide better performance than smaller SCSs due to its advantage on combat the ICI, especially for high MCS. Therefore, 960kHz SCS should be supported in frequency range between 52.6 GHz-71GHz. For licensed band operation between 52.6-71GHz, we could pick up another SCS when comprehensively considering performance, complexity, standard effort, etc. So far, 240kHz SCS for data/control channel or signals seems to be a good candidate. Stepping forward from FR2 (only up to 120kHz for data/control channel), 240kHz with half symbol duration of 120kHz may introduce shorter latency and higher bandwidth. Meanwhile the complexity and performance can somehow expected from the experience of adopting 120kHz SCS. So in total, we think at least two SCS for 52.6-71GHz are needed.  |
| Intel | One new SCS is preferred for us. However, we could agree with two new SCS values to facilitate the support of various deployment scenarios and to optimize system configurations. |
| Xiaomi | Agree to support as few as SCS as possible to alleivate spec effort and implementation complexity, a possible way can be supporting one SCS as mandatory and (maybe,if needed) some other SCS as optional. |
| OPPO | We prefer to support up to 2 numerologies, i.e., 120kHz and 960kHz. |
| Spreadtrum | The number of SCS should be kept to a minimum to minimize the specification effort. We prefer to introduce one new SCS. |
| Apple | The choice of numerology should be based on factors such as performance, implementation complexity and specification impact. Two SCSs can be supported with 1 new SCS specified e.g. 480 kHz. |

##### Company comments on specification impacts of numerologies:

*Moderator note:* For this, I suspect that this can be a long list for each subcarrier spacing. Formulating an exhaustive list during SI may not be feasible, as we may find other aspects as work progresses. Therefore, I would like to ask companies to provide a high-level description of what they think is the most impacting. We could put a disclaimer to this list to state that this is not an exhaustive list.

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|  **Company** | **Comments** |
| Futurewei | This request from moderator is not clear to me. Seems redundant. Detailed impacts are addressed in this document sections 2.3-2.13 |
| LG Electronics | Agree with Moderator’s note that we don’t need to put our efforts on making exhaustive list for specification impacts. At the same time, observing high-level view on which specification impact can be foreseen seems essential. With this regard, we provide the below table which can be used for the starting point.

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|  | 120 kHz SCS | 240 kHz SCS | 480 kHz SCS | 960 kHz SCS |
| SS/PBCH block | SS/PBCH block time domain pattern is already supported in Rel-15. | SS/PBCH block time domain pattern is already supported in Rel-15. | SS/PBCH block time domain pattern is not supported in Rel-15/16. | SS/PBCH block time domain pattern is not supported in Rel-15/16. |
| Signal or channel other than SS/PBCH block | Already supported in Rel-15. | Not supported in Rel-15/16. | Not supported in Rel-15/16. | Not supported in Rel-15/16.Time unit should be updated since it is defined as  where$ Δf\_{max}=480∙10^{3}$ Hz. |

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| Ericsson | Agree that the above table can be used as a starting point. UE processing timelines and timing error tolerances need to be established for numerologies not currently supported in Rel-15/16. |
| Nokia, NSB | With respect to 480kHz or 960kHz we expect the same amount of specification impact in RAN1. With 240kHz we believe that slot-based scheduling could still be operated, and clearly no new SSB SCS are required. We see that 960kHz can be operated also with existing Time unit. |
| NTT DOCOMO | In general wider SCS (which would be beneficial to support wider BW) could need quite some specification impacts, as captured in the last e-meeting and to be captured in this e-meeting. For the same SCS as FR2 (if supported), few impacts are assumed on PHY in our view. Another point is whether to support mixed numerology operation or not, which could also require specification impacts as well.  |
| Lenovo/MotorolaMobility | Agree with Futurwei’s comments that this is redundant. Infact, based on the summary of sections 2.3-2.13, a high level table could be created to summarize the necessary impacts with different numerologies on different channel/signals/procedures |
| ZTE, Sanechips | If larger SCSs e.g. 960/1920 kHz are supported, the short CP may be not enough to cover delay spread, beam switching time and possible timing errors. To handle above issues, it will cause larger specification impacts. The specification impacts brought by 240/480 kHz will be smaller. |
| Huawei, HiSilicon | The TR should eventually capture the outcome of the study analyzing the specification effort for each candidate numerology. Here we try to provide a more exhaustive list of specification effort for 120 kHz and 240 kHz SCS:

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| SCS | PHY impact (other than common impact for unlicensed support) |
| 120 kHz | - PTRS for CP-OFDM: for better BLER performance with high MCS, higher density PTRS or new PTRS patterns (such as block-PTRS) may need to be designed- PTRS for DFT-s-OFDM: for better BLER performance with high MCS, new PTRS pattern with more PTRS groups within one DFT-s-OFDM may need to be designed- For unlicensed: PRACH ZC lengths such as 571 and 1151 may be considered |
| 240 kHz | - PTRS for CP-OFDM: for better BLER performance with high MCS, higher density PTRS or new PTRS patterns (such as block-PTRS) may need to be designed- RO configuration- structure of DM-RS- PDCCH Monitoring- HARQ process |
| 480 kHz | - ECP is needed to account for the combined effect of some or all of delay spread, time alignment error, analog beam switching time, DL/UL switching time, and Multi-TRP delay.- SSB patterns- SSB and CORESET#0 multiplexing pattern- Scheduling, processing, HARQ timelines- RO configuration- Structure of DM-RS- PDCCH Monitoring |
| 960 kHz | - ECP is needed to account for delay spread and time alignment error.- SSB patterns- SSB and CORESET#0 multiplexing pattern- Scheduling, processing, HARQ timelines- RO configuration- Structure of DM-RS- PDCCH Monitoring |

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| Samsung | Other than 120 kHz SCS, we expect all other SCSs have similar work load for the potential specification impact. Also, to clarify, even multiple candidate numerologies are supported, the system can still operate with one of them, depending on its development scenario. So no mixed numerology is needed to be supported, which can further simplify the specification impact.  |
| vivo | We don’t think spec impact should be a criterion for numerology selection. It is a waste of time to compare then select a numerology based on the spec impact since the numerology with less spec impact may not meet the requirement of target use case. The most important criterion is whether to fulfill the target use case by the numerology. Agree with moderator’s comment, the spec impact could be a long list which needs much time and any introduced new numerologies (e.g. 480KHz/960KHz) almost share the same spec impact in RAN1.  |
| InterDigital | We agree with Samsung that we also expect all newly introduced SCSs require similar work loads for the specification impact. In addition, we don’t think that ECP is essential specification support such as 480 kHz and 960 kHz. Based on the operator’s implementation, 480 kHz and 960 kHz can be used only when the SCSs are beneficial with NCP.  |
| Qualcomm | Except 240kHz SCS, we think the specification impact of adding a new numerology, such as 480kHz or 960kHz, would not differ much. However, based on the collected view throughout the SI meetings and previous experience in Rel-15 and Rel-16, we don’t think the work load is unmanageable for the given TU. |
| MediaTek | Agree with Samsung that for all numerologies other than 120KHz SCS (if introduced), the specification impacts are similar. |
| CATT | Introducing a numerology would not only affect all specifications of physical layer structure, procedures, processing timeline but also the interaction with existing feature, such as cross-carrier scheduling. We should introduce the minimum number of new numerologies. |
| Sony | Since it is not exhaustive list, the most impacting factor to us is the maximum channel bandwidth the SCS could provide, considering the co-existence issue with 802.11ad/ay, as well as the EVM performance with the strong phase noise assumed in this frequency range. |
| Intel | Similar specification impact from SCS larger than what is currently supported in FR2. |
| Xiaomi | Agree with LG and HW that we can start by listing a table for SSB/other channel for various SCS and analysis its impact on spec/implementation complexity and so on. |
| OPPO | We share same view as Samsung. |
| Spreadtrum | We envision similar specification impacts for 480kHz SCS and 960kHz SCS. |
| Apple | We think that LG’s table could serve as a good starting point for discussion. |

##### Company Comments on whether design can operate with a single numerology:

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|  **Company** | **Comments** |
| Futurewei | Prefer a single numerology that performs well at lower and higher MCS, that mitigates ISI due to larger delay using NCP and offers longer SSB cover range.  |
| LG Electronics | Similar to start of NR-U SI discussion, we can conclude that being able to operate all DL (and/or UL) signal/channels with the same numerology for a carrier is beneficial in terms of lower complexity and no required measurement gap. However, it doesn’t necessarily mean that we necessitate to design 480 kHz SS/PBCH block in case 480 kHz SCS is to be introduced, e.g., considering non-stand-alone case. |
| Ericsson | From a coverage point of view, it is beneficial to operate an initial DL/UL BWP using existing FR2 numerologies for SS/PBCH and PRACH. Additional BWP(s) can be configured with larger numerology to achieve higher data rates as needed, and when coverage allows. In this sense, support of different numerology for SS/PBCH block and data/control is acceptable compared to re-design of all existing signals/channels to guarantee coverage. Agree with LG in that for NSA operation, it is not necessary to support 480 kHz SS/PBCH block to be able to operate in a 480 kHz BWP. Existing FR2 numerologies (120/240 kHz) work well. |
| Nokia, NSB | For 480kHz or 960kHz SCS, design of corresponding SSB/PRACH SCS is required to achieve single numerology deployments, but design could be straightforward. Single or mixed SCS deployments should be implementation option and dependent on scenario of use. |
| NTT DOCOMO | In our understanding, this is related to whether to support mixed numerology operation or not. As we described above, mixed numerology operation would require a certain amount of specification impacts. It also lead to implementation complexity. Therefore a single numerology operation can generally be preferred in our view. On the other hand, below aspects may need to be considered:* Among signals/channels other than SSB, it may not be neccesary to support mixed numerology operation as well as FR2. On the other hand, some channels with fixed duration (e.g. PRACH, PUCCH) may suffer from coverage issue due to shortened OFDM symbol length by higher SCS. Mixed numerology b/w channels with fixed duration and others can be beneficial.

Between SSB and data, in our evaluation lower SCS performs better slightly. Thus, if higher SCS is applied to data, mixed numerology between SSB and data can be beneficial.  |
| Lenovo/Motorola Mobility | Based on stringent requirements in terms of BLER and/or throughput, we think that a higher numerology such as 960kHz would be more suitable. However, for less stringent requirements such as higher BLER and/or lower MCS, lower numerology should suffice. So, in our view, supporting two numerologies would be reasonable. Also, agree with LG and Ericsson’s comment that it is not necessary to support same set of numerologies for SSB/PBCH and other data/control channels |
| ZTE, Sanechips | We don’t see the need to restrict data/control channels using the same numerology with SSB/PBCH and PRACH since the requirements for these signals are different. To achieve a high data rates, a larger channel bandwidth and associated SCS is needed. As for SSB/PBCH and PRACH channel, the existed NR numerology is enough considering the coverage. |
| Huawei, HiSilicon | We agree with Ericsson that support of different numerology for SS/PBCH block and data/control is acceptable compared to re-design of all existing signals/channels to guarantee coverage. From the network point-of-view, we don’t think it is necessary that the same numerology be used by all UEs, in case multiple numerologies for data are supported. If there is a need for a mode where all signals and channels operate with the same numerology, then 120 kHz SCS achieves that based on current specifications. |
| Samsung | In Rel-16 NR-U, we discussed this issue, and the conclusion was supporting same numerology for all the channels and signals is beneficial for implementation. RAN1 shall at least provide the feasibility to support implementing all the channels and signals using the same numerology.  |
| vivo | Single numerology is preferred for implementation simplicity if a single numerology can fulfil the requirements for all expected deployment scenarios. However, in case that’s not possible, we’re open to have different numerologies between SSB and other channels if needed. |
| InterDigital | While single numerology can achieve simple implementation and specification support, we are open to have different numerologies especially for SSB and PRACH considering coverage issues. |
| Qualcomm | Mixed numerology operation is an intrinsic feature of NR, and we think it should also be supported in the 60GHz band. However, we think at least the same numerologies should be supported for different channels. If we introduce a new SCS (e.g., 960kHz) only for data channels and not for SS/PBCH, then it may induce practical issues, particularly in SA operation; some details if the issues are discussed in our comments in Section 2.3. |
| Mediatek | We prefer single numerology operation. However, if SCS of 480 KHz or 960 KHz is supported, we are also fine with having the SSB operating at 120 kHz SCS. |
| CATT | Single numerology works fine without further complication.  |
| Sony | Don’t prefer single numerology operation. There seems no clear evidence to restrict all channels/signals to operate with the same SCS. On the contrary, the NR system are designed with different performance requirements for different channels/signals. Assuming 960kHz SCS supported for data channel, e.g. PDSCH, we may not need to support 960kHz SSB for DL coverage and synchronization.  |
| Intel | The ability for a deployment to utilize same numerology for all channel and signal operations is preferred as it would allow gNB and UE to streamline operations. We recognize that some specific deployment might benefit from having mixed numerology operation. However, we do not think that this potential benefit should purpose as a justification for mandating only mixed numerology operation by having only misaligned numerology among SSB/COREST#0 and other control/data channels signals as it significantly complicates implementation and deployment for scenarios that do not require such operation. |
| Xiaomi | Agree with LG and Ericsson. But also think that even design can operate on a single numerology, UE/gNB may be able to support multiple SCSs.  |
| OPPO | Mixed numerology works fine and we don’t see the necessity to support single numerology operation. |
| Spreadtrum | In order to simplify the implementation, we prefer single numerology operation. |
| Apple | We agree with Ericsson and Huawei that there is no need to mandate the same numerology for the SS/PBCH and data channels. The current numerology for SS/PBCH shows good performance in this spectrum band and changing this would require (a) a re-design of the entire SS/PBCH block and (b) result in non-reuse of existing FR2 implementations.  |
| Convida Wireless | We are fine with single numerology for SSB and PRACH and are open with different numerologies for SSB and PRACH design. |

##### Company Comments on maximum supported subcarrier spacing and NCP/ECP usage:

*Moderator note:* Provide inputs on supported maximum subcarrier spacing and NCP/ECP usage for the supported subcarrier spacing.

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei |  Prefer NCP, and a maximum SCS of 240 kHz |
| LG Electronics | We prefer SCS up to 480 kHz, with NCP. |
| Ericsson | Agree with LG – consider up to 480 kHz with NCP. Use of ECP is unjustified – we have demonstrated that 960 kHz + ECP has a 6 dB degradation compared to 480 kHz + NCP at 10% PDSCH BLER when comparing on the basis of equal data rate; ECP requires a larger effective code rate to support the same data rate. |
| Nokia, NSB | We observed that when SCS is selected correctly for the target scenario, NCP is sufficient for up to 960kHz. Based on that we propose to prioritize NCP in 60 GHz studies. ECP can be considered later, if needed. |
| NTT DOCOMO | We are ok with 960 kHz as max. candidate SCS. Also ok with NCP as a baseline and ECP for further study and/or discussion.  |
| Lenovo/Motorola Mobility | For 1% BLER requirement (with higher MCS), 960kHz performs significantly better and for that reason we think that 960 kHz could be considered as the maximum SCSFor CP, there is no need for ECP for SCS upto 480kHz and ECP should only be supported with 960kHz, if agreed |
| ZTE, Sanechips | We prefer SCS up to 480kHz, with NCP. |
| Huawei, HiSilicon | Our observation is that NCP is not sufficient for SCS larger than 240 kHz when we consider the combined effects of all or some of delay spread, time alignment error, analog beam switching time, DL/UL switching time, and Multi-TRP delay. If a SCS like 120 or 240 kHz is supported for scenarios that require relative large CP, then there is no need to optimize the CP for larger SCS like 480 or 960 kHz (if supported) for indoor environments with small delay spread where the target would be to support very large aggregated bandwidths (> 2 GHz) rather than coverage. |
| Samsung | 960 kHz SCS has much better performance gain over other SCS regarding the 1% BLER, so we consider 960 kHz SCS as the maximum SCS, and can further study whether ECP is needed for 960 kHz SCS.  |
| vivo | Prefer NCP and a maximum supported SCS of 960 kHz |
| InterDigital | Our preference is supporting SCSs up to 960 kHz with NCP |
| Qualcomm | Based on our observation from a system-level analysis, we think NCP is enough for a higher SCS up to 960kHz, particularly in the scenarios that 960kHz is beneficial over 120kHz, e.g., indoor, unlicensed, wide band, and high peak rate applications. The scenarios that see large delay spreads are usually large coverage, licensed, small bandwidth, and low-to-medium peak rate applications, and can be covered by 120kHz SCS.  |
| MediaTek | We prefer maximum SCS of 960KHz and NCP only. |
| CATT | NCP is sufficient for SCS below 480 kHz. The support of 960 kHz SCS needs strong justification.  |
| Sony | We prefer SCS up to 960kHz with NCP, and ECP can be FFS. |
| Intel | 960 kHz SCS with NCP. The applicability of ECP is FFS depending on RAN4 feedback on MIMO TAE requirements. For smaller SCS than 960 kHz, NCP seems to be sufficient (based on our analysis). |
| OPPO | NCP is enough. |
| Spreadtrum | We prefer SCS up to 480kHz with NCP. |
| Apple | SCS up to 480 kHz with NCP.  |
| Convida Wireless | Agree for SCS up to 960 KHz. The need to support of ECP for large SCS e.g., 480 KHz and above should be further studied for NR operation from 52.6 to 71 GHz. |

##### Company Comments on implementation complexity:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | {120 kHz, 240 kHz } low spec impact, with ICI filter perform well for low and high MCS, {480 kHz,960 kHz } substantial changes to the specs, potential lower spectrum efficiency with the use of ECP. |
| LG Electronics | At least, numerologies that are already supported for FR2 should be also supported for frequency range over 52.6 GHz, which can minimize additional implementation complexity. |
| Ericsson | Clearly, implementation burden is eased by minimization of the enhancements that are specified for operation in 52.6 – 71 GHz. Only enhancements that have a clear technical and performance benefit should be considered. |
| Nokia, NSB | Unlike 480kHz SCS, 960kHz SCS may be operated up to 64QAM without ICI compensation. ICI compensation clearly increases complexity. Particularly 64QAM with 480kHz has trouble in wide channels, such as 1600MHz, which is a scenario for high SCS deployments. Furthermore, 960kHz will minimize the number of component carriers (as we shown in our TDOC) needed for support of certain bandwidth, this also clearly decreases the implementation complexity  |
| NTT DOCOMO | As we described on ”whether design can operate with a single numerology”, mixed numerology could lead more complexity to implementation.  |
| Lenovo/MototolaMobility | Effort should be to support one or more numerology withtout significant impact on implementation complexity. Therefore, all the enhancements that should be considered should aim towards reasonable complexity |
| ZTE, Sanechips | Reuse FR2 numerologies as much as possible and minimize specification impacts to reduce implementation complexity, except for some necessary enhancements for above 52.6 GHz e.g. to match larger bandwidth.Compared with CPE compensation, ICI shows larger implementation complexity and better performance especially for lower SCS. In our opinion if the ICI compensation could be based on the existed Rel-15 PTRS pattern, the increased complexity is worth it since the spec impact could be alleviated. |
| Huawei, HiSilicon | Implementation complexity is well understood for SCS already supported by NR. If the only major enhancement for PHY is the design of denser PTRS and the implementation of ICI compensation at the receiver then this is clearly less challenging than the brand new design required to support the shorter sampling rates, processing timelines and switching times required with 480 or 960 kHz SCS.We do not think that the complexity of CA is prohibitive up to 8 component carriers, since requirements for such band combinations are already specified in 5G. Reaching aggregated channel bandwidth on the order of 2 GHz does not require more than 5 carriers with 120 kHz SCS.  |
| Samsung | It is not quite desirable to introduce too much change to the implementation side, e.g. more advanced receiver algorithmAlso, it would be beneficial to provide the implementation possibility to use a single carrier to achieve wide carrier bandwidth (e.g. 2.16 GHz), which implies a preference to 960 kHz SCS |
| vivo | The implementation complexity should be compared when achieving the same target which fulfill the requirement of a particular use case, e.g. peak data rate, maximum channel bandwidth and etc. For example, in the following table, supporting the same peak data rate 10Gbps, (960K, NCP) needs the minimum number of carriers and doesn’t need ICI. In this sense, (960K, NCP) has the least implementation complexity.

|  |  |  |  |
| --- | --- | --- | --- |
| **Numerology** | **Maximum supported MCS** | **Peak Data Rate for a single carrier** | **Number of carriers for 10Gbps data rate** |
| (120 K, NCP) w/o ICI | MCS 16 | 758 Mbps | 14 |
| (240 K, NCP) w/o ICI | MCS 16 | 1516 Mbps | 7 |
| (120 K, NCP) with ICI | MCS 22 | 1516 Mbps | 7 |
| (240 K, NCP) with ICI | MCS 22 | 3032 Mbps | 4 |
| (480 K, NCP) w/o ICI | MCS 22 | 4603 Mbps | 3 |
| (960 K, NCP) w/o ICI | MCS 22 | 5754 Mbps | 2 |

 |
| InterDigital | We also agree with Nokia that applying ICI filter increases UE complexity and carrier aggregation based specification support increases control signaling overheads.  |
| Qualcomm | Implementation complexity is also bundled with UE capability and processing timeline discussion, which will follow in later sections. Therefore, we don’t think it is a critical factor for the numerology selection, unless the basic operations, such as RF, FFT, etc., are feasible. |
| MediaTek | Complexity should be defined w.r.t. FR2 baseline. From this perspective, options with more specification impacts lead to more implementation complexity. Regarding ICI filter/equalizer, we think simple linear equalizer could enhance performance significantly without much increase in complexity. |
| CATT | Higher SCS implies higher sampling rate and faster processing time. We should consider the practical implementation on the sampling rate.  |
| Sony | We share a similar view as Nokia that supporting 960 kHz SCS can minimize the number of CCs for supporting 2.16 GHz, also it can reduce the complexity in ICI compensation design. So, we think that supporting 960 kHz SCS can be a benefit to reduce the implementation complexity. |
| Intel | From perspective of time required for signal processing, it’s similar complexity of SCS larger than what is currently supported in FR2. However, the considered SCS values other than 960 kHz require advanced ICI compensation techniques to operate with 64QAM. The complexity of these techniques is higher than in case of simple CPE compensation used for SCS = 960 kHz to enable 64QAM. Moreover, even with ICI compensation the SCS values smaller than 960 kHz cannot operate with some higher-order MCSs (e.g. MCS 28) and/or small frequency allocations. In other words, ICI compensation cannot be considered as a universal solution for SCSs up to 960 kHz. |
| OPPO | We share same view as Nokia. |
| Apple | Essentially, the discussion on the maximum SCS is a trade-off between signal processing complexity (assuming an ICI filter) and complexity brought about by the increased timing constraints as we increase the size of the SCS. Both issues should be considered. Note that as pointed out by Huawei and Ericsson, the phase noise model used for evaluations is relatively conservative compared with reality and may result in an over-design in our choice of SCS. As such, there may not be a need to implement aggressive PN ICI compensation  |

##### Company Comments on Scenarios enabled by different SCS:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Indoor/Outdoor enabled by :{120 kHz,240 kHz,480 kHz }, Indoor mainly{960 kHz }. We do not see necessary to have special numerology for indoor only scenarios if there are numerologies that perform equally well both in idoor and outdoor scenarios. |
| Ericsson | We do not see that 960 kHz enables any more scenarios than 480 kHz SCS. In fact, 960 kHz is penalized, even indoors, due to timing error tolerances exhausting the CP budget. Furthermore, environments such as InF-DH with larger delay spread become especially problematic. |
| Nokia, NSB | 120kHz provides an evolutionary solution for outdoor deployments, and with ICI compensation may enable support of up to 64QAM.Unlike 480kHz and below, 960kHz SCS provides a competitive solution to WiGig for indoor deployments, when it comes to high peak data rates and low cost implementations (no ICI compensation needed with 960kHz SCS). |
| NTT DOCOMO | No strong view from our side. One possible point may be whether it is operated in licensed or unlicensed band. Given 11ad/ay, wider BW may be more required in 60 GHz unlicensed band, which could be achieved by higher SCS. On the other hand, similar BW to FR2 could be reused in 60 GHz licensed band, which could be achieved by the existing (or relatively smaller) SCS, expecially for outdoor scenario.  |
| Lenovo/MotorolaMobility | In addition to deployment scenarios, also the target requirements for different use cases that would be supported in those scenarios are important |
| ZTE, Sanechips | We think each of {120 kHz,240 kHz,480 kHz} could be used for both indoor and outdoor. We do not think it is necessary to determine numerologies according to usage scenarios. |
| Huawei, HiSilicon | Since 3GPP is primarily designing solutions for cellular networks, it is important to ensure that some configurations are available that maximize the coverage, and those scenarios are best served with 120 kHz SCS and relatively smaller carrier bandwidths. It is not clear that using a larger SCS like 960 kHz with the same maximum FFT size allows achieving larger throughputs than 120 kHz with the same FFT size. Achieving larger throughput is achieved by CA on top of the largest supported single carrier bandwidth. So in any case, CA needs to be supported and as written in response to the question on complexity, we don’t see any feasibility issue with CA. Just matching the maximum single carrier bandwidth as WiGiG does not ensure the same peak rate. |
| Samsung | From our observation, two numerologies, 120 kHz and 960 kHz SCS, are sufficient to cover all the development scenarios, and each has its own benefit. * 120 kHz SCS is more suitable for larger coverage and low MCS scenario
* 960 kHz SCS is more suitable for higher throughput and high MCS scenario
 |
| vivo | In general, there are two kinds of scenarios, indoor and outdoor.For outdoor scenario, 120KHz is a good candidate with large coverage;For indoor scenario, one of the target use case is to enable application with peak data rate around or above 10Gbps, (960K, NCP) is preferred with minimum implementation complexity as discussed above in complexity part. |
| InterDigital | We do see a necessity of supporting 960 kHz SCS as 960 kHz SCS achieves the best performance without implementing any additional interference mitigation algorithm. According to our evaluation results, 960 kHz fully satisfies the requirement that some scenario requires. For other scenarios, we are open to consider 120 kHz or 480 kHz. |
| Qualcomm | We share the same view as Nokia and vivo. 120kHz is predominant for outdoor, large coverage, relatively small bandwidth, and high EIRP scenarios, while 960kHz is for indoor, large bandwidth, unlicensed, high peak rate scenarios. |
| MediaTek | 120KHz SCS should be able to support both indoor and outdoor scenarios, while 960KHz could support indoor, high throughput scenario. |
| CATT | For 52.6-71 GHz, the propagation and penetration losses are severe. There is very little benefit to support different numerology. Single numerology is sufficient for both indoor and outdoor. |
| LG Electronics | We share the view with Ericsson and ZTE. SCSs up to 480 kHz can be used for any deployment scenarios. |
| Sony | Our understanding on determining numerologies is that we perhaps need to pay more attentions on the key performance metrics in EVM, co-existence with 802.11 ay/ad implementation complexity, etc, rather than the scenarios (either indoor or outdoor). |
| Intel | While it is difficult to list all potential deployment scenarios and the recommended bandwidths with corresponding SCS, we acknowledge that supporting various deployment cases with a single SCS could be difficult.For the deployment scenarios tested (outdoor LPN-like scatter deployments, Indoor deployments), SCS = 960kHz seems to be able to meet the requirements. While it may be possible to obtain longer coverage with use of smaller SCS, it’s not clear to us whether 60 GHz operation actually needs to target for coverage. There are various other FR1 and FR2 bands supported in NR, that have far better coverage that can be exploited if coverage is important. We believe the main usage for 60 GHz lies in extreme high throughput and low latencies that make the band attractive and the NR technology competitive with rivals such as WiGig technology.To support other use cases and deployment scenarios such as indoor factory hall, we think supporting 480 kHz SCS could be sufficient. |
| Xiaomi | A higher SCS, such as 960kHz can be used in scenarios with lower delay spread,mainly for indoor. For outdoor, larger delay spread can be expected and is more suitable for lower SCS such as 120kHz. And for sure, lower SCS can also apply to indoor scenario,but may not be able to achieve that high data rate as 960kHz |
| OPPO | We think that 960 kHz is at least for peak-data-rate-driven scenario. |
| Apple | We do not think it is necessary to tie SCSs to specific scenarios. On the peak data rate issue, this can be achieved with CA.  |

##### Moderator summary of comments received:

* For number of supported numerologies
	+ Majority of the companies mentioned number of supported numerologies should be minimized.
	+ Some companies have noted that introduction of a supported numerology should taking into account performance, implementation, impact on specification, and justified by relevant user case and scenario.
	+ Some companies have noted that selection of the numerologies should also be associated with supported bandwidths, and numerology and bandwidths supported should be decided together.
	+ Some companies have noted while keeping supported number of numerologies to a minimum is important, single numerology may not be versatile enough to support various applications and deployment scenarios.
	+ A company have noted RAN1 should start with single numerology and introduce more only if needed.
	+ Some companies have mentioned they would be able to accept up to two numerology.
		- Some subset of companies has mentioned if two numerologies are supported, one should be from the supported numerology in current NR specification and the another should be a new numerology.
* For specification impact of numerologies:
	+ Some companies commented defining a non-exhaustive table is redundant as companies have provided potential specification impact and issues in other sections of this summary.
	+ Most companies seem to agree that specification impact and effort other than currently supported SCS, 120 kHz, would be similar.
	+ Some companies mentioned that effort to standardize 240kHz could be relatively smaller.
	+ A company mentioned that specification impact should not be sole criteria for selection of numerology and support and fulfillment of target use case and scenario is key.
	+ Below table can be starting point to compile potential specification impact.

|  |  |
| --- | --- |
| SCS | Potential PHY impact |
| Common to all SCS | Support of unlicensed operationIf mixed numerology is supported, additional PHY impact from supporting mixed numerology operation.SSB and CORSET#0 offsets from supported channelization |
| 120 kHz | Potential PTRS enhancement for CP-OFDM and DFT-s-OFDM |
| 240 kHz | Potential PTRS enhancement for CP-OFDM and DFT-s-OFDMRO configurationPotential enhancement to DM-RSPDCCH monitoringHARQ processPotential enhancement to DM-RSPDCCH monitoringHARQ process |
| 480 kHz | Note: Similar specification impact envisioned between 480 and 960 kHz.Potential consideration of ECPSSB patterns, and SSB/CORESET#0 multiplexing patternsScheduling, processing, HARQ timelinesRO configurationPotential enhancement to DM-RSPDCCH monitoringHARQ process |
| 960 kHz |

* For whether design can operation with single numerology
	+ Some companies commented that operation with a single numerology beneficial, and there will be some associated effort in supported mixed numerology.
	+ A company commented that mixed numerology operation is functional and there is no need to support single numerology operation.
	+ Some companies commented SSB SCS could be an exception to the single numerology operation.
	+ Some companies commented need to have same SCS between SSB and other channels may not be warranted.
* For maximum supported subcarrier spacing
	+ Many companies seem to agree that for SCS up to 480 kHz NCP is sufficient.
	+ Some companies observed that NCP is sufficient for 960 kHz. Some companies commented ECP could be considered further and a company commented ECP can be considered depending on RAN4 feedback.
	+ A company commented that use of 960 kHz with ECP may result in performance degradation compared with 480 kHz with NCP.
	+ As for the largest subcarrier being considered:
		- 120 kHz: no company provided comments
		- 240 kHz: 3 companies
		- 480 kHz: 6 companies
		- 960 kHz: 11 companies
* For implementation complexity
	+ Based on comments from companies, implementation complexity discussion spans complexity involving processing ICI compensation, ability to support faster processing latency, complexity in supporting a number component carriers to reach a target throughput.
	+ A company noted that overall implementation complexity is dependent on the supported features from UE capability and processing timeline (to be yet defined for SCS not supported in current NR).
* For scenarios enabled by different SCS
	+ Companies have commented one specific SCS may not necessarily support more deployment scenarios compared to another specific SCS. So, the discussion on whether a SCS supports more or less deployment scenarios might not be the best discussion direction.
	+ Based on commented received, larger SCS seems to be geared towards indoor scenarios or peak data-rate driven scenarios, while smaller SCS seems to be geared towards indoor and outdoor scenarios or coverage driven scenarios.

##### Conclusions from GTW Session

* **Agreement:**
	+ Numerologies below 120 kHz or above 960 kHz are not supported for any signal or channel.
* **Agreement:**
	+ For operation in 52-71 GHz:
		- 120 kHz should be supported
		- Up to two additional SCS may be considered and at least one should be supported
		- FFS: Applicability of additional SCS to particular signals and channels

##### 2nd round of Discussion:

If narrowing down the applicable SCS is difficult at this time due to diverse views from companies, as chairman guidance, moderator asks to focus on compiling relevant information that may be able to be captured into the TR for conclusion of applicability and issues for each candidate SCS.

For this moderator suggest to split the conclusions into three categories, (1) issues/observations that are applicable to all numerologies or with regards to overall system operation and standardization efforts (and not limited to a specific numerology), (2) issues/observations that are applicable to smaller subcarrier spacing (e.g. 120 or 240kHz) and larger subcarrier spacing (e.g. 480 or 960kHz), (3) issues/observations for each specific numerology, 120, 240, 480, and 960 kHz.

Please provide comments on the bullet listed text. If there are additional aspects that should be listed, please suggest them as well. We can discuss further about the ordering of the bullets. Moderator suggest first focus on getting each bullet stable and work further on how to order them. Bullets are enumerated so that they can be referenced.

(1) Issues/observation that are applicable to all numerologies, or with regards to overall system operation and standardization efforts (and not limited to a specific numerology)

1. RAN1 observes amount of specification effort increases with larger number of numerologies enabled and supported for 52.6 GHz to 71 GHz frequency.
2. In order to minimize specification effort while maximizing supported use cases and deployment scenarios applicable for 52.6 GHz to 71 GHz frequency, RAN1 recommends support of 120 kHz subcarrier spacing with normal CP length, and at least one more subcarrier spacing. RAN1 recommends consideration of supporting at most up to three subcarrier spacings, including 120 kHz subcarrier spacing.
3. In order to bound implementation complexity, RAN1 recommends limiting maximum FFT size required to operate system in 52.6 GHz to 71 GHz frequency to less or equal to 4096 and limiting maximum of 275 RBs per carrier.
4. RAN1 recommends consideration of numerologies from 120 kHz to 960 kHz, and numerologies outside this range are not supported for any signals or channels.
5. Selection of the additional subcarrier spacing (on top of 120 kHz) should consider versatility of being able to support various applications and deployment scenarios with all the subcarrier spacings that would be supported by specification.
6. Some companies have noted that ability for a deployed system to operate with a single numerology for all channels and signals, with the possibility of exception to SSB numerology, is beneficial. Some companies have noted mixed numerology operation is functional and consideration of single numerology operation is not needed.
7. Overall implementation complexity for supporting a specific subcarrier spacing may need to consider the following, but not limited to:
	1. processing complexity for equalization and potential inter-carrier interference mitigation and compensation,
	2. complexity in support of multiple component carriers to reach a specific target throughput
	3. ability to process signals in time frames relative to symbol duration for each subcarrier spacing
	4. supported features indicated by UE capability signaling or implemented by the gNB
	5. [*Moderator: please provide additional aspects if any. Don’t need this to be exhausitive, so if there are formulation that could be generic, that would be preferred*]

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| --- | --- |
|  **Company** | **Comments on (1)** |
| Nokia, NSB | 1. “RAN1 observes amount of specification effort increases with ~~larger~~ the number of numerologies enabled and supported for 52.6 GHz to 71 GHz frequency.”

4) ”RAN1 recommends consideration of numerologies 240 kHz, 480kHz and 960 kHz,”1. Some companies have noted that ability for a deployed system to operate with a single numerology for all channels and signals, with the possibility of exception to SSB numerology, is beneficial. Some companies have noted mixed numerology operation is functional and consideration of single numerology operation is not needed.  For example using 120kHz for intial BWP and higher SCS for dedicated BWP.
 |
| Lenovo,Motorola Mobility | Agree with Nokia’s proposed updates to 1) and 4)I suppose Nokia’s last proposed update is to 6) not 8). We don;t think that there is a need to add the example as the text is quite self explanatory. Agree with rest of the bullets as well. |
| Qualcomm | Agree with the proposal with Nokia and Lenovo’s update. |
| InterDigital | Agree with the proposal from Moderator and updates from Nokia and Lenovo with the following update.4) RAN1 reccomends consideration of numerologies 240 kHz, 480 kHz and 960 kHz as additional numerlogies in addition to 120 kHz. |

(2) issues/observations that are applicable to smaller subcarrier spacing (e.g. 120 or 240kHz) and larger subcarrier spacing (e.g. 480 or 960kHz)

*Moderator note: for observations based on evaluated cases, those can be address in 8.2.3 discussion thread, and moderator suggests focusing on aspects that aren’t able to be directly derived by evaluations.*

1. RAN1 observes in general smaller subcarrier spacing may potentially provide larger coverage due to use of smaller bandwidth and gears towards (but not limited to) indoor and outdoor scenarios or coverage driven scenarios.
2. RAN1 observes in general larger subcarrier spacing may potentially provide higher peak data rates due to use of larger bandwidth and gears towards (but not limited to) indoor scenarios or peak data-rate driven scenarios.

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| --- | --- |
|  **Company** | **Comments on (2)** |
| Nokia, NSB | Agree |
| Lenovo, Motorola Mobility | Agree |
| Qualcomm | Agree |
| InterDigital | Agree |

(3) issues/observations for each specific numerology, 120, 240, 480, and 960 kHz.

*Moderator note: for the list in (3)-2 and (3)-3, we can continuously build up as we get further agreements and progress.*

1. Some companies noted that standardization effort to support 240 kHz, 480 kHz, and 960 kHz numerologies are comparable. Some companies noted that standardization effort for 240 kHz numerology could be relatively smaller compared to 480 kHz or 960 kHz numerologies.
2. The following, which is not an exhaustive list, are some potential physical layer impact that are common to all numerologies:
	1. supporting unlicensed operation
	2. if mixed numerology is supported, supporting mixed numerology operation.
	3. SSB and CORSET#0 offsets needed for supported channelization
3. The following, which is not an exhaustive list, are some potential physical layer impact areas for each numerology:
	1. 120 kHz:
		1. Potential PTRS enhancement for CP-OFDM and DFT-s-OFDM
	2. 240 kHz:
		1. Potential PTRS enhancement for CP-OFDM and DFT-s-OFDM
		2. If needed, SSB patterns, and SSB/CORESET#0 multiplexing patterns
		3. RO configuration
		4. Scheduling, processing, HARQ timelines
		5. Potential enhancement to DM-RS
		6. PDCCH monitoring
	3. 480 kHz and 960 kHz:
		1. Potential consideration of ECP
		2. SSB patterns, and SSB/CORESET#0 multiplexing patterns
		3. Scheduling, processing, HARQ timelines
		4. RO configuration
		5. Potential enhancement to DM-RS
		6. PDCCH monitoring

|  |  |
| --- | --- |
|  **Company** | **Comments on (3)** |
| LG Electronics | Even though we agree that similar specification impact can be expected for 480 and 960 kHz SCSs, we prefer to separate them. To be specific, for 480 kHz, potentail PT-RS enhancement can be considered as well. Furthermore, for 960 kHz, time unit needs to be re-defined since it is currently defined as  where$ Δf\_{max}=480∙10^{3}$ Hz. |
| Nokia, NSB | 1) We agree with LG that potential PTRS enhancement are applicable also to 480kHz not only 240kHz. 2) Potential consideration of ECP depending on deployment scenario3) Time unit update: Or understanding is that current timing unit is applicable to up to 2000MHz irrespective of SCS. So 960kHz with 2k FFT may work as well with current Tc. Moreover, changes to Section 4.3.2 of TS 38.211 are expected anyway with introduction of new SCS, even if Tc is updated |
| Lenovo, Motorola Mobility | Agree with LG’s suggestion to separate impact areas for 480kHz and 960kHz. Also, agree that PT-RS enhancement should be considered for 480kHz as well. |
| Futurewei | Agree with Moderator’s proposal. Our simulations showed that time density increase of PTRS is good enough for de-ICI at all SCS where de-ICI is applied, including 240kHz and 480kHz |
| Qualcomm | Agree with LG’s view. |
| InterDigital | We agree with Nokia that the current timing unit may be applicable and degree of specification impacts of 960 kHz can be similar with other additional SCSs |

## 2.2 System Bandwidth & Channelization

### 2.2.1 Observations and Proposals from Contributions

From [3]:

* + Observation 6: There is no significant difference between using multiple component carriers with a smaller SCS or a single carrier with a larger SCS in terms of signalling overhead and spectral efficiency. UE capabilities for aggregating up to 8 component carriers is already specified for NR.
	+ Proposal 2: 400 MHz can be the starting point for the maximum bandwidth of a single carrier in the frequency band between 52.6 GHz and 71 GHz.
	+ Proposal 3: For NR system operating in 52.6 GHz to 71 GHz, NR should be designed with minimum 32 RBs per carrier. The supported minimum carrier bandwidth for a cell is 50 MHz.
	+ Proposal 4: The choice of supported maximum carrier bandwidth for NR operating in 52.6 GHz to 71 GHz should ensure a minimum of at least 6 channels in any regulated range.
* From [5]:
	+ Observation 4: (960K, NCP) and (960K, ECP) could achieve a comparable maximum carrier bandwidth (i.e. 2 GHz) as 802.11ad/ay.
	+ Proposal 12: NR design in the frequency range of 52.6 – 71 GHz should support multiple channel bandwidths for different deployment scenarios and considering different available regional frequency allocations.
* From [7]:
	+ Proposal 1: Study multiples of 400 MHz up to 2 GHz should be considered for frequencies from 52.6 GHz to 71 GHz.
	+ Proposal 2: Study potential coexistence issue with other RAT in the spectrum of 52.6 GHz to 71 GHz.
* From [8]:
	+ Proposal 1: The maximum system bandwidth should be supported at least 1 GHz and up to 1.6 GHz. The system analysis of supporting more than 1.6 GHz system BW should be carefully evaluated before making the decision.
* From [10]:
	+ Proposal 1: Define channelization according to 2.16 GHz CBW, which is preferred from coexistence point of view.
	+ Proposal 2: Support sub-channelization for 2.16 GHz channels to facilitate smooth coexistence for narrowband operation.
	+ Observation 3: For given bandwidth, 960 kHz SCS supports considerably smaller number of component carriers (CC) compared to 480 kHz SCS. Reduced number of CCs allows for smaller system complexity, smaller system overhead and better RF efficiency (e.g. lower MPR).
	+ Proposal 3: For operation without CA, support two CBWs: 400 MHz (120 kHz SCS) and 2.16 GHz (960 kHz SCS)
	+ Proposal 4: Support CA within a 2.16 GHz channel, and between 2.16 GHz channels
	+ Proposal 5: Consider n x 400 MHz, n=[2, 3, 4, 5] as the supported channel BW options for CA operation within a 2.16 GHz channel.
* From [13]:
	+ Proposal 1: The following options are proposed for determining channel bandwidth(s) for Rel-17 NR beyond 52.6 GHz, wherein Option 2 is preferred.
		- Option 1: Align the channelization of Rel-17 NR with Wi-Fi design at least in unlicensed band (e.g. 57 GHz - 71 GHz) and support 2.16 GHz channel bandwidth
		- In other licensed frequency band (e.g. 52.6 GHz - 57 GHz) or in a controlled environment without Wi-Fi devices, it can be designed uniformly with unlicensed band (i.e. 2.16 GHz) or independently (e.g. 400/800/1600 MHz)
		- Option 2: No need to align the channelization of Rel-17 NR with Wi-Fi design even in unlicensed band. Support the same bandwidth(s) (e.g. 400/800/1600 MHz) in licensed and unlicensed frequency bands
		- Option 2-1: No need to support a nominal channel bandwidth of 2.16 GHz
		- Option 2-2: Support a nominal channel bandwidth of 2.16 GHz by the aggregation of above basic bandwidth(s) (e.g. 400/800/1600MHz)
	+ Observation 1: Considering the requirement of OCB and the limitation of the maximum number of available RBs, it is difficult to use less than 480 kHz as the candidate SCS for 2.16 GHz bandwidth if it should be supported.
	+ Proposal 5: In addition to the existing supported 120 kHz, 240/480/960 kHz can be served as the candidate SCS(s) for the maximum carrier bandwidth(s) 400 MHz, 800 MHz and/or 1600 MHz channel bandwidth.
* From [14]:
	+ Capture the following observation in TR 38.808. If NR adopts the same channelization design as IEEE 802.11ad/ay, large wastage of spectrum would occur in many regions.
		- 240 MHz at the lower edge of the band is unused in all regions
		- 800 MHz at the upper edge of the band is unused in USA and Europe
		- 680 MHz of the 5 GHz allocation in China is unused
			* In recognizing the need to have at least three channels for cell planning [22], IEEE 802.11aj standard defined four 1.08 GHz channels nested within the two 2.16 GHz channels for the 60 GHz band in China. As a result, the spectrum wastage issues are left unaddressed in the 802.11aj channelization.
		- 280 MHz of the 7 GHz allocation in Canada/Brazil/Mexico is unused
			* In the IMT (licensed) allocation in Europe, one out of the 2 available 2.16 GHz channels is unusable since it extends outside the IMT allocation
	+ Capture the following observation in TR 38.808: It is beneficial to define NR channelization to allow full utilization of the various regional frequency allocations around the world. It is not necessary to align NR channelization with IEEE 802.11ad channelization from a coexistence point of view.
	+ There is no regulatory or practical need to align the channel bandwidth (e.g., 2.16 GHz) with other technologies operating in the same 60 GHz band for coexistence purposes.
	+ Capture the following observation in the TR: Targeting 2.16 GHz channel bandwidth results in low FFT utilization compared to Rel-15/16, causing larger computation overhead, and thus larger power consumption.
	+ Consider channel bandwidths up to 1.6 GHz for NR operation in 52.6 to 71 GHz.
* From [15]:
	+ Proposal #1: Consider the followings as candidate numerologies to support NR in FR-X band by taking frequency utilization efficiency, unlicensed band operation, the ICI mitigation, and the UE implementation into account.
	+ Maximum carrier BW
		- 800 MHz for the SCS of 240 kHz
		- 1.6 GHz (and/or 800 MHz) for the SCS of 480 kHz
* From [16]:
	+ Proposal 2: The maximum supported channel bandwidth in 52.6GHz ~71 GHz should be 1.6GHz.
	+ Proposal 3: Carrier aggregation is needed to achieve competitive high peak data rate with 802.11ad/ay in 52.6GHz ~71 GHz
* From [20]:
	+ Proposal 1: NR devices support that transmissions occupy a 2.16 GHz bandwidth in 60GHz unlicensed spectrum.
	+ Observation 1: CA (either inter-band or intra-band) can be supported, but we prefer not to rely on CA with maximum bandwidth 400MHz per carrier to achieve 2.16GHz bandwidth.
	+ Observation 2: To support 2.16 GHz bandwidth by single carrier, 960 kHz SCS is required.
	+ Proposal 2: Support up to 960 kHz SCS, in order to support 2.16 GHz bandwidth by single carrier.
* From [21]:
	+ Observation 1: There is a need for multi-carrier operation to achieve the high bandwidth allocations in the unlicensed band between 52.6GHz and 71 GHz.
	+ Proposal 1: NR operation above 52.6 GHz should support multi-carrier operation to achieve 2 GHz bandwidth utilization. The BW candidates should be in multiples of 400 MHz.
	+ Proposal 2: A UE should be able to indicate a capability for a component carrier bandwidth/SCS combination to achieve 2 GHz transmission.
* From [24]:
	+ Proposal 2. To support various wide bandwidth and use cases for NR operation from 52.6 GHz to 71 GHz, a wide range of numerologies with the carrier aggregation need to be studied, also considering the LBT bandwidth (or the RB set) for co-existing issues, UE capability, processing time and power consumption.
* From [26]:
	+ Proposal 1: For physical control, data, and random access channels and for SSB in the high frequency regime from 52.6GHz to 71GHz, SCSs of 120kHz and 960kHz should be considered.
* From [31]:
	+ Proposal 2: For bandwidth, at least wider maximum channel bandwidth than 400 MHz should be defined for 52.6- 71 GHz.
		- 2 GHz or slightly smaller but sufficiently wide bandwidth such as 1 GHz should be considered.
		- FFT size should remain the same or smaller than 4k
		- Wider minimum channel bandwidth for 52.6 – 71 GHz than 50 MHz should be considered.

### 2.2.2 Discussions

Focus for discussion for Wednesday or Thursday GTW (10/28 or 10/29) session (if possible)

##### Moderator Summary of observations and proposals from Contributions:

* Companies views are somewhat diverse and there seems to be few sub issues, (1) minimum channel bandwidth, (2) maximum channel bandwidth, (3) channelization
	+ Note: there may be other issues not listed above. The above are few outstanding issues that moderator noted and does not hint higher priority or otherwise.
* Similarly, system bandwidth is another fundamental aspect needed for further progress on physical layer aspect. Try to see we can come to a conclusion (if possible).

##### 1st round of Discussion:

Chairman has suggested to gather input from companies on various aspects related to numerology. As such, companies are encouraged to provide additional inputs on channel bandwidth and related aspects.

##### Company Comments on supported minimum and maximum channel bandwidth:

Moderator note: provide inputs on supported minimum and maximum channel bandwidth, including potential specification implications, motivation, advantages and disadvantages, and other related aspects.

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|  **Company** | **Comments** |
| Futurewei | Min BW: 400MHz; a bandwidth of eight times carrier BW should be supported. For a CC of 400 MHz the max supported should be 3200 MHz for a single connectivity. For dual connectivity it would correspond to 6400 MHz. |
| LG Electronics | Max BW: 1.6 GHz; As we commented in Section 2.1, given the maximum SCS of 480 kHz (based on our preference) and the maximum FFT size of 4096 (based on earlier RAN1 agreement), the channel bandwidth can be up to 1.6 GHz. |
| Ericsson | Maximum carrier BW = 1.6 GHz based on 480 kHz SCS. Minimum carrier bandwidth can be further discussed considering both unlicesned and licensed operation. At most the the minimum should be 400 MHz; smaller values can still be discussed. See comment below on channelization.With a maximum carrier BW of 1.6 GHz, the FFT utilization can be maintained at Rel-15/16 levels. In contrast, a 2160 MHz carrier BW results in <50% FFT utilization, thus impacting power consumption and/or chip area. |
| Nokia, NSB | For operation without CA, support two CBWs: 400 MHz (120 kHz SCS) and 2.16 GHz (960 kHz SCS):* Considering outdoor deployment scenario, and close to zero specification effort, it seems that 400 MHz CBW (& 120 kHz SCS) for physical data channels is valid option for 60 GHz scenario.
* Considering indoor deployment scenario from specification effort, coexistence with WiGig, low delay spread, high peak data rate, and low implementation complexity, it seems that 2.16 GHz CBW (& 960 kHz SCS) for physical data channels would be the best option for 60 GHz scenario.

With 960kHz it is possible to operate channel BW of up to 2GHz, with current sampling rate and possibly with 2k FFT. Alternatively, 3k FFT can be used (FFT size as such is an implementation issue). W.r.t. minimum BW, SSB/PRACH numerologies need to be decided first. |
| NTT DOCOMO | For maximum bandwidth, one important aspect is to consider 11ad/ay where a single channel spans 2.16 GHz. We need to consider it to be competitive. For minimum bandwidth, it would be necessary to consider the number of SSB rasters to be required if SA initial access to 60 GHz is supported. Smaller BW would cause more SSB rasters.  |
| Lenovo/MotorolaMobility | Depending upon the maximum numerology to be supported, the maximum channel bandwidth could be agreed. For example, with 480kHz, maximum carrier BW of 1.6GHz would be supported. |
| ZTE, Sanechips | We prefer a maximum channel bandwidth 1600MHz. As for the co-existence with WiFi system, 2.16GHz could be achieved by carrier aggregation.For minimum channel bandwidth, the candidate values less than 400MHz could also be considered, e.g. 100MHz or 200MHz. |
| Huawei, HiSilicon | For 120 kHz SCS, maximum BW of a single carrier is 400 MHz. If a larger SCS is additionally supported then a larger maximum BW of a single carrier can be supported for that SCS, such as 1.6GHz. Larger bandwidths can be achieved with CA, e.g. 8 carriers would allow at least 3.2 GHz of aggregated BW with 120 kHz SCS, or larger with a larger SCS. Minimum single carrier BW should be carefully considered since it allows increasing the coverage especially where regulations put a strict limit on PSD and EIRP. A minimum BW of 50 MHz or 100 MHz should be allowed with 120 kHz SCS. If a larger SCS is additionally supported then a larger single carrier minimum BW can be supported for that SCS. As long as the number of RBs is not smaller than 32, there is no reason to exclude carrier bandwidths smaller than the maximum supported by a 4096 FFT size. |
| Samsung | Maximum channel bandwidth can be determined as the system bandwidth using the largest candidate SCS and FFT size of 4096. Also, achieving 2.16 GHz BW as a single carrier is beneficial for simple implementation (we should not mandate using CA to achieve 2.16 GHz). Minimum channel bandwidth can be determined as the system bandwidth including the SS/PBCH block bandwidth using the smallest candidate SCS |
| vivo | Max BW: 2GHz/2.16GHz for (960 kHz, NCP), 400MHz for (120 kHz, NCP) |
| InterDigital | Supporting 2 GHz bandwidth provides significant benefits on the coexistence and the control overhead reduction. For minimum bandwidth, we can start from 400 MHz, but can consider smaller than 400 MHz. |
| Qualcomm | We support maximum bandwidth of 400MHz and 2.16GHz for 120kHz and 960kHz SCSs, respectively.  |
| MediaTek | Maximum channel bandwidth for 120 KHz SCS is 400MHz. Maximum channel bandwidth for larger subcarrier spacing should scales accordingly (e.g., 3.2GHz for 960KHz SCS). Channel bandwidth smaller than the maximum channel bandwidth should be allowed. |
| CATT | Minimum BW = 50 MHz (FR2 minimum BW)Maximum BW = 400 MHz, 800 MHz, 1.6 GHz. |
| Sony | Max BW: 2.16GHz with 960kHz SCS. The main motivation behind this choice is that we have to consider 802.11ad/ay which could occupy 2.16GHz bandwidth with a single channel.  |
| Intel | In order for 60 GHz operation to have a distinct identity and differentiating factor compared to other (lower frequency) bands, the mimimum channel bandwidth supported should be in the order of 400 MHz to 800 MHz.It does not seesm attractive trying to deploy a narrower system bandwidth (than 400MHz) to obtain larger coverage, since NR operating with FR1 and/or FR2 band can provide even better coverage while supporting similar bandwidth.Maximum channel bandwidth (of a single component carrier) could be around ~2 GHz (or to maximize spectral efficiency, about 3 GHz using 960kHz). |
| OPPO | Support maximum bandwidth: 400 MHz, 800 MHz, 1.6 GHz, FFS 3.2 GHz. |
| Spreadtrum | We prefer maximum channel bandwidth of 400MHz for 120kHz and 1600MHz for 480kHz. |
| Apple | Maximum bandwidths of 400 MHz and 1.6 GHz. 2.16 GHz can be achieved by CA. Minimum BWs can be selected to minimize the wastage of spectrum when aligning with existing 2.16 GHz 802.11ad/ay channels. |
| Convida Wireless | We prefer 400 MHz BW for SCS = 120 kHz as baseline. We are open for 3200 MHz for SCS 960 KHz as maximum BW for FFS. |

##### Company Comments on channelization from RAN1 perspective:

Moderator note: channelization is defined in RAN4. Please try to limit the inputs on channelization that would be relevant for RAN1 design and to comments on aspects where RAN1 might have the best expertise.

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|  **Company** | **Comments** |
| Futurewei | BW of 400 MHz should be used for initial channel access and for the basic LBT procedure. |
| Ericsson | It is important to choose channelization that avoids spectrum wastage in the various regions of the world. For example, in China and the IMT allocation in Europe, 5 GHz is allocated, and with a maximum bandwidth on the order of 1640 MHz, the 5 GHz allocation can support 3 channels thus fully utilizing the 5 GHz allocation without wastage. This is to be compared, e.g., to a wastage of approximately 680 MHz if channels must be strictly aligned with .11ad channelization in which case only two 2.16 GHz channels are supported in the 5 GHz allocation.In our contribution (R1-2007982), we have provided a detailed analysis about the drawback of aligning the channelization with .11ad. The main drawbacks are: 1. extensive evaluation results from different companies shows there are no coexistence issues even without deploying LBT
2. If NR adopts the same channelization design as IEEE 802.11ad/ay, large wastage of spectrum would occur in many regions:
* 240 MHz at the lower edge of the band is unused in all regions
* 800 MHz at the upper edge of the band is unused in USA and Europe
* 680 MHz of the 5 GHz allocation in China is unused
	+ In recognizing the need to have at least three channels for cell planning, IEEE 802.11aj standard defined four 1.08 GHz channels nested within the two 2.16 GHz channels for the 60 GHz band in China. As a result, the spectrum wastage issues are left unaddressed in the 802.11aj channelization.
* 280 MHz of the 7 GHz allocation in Canada/Brazil/Mexico is unused
* In the IMT (licensed) allocation in Europe, one out of the 2 available 2.16 GHz channels is unusable since it extends outside the IMT allocation
1. If .11ad channelization is used, only 2 non-overlapping 2.16 GHz channels are available, and 680 MHz would be wasted. Instead, NR can divide the 5GHz allocation into 3 non-overlapping 1.6 GHz nominal channels which (1) increase the number of available channels, and (2) full use of the allocation.
2. the 802.11ad standard itself supports partially overlapping channels for channel bandwidths >2.16 GHz
3. In R1-2007982, we demonstrate that misaligned channels do not create a coexistence problem either. We evaluated Coexistence scenario between two operators (a) both operators use aligned 2 GHz channels, and (b) Operator #2 uses three 1.6 GHz channels misaligned with the two 2 GHz channels used by Operator #1. We show that misaligned channels do not cause any coexistence issue.
 |
| Nokia, NSB | Channelization should be based on existing WiGig channels with 2.16 GHz bandwidth. Narrowband operation (n\*400 MHz) within a 2.16 GHz channel should be arranged around 5 sub-channels each 432 MHz. The goal of channelization/subchannelization is to ensure smooth coexistence with WiGig and between NR nodes. It has been already agreed that LBT is supported to address coexistence issues, and thus we cannot agree that coexistence issues are fully non-existence. With respect to unused spectrum as pointed up by Ericsson, it can be clearly used by 3GPP technology which will support also channel BWs which are smaller than 2.16 GHz, such as 200 or 400 MHz with 120kHz SCS. For large BW deployments and peak data rates, if gNB wants to operate with 1.6GHz then there is waste of 600MHz as well in 7 GHz allocation of Canada/Brazil/Mexico, for example.Therefore, the 1.6GHz channelization with 480kHz cannot ensure efficient usage of available spectrum either. And one requires 17,5 carriers of 400MHz to cover 7GHz spectrum, which is far away from being low complex solution. |
| ZTE, Sanechips | A more flexible channelization for Rel-17 NR above 52.6 GHz is preferred to avoid frequency resource waste and achieve a flexible operation above 52.6 GHz. 400 MHz can be used as a basic granularity for channelization. We think it is not necessary to strictly align the channelization of Wi-Fi as it will greatly limit the design of Rel-17 NR and cause a waste of spectrum resources. |
| Huawei, HiSilicon | The choice of supported maximum carrier bandwidth for NR operating in 52.6 GHz to 71 GHz should ensure a minimum of at least 6 channels in any regulated range. This is relevant for both licensed operation (with typically 3 or 4 MNOs) as well as unlicensed operation (where as reference 5 GHz band allow up to 23 non-overlapping 20 MHz channels). From coexistence perspective we don’t see a need to align with the channelization of WiGig. |
| Samsung | There is no need to mandate same channelization as WiFi, but we should provide a feasibility to implement same channelization as WiFi.  |
| vivo | Our preference is not to define a single channel bandwidth for NR operating in 52.6 GHz to 71 GHz should as we commented to the question above on the minimum and maximum channel bandwidth. With multiple channel bandwidth defined, we don’t see a serious problem of spectrum waste for different regions. |
| InterDigital | We agree with Samsung that a feasibility to implement same channelization with 802.11ad/ay should be supported.  |
| Qualcomm | Share the same view as Samsung |
| MediaTek | At least channelization of integer multiples of 400MHz should be supported. |
| CATT | Channelization should align with NR channelization and be independent to that of WiFi.  |
| LG Electronics | We share the view with Samsung. Channelization alignment with WiGig does not need to be mandated. Even though same bandwidth as WiGig is required, CA based approach should be sufficient. |
| Sony | We think the channelization in this frequency range, especially in the unlicensed spectrum, should be aligned with IEEE 802.11 to ensure the best co-existence performance.  |
| Intel | In order to have better coexistence with other technologies, the specification should at least support channelization that can be aligned with WiGig channels with 2.16 GHz bandwidth.Even the harmonized ITS band was moved from 63-64 GHz to 63.72 – 65.88 GHz (band 4 of WiGig) to align the bands. So, we believe there is a great value in supporting scenarios where alignment can happen. In addition to channels that could be aligned with WiGig channels, we can further discuss on support of other channels that can maximize spectrum usage for 56 ~ 71 GHz band. Additional spectrum could be efficiently utilized by supporting a select range of bandwidth possibly from (400 or 800) to 3 GHz. |
| OPPO | The decision on channelization depends on the nominal channel bandwidth discussion outcome. If 400MHz, 800MHz, or 1.6GHz channel bandwidth is adopted, channelization of integer multiples of 400MHz should be supported. |
| Spreadtrum | We share the same view as Samsung. |
| Apple | Channelization should be aligned to the 802.11ad/802.11ay channels to avoid crossing 2.16 GHz channel boundaries. The individual channels may have bandwidths less than 2.16 GHz.  |
| Convida Wireless | Whether aligning the channelization of 802.11ad/ay or not should be further studied. In addition, we agree with Samsung that feasibility to implement the same channelization with 802.11ad/ay should be supported. |

##### Moderator summary of comments received:

* If NR adopts the same channelization design as IEEE 802.11ad/ay, following spectrum may be unused:
	+ 240 MHz at the lower edge of the band in all regions
	+ 800 MHz at the upper edge of the band in USA and Europe
	+ 680 MHz of the 5 GHz allocation in China
	+ 280 MHz of the 7 GHz allocation in Canada/Brazil/Mexico
* Some companies have noted support of channelization that are aligned IEEE 802.11ad and 802.11ay channelization is beneficial to ensure best coexistence. While some companies have noted alignment of channelization is not necessary.
* Some companies suggested use of integer multiple of 400 MHz channel bandwidths.

##### 2nd round of Discussion:

Similarly with SCS, moderator would like to encourage companies comment on the following bullets. Please feel free to suggest additional bullet that could be agreeable as well.

*Moderator note: bullet 3 seems to be something few companies suggested, not entirely sure it is stable enough for agreement, but we can discuss the proposal.*

1. RAN1 observes that if NR adopts the same channelization design as IEEE 802.11ad/ay, following spectrum may be unused:
	1. 240 MHz at the lower edge of the band in all regions
	2. 800 MHz at the upper edge of the band in USA and Europe
	3. 680 MHz of the 5 GHz allocation in China
	4. 280 MHz of the 7 GHz allocation in Canada/Brazil/Mexico
2. Some companies have noted support of channelization that are aligned IEEE 802.11ad and 802.11ay channelization is beneficial to ensure best coexistence. While some companies have noted alignment of channelization is not necessary.
3. RAN1 recommends NR bandwidths in 52.6 GHz to 71 GHz to have integer multiple of 400 MHz.

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|  **Company** | **Comments** |
| Nokia, NSB |  We do not agree with Proposal 1) and 3) because * alignment with Wifi does not mean 3GPP cannot use that spectrum. Channel BW as small as 50MHz, 100MHz, 200MHz, are considered in RAN4 for the band.
* and aggregations of smaller channels may be used to form large channels such as 1600MHz or 2000MHz

As we pointed out even n x 1600MHz channels cannot fill in the spectrum fully, but it does not mean that band cannot be fully utilized. Therefore, we suggest following should be captured instead* Some companies propose that 2GHz channel BW raster should consider points aligned with the WiGig channelization
* Support of channel BW such as 200/400MHz may enable efficient usage of available spectrum by 3GPP technology
 |
| Lenovo, Motorola Mobility | Agree with Nokia’s view on 1) and support their suggested updated for first bullet |
| Futurewei | We agree with Moderator’s proposals. Having integer multiples of 400 MHz may satisfy Nokia’s 2GHz BW proposal as well. The frequency raster alignment will be decided in RAN4. We did not see any strong reason that would require raster alignment for coexistence with 802.11ad.  |
| Qualcomm | We do not support Proposal 1. In our view, supporting the same channelization as 11ad/ay means a compatible channelization, not limited to the exact same channelization. That is, NR can support the 11ad/ay channelization at minimum, and can support more than that, e.g., by appropriately defining the raster, as Nokia commented. |
| InterDigital | We agree with Nokia’s comments and proposed updates.  |

## 2.3 SSB

### 2.3.1 SSB numerology - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 7: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, coverage enhancement of channels and signals used for initial access should be considered for NR beyond 52.6 GHz.
* From [3]:
	+ Observation 5: A SCS larger than 240 kHz for SSB is not well-justified.
	+ Proposal 1: Support 120 kHz or 240 kHz SCS with NCP for physical layer signals, control/data channel, and PRACH, SSB, for both licensed and unlicensed band operations.
	+ Observation 7: The numerology of 120 kHz or 240 kHz SCS with NCP is sufficient for initial access.
* From [5]:
	+ Proposal 2: For SCS pair for SSB and initial DL BWP, support (120K, 240K), (120K, 120K) and (960K, 960K) to maintain 4-bit koffset indication as in FR2.
	+ Observation 10: For frequency domain offset estimation during SSB detection, using SSB with low SCS such as 120K/240KHz may increase hardware complexity or cell search latency.
	+ Observation 11: For number of buffering samples during SSB detection, using SSB with high SCS such as 960KHz will need larger buffer cost compared to that in FR2 if adopting the same SSB period (20ms).
	+ Observation 12: For 960KHz SSB, NCP length is not enough to accommodate the time for beam switching.
* From [7]:
	+ Observation 3: Limiting subcarrier spacing choices to keep the minimum FFT size to 512-points can avoid redesign of SS/PBCH block.
* From [8]:
	+ Observation 2: The complexity of SCS indication in the PBCH increase as the total number of SCS supported for FR2 increases.
* From [9]:
	+ Observation 1: FR2 existing SCS and new numerologies can provide a large number of potential SS/PBCH candidate positions to combat channel uncertainty issues.
	+ Proposal 2: It is proposed to investigate how to transmit the indication about additional SS/PBCH candidate positions which can become available with existing FR2 numerologies or future new numerologies.
* From [10]:
	+ Observation 16: To provide enough high time synchronization accuracy for the initial uplink transmission when applying 960 kHz SCS the following options could be considered:
		- 1) Introduce 960 kHz SCS for SSB
		- 2) Use RS available also for IDLE mode UEs like DMRS of CORESET#0 in occasions configured for Type0-PDCCH monitoring.
	+ Proposal 13: Regarding SSB numerologies: 1) Support existing SSB numerologies and 2) support 960 kHz SCS for SSB or provide UE with additional RS available in IDLE mode to provide sufficient time synchronization accuracy to operate mixed SCS scenario of 240kHz SSB and 960 kHz SCS uplink control and data.
	+ Proposal 14: With 960 kHz SCS no explicit beam switching is needed between successive SSB blocks.
* From [14]:
	+ Capture the following observation in TR 38.808: By proper choice of SSB SCS, the initial cell search complexity can be kept at the same level as for FR1 and FR2.
	+ Capture the following observation in TR 38.808: From a frequency error perspective, an SSB SCS of 240 kHz is sufficient for the 52.6-71 GHz frequency range to maintain similar relative error values as for FR1 and FR2.
	+ For NR operations in the 52.6 – 71 GHz band, consider only 120 and 240 kHz SCS for SS/PBCH blocks, as already supported in Rel-15/16.
	+ Capture the following observation in TR 38.808: It is beneficial for SSB coverage to reuse the FR2 already supported subcarrier spacings of 120kHz and 240kHz.
	+ Only support existing FR2 SSB subcarrier spacings of 120 kHz and 240 kHz.
* From [15]:
	+ Proposal #1: Consider the followings as candidate numerologies to support NR in FR-X band by taking frequency utilization efficiency, unlicensed band operation, the ICI mitigation, and the UE implementation into account.
	+ SCS for SSB transmission
		- Reuse the existing value of 240 kHz (and/or 120 kHz)
* From [19]:
	+ Observation 2: Using larger SCS than FR2 SCS can lead to lower SSB detection complexity due to less frequency shift hypotheses.
* From [21]:
	+ Proposal 6: The use of SCS above 240 kHz should be justified for the signals in the SS/PBCH block including the PSS, SSS and PBCH.
* From [22]:
	+ Proposal 2: SSB design for SCS 240kHz and 480kHz could be considered.
* From [29]:
	+ Proposal 5: For SSB, subcarrier spacing no smaller than 240 kHz is considered for NR operating in 52.6 GHz to 71 GHz. Only support same subcarrier spacing between SSB and CORESET #0 configuration.

### 2.3.2 SSB pattern and SSB/CORESET multiplexing - Observations and Proposals from Contributions

* From [2]:
	+ Observation 11: With higher SCS values such as 480kHz and 960kHz, if existing SSB structures are used, then the minimum bandwidth requirements for UE will increase significantly in order to accommodate the required number of frequency resources within a time-symbol for PBCH/PSS/SSS and only multiplexing pattern 1 could be supported
	+ Proposal 6: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, new SSB structures should be investigated
* From [3]:
	+ Proposal 6: The SSB patterns of Case D and Case E can be reused in frequency range above 52.6 GHz for licensed band operation.
	+ Proposal 7: More than 64 candidate SSB indexes should be introduced in NR-U-60.
	+ Proposal 8: The SSB and CORESET0 multiplexing patterns in Rel-15 can be reused for licensed band operation.
	+ Proposal 9: The SSB and CORESET0 multiplexing pattern 2 and 3 are preferred for unlicensed band operation in frequency range above 52.6 GHz when LBT is necessary.
* From [5]:
	+ Proposal 3: The following SSB-Coreset 0 multiplexing patterns are supported for each SCS pair:
		- (120K, 240K): Pattern 1, Pattern 2
		- (120K, 120K): Pattern 1, Pattern 3
		- (960K, 960K): Pattern 1, Pattern 3
	+ Proposal 5: For initial cell search in 52.6-71GHz, a UE may assume that half frames with SSB occur with smaller period than FR2 (e.g. 5ms).
	+ Proposal 6: The following alternatives could be considered to solve beam switching problem for contiguous candidate SSBs:
		- Alt. 1: New SSB pattern introducing gaps between contiguous candidate SSBs;
		- Alt. 2: The same QCL assumptions for contiguous candidate SSBs (e.g. case D in [4]);
		- Alt. 3: Hopping transmission for contiguous candidate SSBs (e.g. case E in [4]).
* From [6]:
	+ Proposal 1: For maximum commonality, SSB patterns and multiplexing pattern of SSB and CORESET#0 are same for licensed and unlicensed operation, and the functions/mechanisms (e.g. LBT) dedicated for unlicensed operation can be configurable by RRC signaling.
* From [8]:
	+ Proposal 6: The same SSB patterns are supported for licensed and unlicensed bands and NRU mechanism for additional transmission opportunity is reused.
	+ Observation 1: No additional gap should be considered to accommodate beam switching delay if only 120 KHz/240 KHz SCS is used for NR operation up to 71GHz.
	+ Proposal 7: The beam switching delay during beam sweeping should be taken into consideration in the SSB burst design for higher SCS.
	+ Proposal 8: For NR operation in unlicensed spectrum in 52.6-71 GHz, the transmission window defined in Rel-16 NR-U is supported.
	+ Proposal 9: More than 64 SSB transmission opportunities shall be defined within a 5ms SSB burst set to support up to 64 beams for SSB beam sweeping in case of occasional LBT failure. The additional bit(s) for the extension of SSB index need to be further study.
	+ Proposal 10: Patterns 2 and 3 of SSB and CORESET for Type0-PDCCH can multiplex with periodic CSI-RS/paging PDCCH&PDSCH in frequency.
* From [9]:
	+ Proposal 1: Introduce groups of SCS in FR2 and all control/data communication will use the SCS from one such group.
* From [10]:
	+ Observation 15: Benefits of reusing FR2 numerologies for both SSB and Type0-PDCCH would be:
		- No CP length or coverage reduction
		- Possibility to reuse FR2 implementation for the initial access
	+ Observation 17: FR2 SSB time domain mapping pattern of SSBs can be reused above 52.6 GHz if the FR2 SSB numerologies are used.
	+ Observation 18: If LBT was used for the SSBs, to provide multiple SSB transmission opportunities for the same beam in the DRS window against LBT failures, two principles could be considered:
		- Max number of SSB positions remains 64 while some of the positions (e.g. last N positions) can be used as a back-up positions for the SSBs which were not transmitted due to LBT failure. The maximum number of SSB beams would be 64-N. There can be further sub-options as follows:
			* Back-up positions could be used in cyclic manner as in Rel. 16 NR-U.
			* gNB could select certain SSB (not transmitted in the original SSB position) to be transmitted in the back-up position. This case would require that SSB transmitted in the back-up position would indicate the beam index explicitly.
		- Increase max number of SSB positions beyond 64, e.g. up to 128, and use similar cycling mechanism as in Rel. 16 NR-U. This option would require increasing the SSB index space and signalling from 64 to 128.
	+ Observation 19: Existing FR2 SSB and Type0-PDCCH multiplexing patterns are a good starting point for above 52.6 GHz operation.
* From [13]:
	+ Proposal 2: Rel-17 NR can maintain the maximum SCS with 240 kHz for SSB and/or 120 kHz for Type0-PDCCH, and reuse the initial access procedure in Rel-15/16 NR.
	+ Proposal 7: SSB pattern needs to be re-considered irrespective of whether higher SCS is supported or not in Rel-17 NR above 52.6 GHz.
	+ Proposal 8: Transmission opportunities, timing and QCI of Rel-17 SSB should be considered.
	+ Proposal 9: The following multiplexing patterns and combinations of SCSs of SSB and Type0-PDCCH are preferred for Rel-17 NR beyond 52.6 GHz, that is, 60 kHz SCS for Type0-PDCCH is not supported.
		- (SSB, Type0-PDCCH): (120, 120) kHz
			* Multiplexing patterns: 1, 3
		- (SSB, Type0-PDCCH): (240, 120) kHz
			* Multiplexing patterns: 1, 2
* From [14]:
	+ Capture the following observation in TR 38.808: It is observed that from a UE complexity point of view it is beneficial to define the same SS/PBCH patterns for licensed and unlicensed operation.
	+ Existing SS/PBCH time domain patterns D and E as specified in Rel-15/16 are proposed to be used also for operation in the 52.6 – 71 GHz band.
	+ Proposal 26 Capture the following observation in TR 38.808: It is observed that with 120 and 240 kHz SCS for SS/PBCH block transmissions, the CP length is at least 293 ns which is sufficient for beam switching which typically requires < 100 ns
	+ Capture the following observation in TR 38.808: SS/PBCH / CORESET0 multiplexing patterns 2 and 3 are restricted to very small RMSI payloads due to the small number (2) of available OFDM symbols for RMSI PDSCH.
	+ Capture the following observation in TR 38.808: For the maximum number of beams (64), it is observed that SS/PBCH / CORESET0 multiplexing pattern 1 can carry larger payload than multiplexing patterns 2 and 3 due to the fact that SS/PBCH and RMSI PDCCH/PDSCH are time division multiplexed.
	+ Capture the following observation in TR 38.808: Existing Rel-15/16 framework for initial access including SS/PBCH-CORESET0 multiplexing patterns, multiplexing of SS/PBCH and other signals/channels, and Type0-PDCCH CSS configurations have significant flexibility to cover a large number of deployment scenarios in the 52.6 – 71 GHz band.
* From [15]:
	+ Proposal #3: Consider the enhancements for the SSB transmission to provide more opportunities in FR-X unlicensed band.
	+ Proposal #4: Study further how to multiplex SSB and corresponding CORESET#0 in case of using new numerologies such as 240/480 kHz SCSs for the DL signal/channels other than SSB.
* From [19]:
	+ Observation 3: introducing additional beam switching gap is needed when SSB SCS is beyond 480 KHz.
	+ Proposal 1: Strive for a unified SSB time pattern independent of with/without LBT modes.
	+ Observation 4: a gap duration larger than 23 us may be enough for LBT gap duration.
	+ Observation 5: Rel. 15 FR2 SSB time pattern can support Omni-directional or directional LBT without further introducing LBT gap.
	+ Observation 6: The resource limitation for SSB-CORESET pattern 2 and pattern 3 is not obvious and can be workaround.
	+ Observation 7: It seems not necessary to preclude pattern 2 and pattern 3 for SSB CORESET#0 multiplexing.
* From [21]:
	+ Observation 9: Introduction of a DRS transmission window introduction will depend on (a) the 10% regulatory rule (b) relative duration of signals that may need to be transmitted without LBT and (c) the overall interference provided by these signals.
	+ Proposal 7: Allow SSB transmission without LBT in an LBT environment provided load of non-LBT transmission is less than 10% within an observation window of 10 ms.
		- Define a DRS transmission for scenarios where the control signaling exceeds this threshold.
	+ Proposal 8: Support Pattern 1, 2 and 3 with additional support of 240 kHz for the SSB and 240 kHz for the Type0-PDCCH for SSB and Type0-PDCCH/RMSI multiplexing.
* From [23]:
	+ Proposal 1: For 52.6-71 GHz band, the existing SCSs, i.e., 120 kHz and 240 kHz, and multiplexing pattern between SSB and CORESET#0 in FR2 for SS/PBCH blocks should be reused.
	+ Proposal 2: For 52.6-71 GHz band, the existing time domain patterns designed in FR2 for SS/PBCH blocks at least for licensed spectrum should be reused.
* From [27]:
	+ Proposal 1: At least one symbol gap in time domain between SS/PBCH blocks with different SSB indices should be considered for higher subcarrier spacing (e.g., equal or larger than 960kHz) taking into account a beam switching gap due to a RF interruption time of Tx/Rx beams and/or LBT gap in unlicensed spectrum.
	+ Proposal 2: We propose that SS/PBCH block and CORESET#0/RMSI can be multiplexed in TDM/FDM within a slot considering multi-beam operation and it can be closely located without the gap between SSB and CORESET#0/RMSI for not allowing any in-between channel access operation in the unlicensed band.
* From [29]:
	+ Proposal 4: When a large subcarrier spacing is defined, SSB pattern and multiplexing of SSB and CORESET0/RMSI need to be updated to accommodate beam switching time.
* From [30]:
	+ Proposal 3: RAN1 shall study the SS/PBCH block pattern for the new numerology, taking into account the beam switching time between neighboring SS/PBCH blocks.
	+ Proposal 4: RAN1 shall study the multiplexing pattern of SS/PBCH block and CORESET#0, and supporting both Pattern 2 and Pattern 3 is beneficial for the flexibility of allocating the CORESET#0.
* From [31]:
	+ Proposal 3: Whether to introduce gap symbol(s) for beam switching time should be discussed not only for SSB but also for any signal/channels with beam switching in case that higher SCS such as 960 kHz is supported.
	+ Proposal 4: For SSB and CORESET multiplexing, following aspects should be discussed
		- Which SCS(s) is supported for SSB and which combination(s) of SCS between SSB and CORESET#0 is supported
			* Whether only single numerology is supported as in Rel-16 NR-U or not
			* Whether the number of supported SCSs for SSB should be minimized
		- Which multiplexing pattern between SSB and CORESET#0 is supported for each combination of SCS between SSB and CORESET#0
			* What are minimum channel bandwidth, minimum required CORESET#0 bandwidth and minimum required bandwidth for RMSI PDSCH
			* Whether beam sweeping overhead should be minimized by FDM between SSB and CORESET#0 and/or RMSI PDSCH

### 2.3.3 Initial access related aspects - Observations and Proposals from Contributions

* From [8]:
	+ Proposal 13: In initial access, the beam adaptation for Msg3 and Msg4 transmission can be adapted based on the beam measurement report from UE.
* From [9]:
	+ Observation 2: The transmission of minimum system information with a large number of active beams makes the system inefficient and imposes beam switching constraints, resulting in reduced scheduler flexibility.
	+ Observation 3: For shared carriers, the transmission of minimum system information with a large number of active beams brings additional issues related to channel ownership, and potential requirements to perform channel access procedures while switching the beams.
	+ Proposal 3: It is proposed to investigate efficient transmission of MSI including the multiplexing patterns for both licensed and shared carriers.
* From [10]:
	+ Observation 13: PBCH using QPSK has DMRS in each OFDM symbol where PBCH REs are allocated.
	+ Observation 14: PBCH using current FR2 numerologies is robust against phase noise.
* From [14]:
	+ Capture the following text in TR 38.808: Increased SCS translates to a loss in coverage for initial access signals and channels (SS/PBCH block, PRACH), fixed payload channels (e.g., PDCCH/PUCCH), and variable payload channels (e.g., PDSCH/PUSCH) due to shorter OFDM symbol duration.
	+ For operation in the 52.6 – 71 GHz band, basic tools in the Rel-16 specifications, e.g., FR2 initial access framework, BWP switching, CA/DC activation already support both standalone and non-standalone deployments that can ensure coverage. It is not needed to specify coverage enhancement approaches for larger SCS for initial access signals and channels or for control/data channels.
	+ Capture the following observation in TR 38.808: The distribution of interference + noise in the 52.6 – 71 GHz band is typically well below the LBT threshold of -47 dBm, and thus deferral due to LBT failure is rare. Hence, it is not beneficial to introduce a transmission window for SS/PBCH + RMSI transmissions.
* From [20]:
	+ Proposal 5: Beam alignment during initial access procedure should be considered for NR above 52.6 GHz

### 2.3.4 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* Diverse views among companies on this issue. There are several sub-issues: (1) supported SSB/CORESET multiplexing pattern, (2) SSB pattern within the slots, (3) DRS window, (4) QCL assumption, (5) how to deal with beam switching (if needed to be considered), (6) whether or not to support different SSB and CORESET #0 numerology
	+ Note: there may be other issues not listed above. The above are few outstanding issues that moderator noted and does not hint higher priority or otherwise.
* Some conclusion on SSB numerology might be needed for further progress on this topic.
* Diverse views on SSB numerologies among companies.
* General consensus is that just from performances perspective, SSB is not as affected by phase noise compared to PDSCH/PUSCH.
* Similar to SSB numerology, it would be great the comments and discussion can include number of supported SSB SCS, specification impact for different supported numerologies, maximum supports SCS, implementation complexity, and scenarios enabled by different numerologies. There could be other aspects, please comment further.
* Since above aspects that span SSB and CORESET#0 design, it would be great if SSB pattern and SSB/CORESET multiplexing section can focus on (but not necessarily limited to) specification impact, single numerology operation aspects, scenario enabled by SSB and CORESET#0 design. The rest of the issues can be also discussed in SSB numerology (section 2.3.1)

Moderator suggests conducting further discussion on SSB. Based on submitted proposals, the discussion could include number of supported SSB SCS, specification impact for different supported numerologies, maximum supports SCS, implementation complexity, and scenarios enabled by different numerologies. There could be other aspects, please comment further.

##### Company Comments on applicable SSB and related issues (including number of supported SSB SCS, implementation complexity, scenario enablement):

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| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Support for the existing SSB numerology 240 kHz with NCP should be considered  |
| Nokia, NSB | We think that R15 SSB SCS are sufficient, on the other hand, if the preference is to enable single SCS deployments, designing SSB putterns for 480 or 960kHz could follow R15 principles and would be straightforward. |
| Huawei, HiSilicon | We agree with the observation on performance from the moderator’s summary. As already agreed for observations from LLS and link budget analysis, smaller SCS have an advantage for SSB coverage.If one SCS is supported as 120 kHz or 240 kHz, then the same SCS can be used for SSB.If an additional SCS is supported as 480 kHz or 960 kHz for data/control, a smaller SCS could be used for SSB even if it comes at the cost of some complexity. Designing SSB for 480 kHz or 960 kHz SCS is of course feasible, but it comes at the cost of coverage. |
| Ericsson | Our view is that existing FR2 numerologies for SSB (120 kHz, 240 kHz) are sufficient, and ensure coverage. We don't see a need to design SSB for larger SCS due to the loss in coverage that has been observed in evaluations. We don't see that support of additional numerologies for SSB enables any different use cases compared to existing FR2 numerologies. |
| Qualcomm | We support matched numerologies between SSB and other physical channels, i.e., 120kHz and 960kHz SCSs for SSB. Having the same numerology for SSB and the active BWP will facilitate multiplexing (i.e., in the standalone scenario), any scheduling restriction or BWP switching is not required for UE to measure the SSB, e.g., for RLM/BFD. |
| MediaTek | We prefer to prioritize existing FR2 SSB SCSs, i.e.,120kHz and 240kHz, to avoid spec and implementation impacts. However, we also support single numerology deployment and therefore, we prefer to remove 240kHz if 240kHz is not supported in >52.6GHz spectrum. |
| CATT | SSB numerology is aligned with the numerology of all other physical channels.  |
| Samsung | We should at least support the possibility to enable single numerology development for the whole system, which is beneficial from both network side and UE side. From network perspective, using single numerology is easy for implementation and could save resources (e.g. guard band in mixed numerology); and from the UE perspective, single numerology can also be easy for implementation and save the measurement gap. |
| NTT DOCOMO | We agree the existing FR2 SSB SCS can be reused as SSB is not affected by phase noise. We additionally believe that higher SSB SCS could be beneficial to support higher data SCS without mixed numerology. As no phase noise issue for SSB detection is observed and SSB in higher SCS works somehow as well as the existing SSB SCS in FR2, new SSB SCS aligned with potential data SCS should be considered. |
| LG Electronics | We think that existing FR2 SSB SCSs are sufficient considering specification impact, UE implementation, and coverage. Even though 480 kHz SCS is to be supported, 120/240 kHz SCS SSB and 480 kHz SCS data can be operated together, similar to 15/30 kHz SCS SSB and 60 kHz SCS data in FR1. |
| Intel | Only SSB numerology above 240 kHz should be considered when factoring into account recevier complexity to handle initial frequency offset.Also based on the coverage enhancement studies, it is evident that SSBs have one the largest coverages compared other channels supported in NR (for the same SCS). Therefore, we do not see a strong need to support SSB SCS with large difference to data/control channel.There are also less motivation to support different SCS between SSB and CORESET #0 as this simply complicate SI multiplexing without providing useful system benefits.SSB SCS same as data/control SCS should enable all scenarios intended for data/control transmission.If we factor our preferences with data/control numerology, we believe supporting 960 kHz and 480 kHz for SSB SCS is most logical choice. |
| ZTE, Sanechips | In terms of coverage and spec impacts, we think reusing FR2 numerologies for SSB i.e. 120 kHz, 240 kHz is sufficient. We don’t think that it is necessary to restrict SSB to use the same SCS as data/control channels. |
| Xiaomi |  Consider the current SCS for FR2 and as our analysis on SSB pattern, as well as the complexity and smaller specification impact, we think 240kHz (for SSB)/120KHz (for data) could be a basic candidate SCS pair for both licensed and unlicensed implantation. However, for ultra wideband application in unlicensed band, a higher SCS pair can be considered.  |
| OPPO | Reuse FR2 initial access procedure by considering existing SSB 120 kHz + CORESET #0 120 kHz or SSB 240 kHz + CORESET #0 120 kHz. After initial access procedure, a higher SCS can be configured for data transmission. |
| Lenovo,MotorolaMobility | We also support to have have same numeroloies between SSB and other physical channels and have similar views as Qualcomm.For this reason, SCS values beyond 240kHz should be considered for SSB |
| Spreadtrum | We prefer to at least reuse the existing FR2 SSB SCS. Higher SSB SCS can be considered in the perspective of using a single numerology. |
| Apple | We prefer to reuse the existing FR2 SSB SCSs.  |
| vivo | At least single numerology for SSB and Coreset#0 is supported for each data/control numerology. Prefer to reuse FR2 design as much as possible. For already agreed 120KHz numerology for data/control, 120KHz SSB is supported for single numerology and 240KHz SSB is still supported as FR2 does (which may ease the implementation complexity on Frequency sync);For any new numerology (e.g. 960K) for data/control, at least the same numerology is supported for single numerology. |

##### Company Comments on SSB pattern and SSB/CORESET multiplexing and related issues (including specification impact, single numerology operation, scenario enablement):

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|  **Company** | **Comments** |
| Futurewei | Our approach is based on minimum changes to the existing design, a lower implementation complexity and a simplified usage in the unlicensed band. Use the same SSB and CORESET# numerology, use existing FR2 multiplexing pattern, reuse initial access procedures Rel15/16, no additional beam switching time gap necessary (100ns switching time is less than NCP of 240 kHz SCS) |
| Nokia, NSB | First shared channel and SSB SCS shall be agreed, to proceed here. |
| Lenovo/Motorola Mobility | Considering the minum reuqired bandwidth for SSB, coverage requirements and beamforming related aspects, new SSB design could be considered, dependipn upon the new SSB numerology, if any |
| Huawei, HiSilicon | These considerations are secondary to the choice of SCS for data, control, SSB. SSB pattern and SSB/CORESET multiplexing are also impacted when LBT is used before SSB transmission. |
| Ericsson | We see that existing FR2 SSB/CORESET0 multiplexing patterns are sufficient, especially Pattern 1 (TDM mux of SSB/RMSI) operating with either (120/120) or (240/120) kHz SCS. This can enable practical RMSI payloads (~700 bits). Patterns 2 and 3 (FDM mux of SSB/RMSI) are limited by 2 OFDM symbols for RMSI which is insufficent for ptractial RMSI payloads. Our view is that an initial BWP (assuming standalone) can be operated using FR2 numerologies. The BWP can be switched to a larger numerology based on data rate needs. This BWP can operate with 480 kHz SCS for data/control/reference signals and 240 kHz SSB, for example. |
| Qualcomm | We support the same numerology for SSB, data, and CORESET#0. Within the supported numerologies, mixed numerology operation may still be supported. Also, depending on the combination of SSB and COREST#0 numerologies, the existing CORESET#0 multiplexing pattern may be reused with some enhancement. Regarding the SSB pattern, we can reuse the legacy FR2 pattern for 120kHz SCS. For 960kHz SCS, if supported, we think a SSB pattern with an additional beam switching gap (at least one-symbol duration) between adjacent SSB bursts should be supported as an option, in addition to the existing patterns.Regarding DRX window and QCL assumption, the same principle as Rel-16 NR-U can be applied, with potential increase in the transission opportunities and the SSB ID space. |
| MediaTek | If 120kHz or 240 kHz SSB SCS are supported, we prefer to reuse the existing FR2 SSB designs, e.g., SSB pattern and SSB/CORESET multiplexing, to minimize the spec impact. |
| CATT | The numerology of SSB, CORESET#0, and all physical channels should have same numerology. The slot structure shoud be reused for the SSB location. SSB pattern for 120 kHz could be reused for other numerology if introduced.  |
| Samsung | Similar to the comment for SSB, at least some numerology of SSB and CORESET#0 should be supported.  |
| NTT DOCOMO | After discussing about 2.3.1, we can discuss further on this. It would be preferred to reuse the existing SSB pattern and SSB/CORESET#0 multiplexing approach in NR FR2 in order to minimize the specification efforts, but assuming data SCS can be higher than FR2 NR, specification efforts would be necessary anyway.  |
| LG Electronis | We agree that existing SSB pattern and SSB/CORESET multiplexing patterns should be prioritized. In addition, DRS window and QCL assumption introduced for Rel-16 NR-U can be considered to combat with LBT failure in unlicensed spectrum operation. |
| Intel | Supporting 120kHz or 240 kHz SSB SCS does potentially allow for reuse of existing NR specification.For each newly supported SSB SCS (currently not supported) in NR specification does require RAN1 to effort in standardizing the specification.Coupled with data/control subcarrier spacing, enabling single numerology operation by supporting the same SCS for SSB as data SCS is still preferred. |
| ZTE, Sanechips | The SSB patterns and multiplexing patterns between SSB and Type0-PDCCH in FR2 can be reused for above 52.6 GHz in terms of coverage and spec impact. |
| Xiaomi | Reusing the current design and enhancing where it is necessary. |
| OPPO | Support reusing current SSB pattern and SSB/CORESET multiplexing patterns. |
| Spreadtrum | The existing FR2 SSB pattern and SSB/CORESET#0 multiplexing patterns should be reused to minimize the specification impact. |
| Apple | Ideally, the SCSs for the SSB and data need to be decided first. However, we prefer to maximally reuse the R15 design. |
| vivo | Regarding SSB pattern, if SSB and coreset#0 share the same numerology (e.g. (120K, 120K) and (960K, 960K)), the design of (120K, 120K) in FR2 is reused, i.e. Case D SSB pattern, support multiplexing pattern 1 and 3 in these cases. If not, especially when SCS for Coreset #0 is larger than SSB SCS, the new multiplexing pattern needs to be designed. Regarding extending the number of candidate SSBs, it depends on whether LBT is needed for SSB transmission. If no need to have LBT, the reuse of NRU mechanism is not needed. |

##### Company Comments on initial access:

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|  **Company** | **Comments** |
| Futurewei | Use FR2 initial access design as the basic framework |
| Ericsson | Agree with Futurewei, that FR2 initial access should be the basic framework with 120 kHz PRACH and 120/240 kHz SSB. |
| CATT | We agree to use FR2 initial access as the principle. Enhancement, e.g., support 64 beam sweeping for the operation in unlicensed spectrum, could be considered.  |
| Apple | Same view as FutureWei |

##### Moderator summary of comments received:

* Some companies commented in order to enable single SCS deployments, the supported SCS of SSB should be the same the data/control SCS.
* Some companies commented use of 120 kHz and/or 240 kHz SCS for SSB is preferred as existing NR design can be reused.
* Some companies commented that when 480 kHz or 960 kHz SCS is used for data/control, use of 120 kHz or 240 kHz for SSB SCS is beneficial from coverage perspective. One company noted that SSB has one the largest coverages compared other channels for the same SCS, and larger coverage for SSB is not needed.
* One company noted SSB SCS above 240 kHz should be considered when factoring into account receiver complexity to handle initial frequency offset.
* Some companies commented for 120kHz and 240kHz SSB SCS, re-use of existing NR design for SSB patterns and SSB/CORESET#0 multiplexing patterns is preferred.
* One company commented SSB/CORESET#0 multiplexing pattern 2 and 3 provide limited symbols for system information transmissions are not suitable for practical system information payload sizes.
* Companies commented the FR2 initial access framework could be the basis for initial access for NR operating in 52.6 GHz to 71 GHz.

##### 2nd round of Discussion:

Based on discussions above, moderator has put together some bullets that could be used for further discussion and conclusions/observations. If there are other statement that companies believe would be useful to conclude and agree, please provide your suggestions as well.

1. Some companies noted SSB SCS selection should consider SCS of data/control channels and enablement of single subcarrier spacing operation.
2. Some companies noted use of support and use of 120 kHz and/or 240 kHz SCS for SSB (even if data/control channel may have different SCS) may enable re-use of existing NR specification and minimize standardization effort.
3. RAN1 observes SSB and CORESET multiplexing 2 and 3, where SSB and PDCCH and PDSCH for system information are frequency domain multiplexed, may not be suitable to support larger system information payload sizes, such as 700 bits or larger.

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|  **Company** | **Comments** |
| LG Electronics | We suggest to add the consideration of SSB pattern suitable for unlicensed band operation, e.g., SSB cycling transmission withini a DRS transmission window. |
| Nokia, NSB | If LBT is used for SSB, we share the same view as LG that additional transmission opportunities for the SSB could be considered within a DRS transmission window.With respect to 3) we do not support, as capacity of PDSCH depends on minimum supported channel BW |
| Lenovo, Motorola Mobility | We suggest to add that new SSB pattern could be considered for higher SCS (beyond 240kHz) by taking into account the coverge issue and minimum channel BWAlso, agree with LG’s and Nokia’s suggestion |
| Futurewei | We support Moderators first two observations.For the third one we propose FFS as the supported channel BW is not discussed yet. |
| Qualcomm | We are generally fine with 1) and 2). For 3), as Nokia and Futurewei commented, the issue is dependent on the minimun and initial bandwidth selection. Thus it would be removed or revised to clarify that it is contingent to the minimum channel bandwidth discussion. |
| InterDigital | We are also fine with 1) and 2). 3) can be considered as FFS. |

## 2.4 PRACH

### 2.4.1 Observations and Proposals from Contributions

* From [3]:
	+ Proposal 10: For unlicensed band, ZC lengths such 571 and 1151 can be considered for 120 kHz SCS.
	+ Observation 8: Due to the possibility of LBT failure, the support for non-consecutive ROs in the time domain could be beneficial.
* From [5]:
	+ Proposal 4: Format 0-3 with special SCS is not supported and the candidate PRACH numerologies for format A, B and C are the same as the candidate BWP numerologies.
	+ Proposal 7: Both coverage and capacity should be studied for PRACH design with new defined numerology.
	+ Proposal 8: With the usage of higher SCS, the issue of preamble sequence generation needs to be considered to match the certain coverage area.
* From [8]:
	+ Proposal 11: Consider supporting the increasing of symbols in time domain to enhance coverage and the extending of frequency domain by repeating and concatenating the RACH preamble sequence in the unlicensed spectrum.
	+ Observation 3: The current RO configuration of FR2, based on the 60 KHz slot as the basic unit, which supports two slots configuration when SCS is120KHz.
	+ Proposal 12: When the specification supports SCS=240/480 KHz, reusing 120 KHz configuration for each two slots within 60 KHz slot.
* From [10]:
	+ Observation 20: 960 kHz SCS for PRACH can support required range for the indoor scenario.
	+ Proposal 15: Support 960 kHz SCS for PRACH.
	+ Observation 21: Introducing longer sequence lengths for short time domain PRACH preambles, e.g. the ones supported in Rel. 16 NR-U (571 and 1151), would allow transmitting device to achieve 40 dBm EIRP maximum in CEPT scenarios c1 and c2.
	+ Proposal 16: Support PRACH sequence lengths 571 and 1151 for NR above 52.6 GHz.
	+ Observation 22: It would be better to define fixed LBT gap between valid ROs that do not depend on the time domain allocation of the PRACH. In that case the LBT gap length would not depend on the used PRACH format.
* From [13]:
	+ Proposal 10: It is preferred to reuse the existed numerology for PRACH.
* From [14]:
	+ Include the following Observation in TR 38.808. Maximum isotropic loss (MIL) and maximum coupling loss (MCL) degrade as the subcarrier spacing is increased, negatively impacting coverage. PRACH 120 kHz SCS is defined for FR2 already in Rel-15 and for the 52.6–71 GHz range yields 4–5 dB better coverage than 480 kHz SCS and 8–9 dB better coverage than 960 kHz SCS.
	+ If PRACH uses 120 kHz SCS, data transmission can still use higher subcarrier spacings through BWP switching.
	+ Reuse existing FR2 PRACH subcarrier spacing of 120 kHz for 52.6–71 GHz.
	+ Include the following observation in TR 38.808: For operation in the 52.6 – 71 GHz band, it is beneficial to support all existing Rel-15/16 sequence lengths L = 139/571/1151 to allow for larger transmit powers in some scenarios depending on the assumed beamforming gain, regulatory regime, and UE power limits.
	+ Support PRACH with sequence lengths L = 139/571/1151 (as defined for FR2 in Rel-15/16) for 52.6–71 GHz.
	+ Reuse FR2 PRACH configuration tables for 52.6–71 GHz.
	+ Include the following observation in TR 38.808. It is not beneficial to optimize RACH configurations to enable LBT gaps between back-to-back PRACH occasions in the same slot for operation in the 52.6 – 71 GHz band.
* From [15]:
	+ Proposal #6: Design wide-band PRACH and interlaced or multi-RB based PUSCH/PUCCH considering regulatory requirements such as nominal channel BW, occupied channel BW, maximum allowed output power, and maximum power spectral density.
* From [19]:
	+ Observation 12: it is beneficial to introduce larger SCSs for PRACH transmission.
* From [29]:
	+ Proposal 7: When a large subcarrier spacing is defined, PRACH configuration related aspects need to be investigated.
* From [30]:
	+ Observation 2: The LBT result of the selected RO is highly relying on the usage of previous RO.
	+ Observation 3: The consecutive configuration of RO could further increase the LBT failure probability
	+ Proposal 5: Non-consecutive RO configuration is beneficial for alleviating the RACH LBT failure, and shall be supported for 60 GHz unlicensed band.
* From [31]:
	+ Proposal 5: For PRACH sequence, short PRACH sequence supported in Rel-15 NR should be a baseline.

### 2.4.2 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* There are several sub-issues: (1) supported PRACH SCS, (2) RACH RO configuration, (3) Supported PRACH sequence lengths, (4) support of interlace PRACH
	+ Note: there may be other issues not listed above. The above are few outstanding issues that moderator noted and does not hint higher priority or otherwise.

##### Company Comments on PRACH and related issues (including specification impact, single numerology operation, implementation complexity, scenario enablement, etc):

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Use longer PRACH sequences 571/1151, support non-consecutive RO with fixed (short) LBT , prefer SCS of 240 kHz for PRACH  |
| Nokia, NSB | We believe that answers here are dependent on whether mixed SCS deployments are preferred or not, but (1) we do support 960kHz for PRACH, (2) RACH RO depends on whether short control signals will require LBT or not (3) both long and short PRACH from 5GHz should be supported, (4) Do not support interlace for PRACH |
| Lenovo/MotorolaMobility | Considering coverage aspects, enhancements to PRACH could be considered |
| Huawei, HiSilicon | Considering coverage, 120 kHz SCS is recommended for PRACH. ZC lengths such 571 and 1151 that are already supported for NR-U in FR1 can be extended to 120 kHz SCS for FR2. The impact of LBT on the interval of RO should be considered. |
| Ericsson | As demonstrated in evaluations, PRACH coverage degrades significantly as SCS increases. Hence, in our view 120 kHz PRACH is sufficient. The longer sequence lengths 571/1151 can be useful to increase Tx power under a PSD constraint (if UE conducted power is not limiting). |
| Qualcomm | We support the same numerologies for PRACH and other channels, i.e., 120kHz and 960kHz.For the preamble length selection, the consideration of max EIRP/PSD limit in the unlicensed band and the consideration of coverage should be balanced. Thus, longer sequence length, e.g., 571, with existing preamble format A, B, and C can be considered. Also, we don’t see any strong motivation for interaced PRACH. |
| MediaTek | Similar to SSB aspect, we prefer single numerology operation. Longer PRACH sequence can be considered to address coverage issue. However, interlace design for PRACH is not preferred. |
| CATT | The numerology of PRACH should be same as SSB and other physical channels. Considering narrow beam operation and higher SCS in 52.6-71 GHz, RACH format with coverage extension should be considered.  |
| Samsung | Similar comment, it is necessary to support the feasibility of using single numerology for implementation. In this sense, if a new SCS is supported for UL data/signal, it should also be supported for PRACH. In addition, we understand the non-consecutive RO should be included in the “ (2) RACH RO configuration”, otherwise, it should be separately listed.  |
| NTT DOCOMO | Interlaced allocation is NOT necessary in our view as it is not mandatory to always ensure OCB requirement in unlicensed band. The other aspects are debatable and we are quite open at this stage. Our current views are (1) ok to support PRACH of higher SCS and (3) configurable PRACH sequence length could be beneficial.  |
| LG Electronics | At least, 120 kHz PRACH should be supported. If new SCS larger than 120 kHz is introduced for UL signal/channel, RACH with that new SCS also can be considered. |
| Intel | Uplink coverage bottleneck among channels supported in NR (with the same SCS) is bottlenecked by PRACH but other channels such as PUSCH, and possible PUCCH (with PSD limitations).Therefore, from our understanding the use case supporting (significantly) different SCS for PRACH compared to data/control transmission does not exist.Therefore, we prefer to support of the same SCS for PRACH as data/control.Support of longer sequences (such as 571 or 1151) may have additional benefits from larger transmis power (under the presence of PSD limitation), therefore we suggest to also support longer sequences (L=571, 1151) in addition to L=137.If longer sequences for PRACH is supported we do not see the need to support interlace PRACH transmission. |
| OPPO | We support reusing current 120kHz PRACH. Regarding PRACH transmission in active BWP, new SCS, e.g., 960 kHz can be considered. |
| Spreadtrum | We prefer single numerology for PRACH and other channels. To this end, if a new SCS is intrdouced for UL signal/channel, it should be also supported for PRACH. |
| vivo | Prefer single numerology for PRACH and data/control channels. Long sequence could be supported for high transmission power. No need to support interlace PRACH transmission |

##### Moderator summary of comments received:

* Some companies suggested to use longer PRACH sequences such as L=571 and L=1151 to benefit from higher transmit power when PSD limits apply.
* Some companies suggested supporting non-consecutive RO to aid LBT.
* Some companies noted interlace design for PRACH is not necessary.
* Some companies suggested using same numerology for PRACH and other uplink channels.
* Some companies commented that 120 kHz PRACH would be sufficient even if other channel may use different subcarrier spacing.

##### 2nd round of Discussion:

Based on discussions above, moderator has put together some bullets that could be used for further discussion and conclusions/observations. If there are other statement that companies believe would be useful to conclude and agree, please provide your suggestions as well.

1. In order to benefit from higher transmit power when maximum PSD regulatory requirements exist, RAN1 recommends support of longer PRACH sequence lengths, L=571 and L=1151, defined in Rel-16 NR specification, to be used for NR operating in 52.6 GHz to 71 GHz.
2. RAN1 recommends not specifying interlace design for PRACH for NR operating in 52.6 GHz to 71 GHz.
3. RAN1 recommends support of non-consecutive RACH occasion configurations to aid LBT processes.
4. Some companies noted that PRACH SCS selection should consider SCS of data/control channels and enablement of single subcarrier spacing operation.
5. Some companies noted that 120 kHz SCS for PRACH (even if data/control channel may have different SCS) may be sufficient to support NR operating in 52.6 GHz to 71 GHz.

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|  **Company** | **Comments** |
| Nokia, NSB | 3) RAN1 recommends support of non-consecutive RACH occasion (in time) configurations to aid LBT processes when LBT is required |
| Lenovo, Motorola Mobility | Agree with Nokia’s proposed update.Also propose to add new bullet:* If higher SCS is agreed to be supported for PRACH, then enhancements should be considered by taking into account the coverage for PRACH
 |
| Futurewei | Agree with Moderator recommendations and Nokia’s update. |
| Qualcomm | According to the companies’ view during the 1st round of discussion, the main motivation of supporting 120kHz PRACH only seems to be the coverage. Thus, it could be clarified:1) Some companies noted that 120 kHz SCS for PRACH (even if data/control channel may have different SCS) may be sufficient to support NR operating in 52.6 GHz to 71 GHz from the perspective of coverage. |
| InterDigital | We are fine with Moderator’s proposals.  |

## 2.5 PDCCH

### 2.5.1 PDCCH - Observations and Proposals from Contributions

* From [5]:
	+ Proposal 9: Coverage enhancement mechanism such as PDCCH repetition should be studied for PDCCH design especially for high SCS.
* From [7]:
	+ Proposal 7: Study channel estimation performance impact of PDCCH and PUCCH with a larger subcarrier spacing.
* From [10]:
	+ Proposal 23: Support improved PDCCH coverage for the cases of high SCS.
* From [14]:
	+ Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz, it is beneficial to support UE PDCCH processing capabilities per multi-slot monitoring period that scale with the size of the monitoring period when the UE is configured with a monitoring period larger than a slot.
* From [19]:
	+ Observation 11: it is beneficial to increase symbols and reduce RBs for the CORESET configuration for a given large SCS if introduced.

### 2.5.2 PDCCH Monitoring - Observations and Proposals from Contributions

* From [2]:
	+ Observation 12: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then the PDCCH monitoring capability would be further reduced and the number of PDCCH candidates per slot would be lower.
	+ Observation 13: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then the PDCCH processing in every slot might not be scalable with increasing subcarrier spacing, due to limitations with UE processing capability.
* From [3]:
	+ Observation 10: Detection probability of PDCCH may decrease for 960 kHz with the limited maximum number of non-overlapped CCEs per slot which may be lower than 16.
* From [10]:
	+ Observation 25: For high SCS, such as 960 kHz and above, PDCCH monitoring capabilities, and especially channel estimation capability of number of unique CCEs per slot is expected to reduce below tolerable limit.
	+ Proposal 17: Increase of the minimum scheduling/ PDCCH monitoring unit to avoid excessive increase in PDCCH monitoring rate and excessive reduction in per-slot monitoring capabilities.
	+ Proposal 18: Determine BD/CCE limits based on nominal scheduling/monitoring unit such as slot of e.g. 120kHz (defined in R15)/240kHz (FFS).
	+ Observation 26: GC-PDCCH is an essential part of unlicensed system, and there seems to be need to supportbeam-dependent information, particularly if some form of directional LBT is chosen as coexistence mechanism.
	+ Proposal 19: Changes to DCI format 2\_0 may be beneficial for at least unlicensed 60GHz NR operation.
* From [15]:
	+ Proposal #7: It would be beneficial in terms of UE implementation complexity or power consumption to perform slot(or symbol)-group level processing instead of every slot(or symbol) processing, e.g. PDCCH monitoring and CSI processing unit availability check.
* From [20]:
	+ Observation 4: The increase of SCS causes frequent PDCCH monitoring, which is not desirable for the UE power consumption.
* From [21]:
	+ Proposal 13: To reduce PDCCH monitoring complexity, reduce the limits per slot or define PDCCH monitoring limits over a group of slots.
	+ Proposal 14: Use beam cycling to improve the coverage of PDCCH with gaps between CORESETs to account for any beam-switching times.
* From [22]:
	+ Proposal 3: The enhancement for PDCCH monitoring for 52.6-71GHz should also consider the requirements from PDSCH scheduling.
* From [23]:
	+ Proposal 3: For new SCS, if agreed, the following aspects should be prioritized to address UE PDCCH monitoring complexity concerns.
		- investigation on the maximum number of BDs/CCEs for PDCCH monitoring per slot
		- potential limitation to PDCCH monitoring configurations, e.g., ks=1 and Ts>1 in search space set configuration
		- related UE capabilities for PDCCH monitoring and processing
* From [29]:
	+ Proposal 9: When a large subcarrier spacing is defined, maximum number of BDs/CCEs for PDCCH monitoring needs to be investigated.
* From [30]:
	+ Proposal 7: RAN1 shall study the mechanism to reduce PDCCH monitoring burden at UE side for new numerology.

### 2.5.3 DCI Formats - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 9: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then consider enhancements to current PDCCH design that includes the following possibilities:
		- To introduce new single DCI format that could simultaneously schedule DL transmission and UL grants for one or more transmission time intervals
		- To limit the monitoring to PDCCH in slots when the UE receives a multi-slot scheduling grant
* From [4]:
	+ Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.
* From [6]:
	+ Proposal 2: If time domain scheduling enhancements for PDSCH is needed, multi-PDSCH scheduled by one DCI should be supported for less standardization workload.
* From [7]:
	+ Observation 8: If the maximum FFT size of Rel-15/16 is kept, it is observed that maximum number of RBs and required payloads of DCI for frequency domain resource allocation do not increase.
* From [10]:
	+ Proposal 20: Support Multi-PDSCH DCI for reaching peak data-rates for the cases of high SCSs
		- R16 Multi-PUSCH DCI design principle shall be the starting point.
* From [13]:
	+ Proposal 12: The combination of multi-PDSCH scheduled by one DCI and enhanced dynamic HARQ-ACK codebook and one-shot HARQ-ACK feedback should be studied.
* From [14]:
	+ Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz it is beneficial to support scheduling multiple PDSCH using one DCI by extending the multi-PUSCH scheduling feature introduced in Rel-16 to the scheduling of multiple PDSCH using one DCI in Rel-17
* From [15]:
	+ Proposal #8: Consider to support multi-PDSCH scheduling by a single DCI.
* From [20]:
	+ Proposal 3: Multi-PDSCH/PUSCH scheduling by one DCI should be supported for NR above 52.6 GHz.
* From [28]:
	+ Proposal 1: Consider enhanced multi-carrier operation where a single DCI can schedule multiple cells, including SCells with a dormant BWP, for energy-efficient and low-latency NR performance.
* From [30]:
	+ Proposal 8: RAN1 shall study more flexible resource allocation in both time and frequency domain for different scenarios, including increasing the time-domain scheduling unit to be larger than one symbol, multi-PDSCH scheduling by one DCI, one TB mapped to multiple slots and subcarrier bundling/sub-PRB.

### 2.5.4 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* Many discussions and issue seem to be dependent on supported SCS, and BD and UE complexity.
* Several companies discussed PDCCH monitoring issue for larger subcarrier spacing and need to provide enhancements to conserve UE complexity/power.
* One company noted that it may be beneficial to support UE PDCCH processing capabilities per multi-slot monitoring period that scale with the size of the monitoring period when the UE is configured with a monitoring period larger than a slot.

##### Company Comments on PDCCH:

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| --- | --- |
|  **Company** | **Comments** |
| Futurewei | The use of SCS (240kHz) can provide enough coverage for PDCCH. |
| Lenovo/Motorola Mobility | Increased number of symbols for CORESET should be considered. Also, based on the channel estimation performance for PDCCH, CORESET design in terms of DM-RS pattern should be investigated |
| InterDigital | In our view, if new SCSs are supported, at least supporting same SCSs between PDCCH and PDSCH should be considered.  |
| Qualcomm | We support the same numerologies for data and control, i.e., 120kHz and 960kHz. Regarding the view on the PDCCH coverage enhancement, we think it should be handled in the CE session. Also, since PDCCH uses QPSK and relatively robost to chanel estimation error, we don’t think the PDCCH DMRS enhancement is critical, compared to the cases of PDSCH/PUSCH with high MCSs. |
| CATT | If the narrow beamforming operation is used for NR operation in 52.6 – 71 GHz, the number of CORESETs could be extended to support dynamic beam switching of PDCCH.  |
| Apple | We are fine with same numerology for data and PDCCH. |
| vivo | In our view, PDCCH coverage enhancement should be considered here, e.g. increase the number of Coreset symbols or PDCCH repetition. |
| Nokia, NSB | Support improved PDCCH coverage for the case of a high SCS. Both single numerology (i.e. increased number of symbols available for PDCCH) and mixed numerology (i.e. different SCS for PDCCH and PDSCH) approaches can be considered.  |

##### Company Comments on PDCCH Monitoring:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Reducing PDCCH monitoring to reduce UE monitoring complexity should be supported |
| Lenovo/MotorolaMobility | Reduced PDCCH monitoring would be needed for higher SCS, if agreed to be supported. Consider limitations on search space configurations, DCI formats to be monitored and reduced need for PDCCH monitoring on consecutive slots. |
| Qualcomm | For higher SCS, multi-slot-based PDCCH monitoring capability would be discussed to reduce complexity. The span-based PDCCH monitoring capability, which was introduced in Rel-16, can be a baseline. |
| CATT | Current specification is very flexible in configuring UE PDCCH monitoring. If higher SCS is introduced, the number of PDCCH candidates in a slot for blind decoding would be reduced. No additional enhancement is needed.  |
| Apple | Reduced PDCCH monitoring capabilities are essential especially if higher SCS values are chosen. We may (a) reduce PDCCH monitoring per slot or (b) perform PDCCH monitoring over a group of slots. The specifics can be discussed in the WI but depend on the SCSs selected. |
| vivo | Support PDCCH monitoring capability definition enhancement from slot/mini-slot level to slot group level |
| Convida Wireless | Reducing UE monitoring PDCCH complexity should be studied for higher SCS if supported.  |
| Nokia, NSB | For the case of a high SCS, increase of the minimum scheduling/ PDCCH monitoring unit to avoid excessive increase in PDCCH monitoring rate and excessive reduction in per-slot monitoring capabilities. |

##### Company Comments on DCI Formats:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Support multi-PDSCH scheduling per DCI |
| Lenovo/Motorola Mobility | New DCI format to support both multi-PDSCH and multi-PUSCH scheduling could be considered |
| InterDigital | In our view, time-domain scheduling enhancement should be considered to reduce the scheduling signal overheads, however, we are not sure that we need to introduce new DCI format for it.  |
| Qualcomm | We support a new DCI format for multi-PDSCH scheduling. |
| CATT | Multi-slot scheduling or slot-aggregation could be considered.  |
| Apple | Support multi-PDSCH/multi-PUSCH scheduling |
| vivo | Support new DCI for multi-PDSCH scheduling |
| Convida Wireless | New DCI format can be studied or considered for NR 52.6 -71 GHz.  |
| Nokia, NSB | Support Multi-PDSCH DCI for reaching peak data-rates for the case of a high SCS |

##### 2nd round of Discussion:

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

|  |  |
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|  **Company** | **Comments** |
| Nokia, NSB |  We added input to first round questions, sorry for delay |

## 2.6 PDSCH/PUSCH

### 2.6.1 Scheduling Aspects - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 9: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then consider enhancements to current PDCCH design that includes the following possibilities:
		- To introduce new single DCI format that could simultaneously schedule DL transmission and UL grants for one or more transmission time intervals
		- To limit the monitoring to PDCCH in slots when the UE receives a multi-slot scheduling grant
* From [4]:
	+ Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.
* From [6]:
	+ Proposal 2: If time domain scheduling enhancements for PDSCH is needed, multi-PDSCH scheduled by one DCI should be supported for less standardization workload.
* From [7]:
	+ Observation 7: The enhancement of time domain resource allocation may be a crucial part for efficient operation in higher frequencies.
	+ Proposal 10: Study the enhanced time domain resource allocation method considering the scheduling efficiency, the UE implementation impacts and the specification impacts.
	+ Observation 8: If the maximum FFT size of Rel-15/16 is kept, it is observed that maximum number of RBs and required payloads of DCI for frequency domain resource allocation do not increase.
	+ Proposal 11: The benefits from frequency domain resource allocation enhancements should be carefully studied.
* From [10]:
	+ Observation 23: Scheduling principle needs to be revisited for the cases with high SCS.
	+ Proposal 20: Support Multi-PDSCH DCI for reaching peak data-rates for the cases of high SCSs
		- R16 Multi-PUSCH DCI design principle shall be the starting point.
	+ Observation 27: There seems to be no need to modifying the existing frequency domain resource allocation mechanisms with high SCSs.
	+ Proposal 21: Reuse NR R15 RBG size determination, which is FR and SCS agnostic.
* From [13]:
	+ Proposal 12: The combination of multi-PDSCH scheduled by one DCI and enhanced dynamic HARQ-ACK codebook and one-shot HARQ-ACK feedback should be studied.
* From [14]:
	+ Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz it is beneficial to support scheduling multiple PDSCH using one DCI by extending the multi-PUSCH scheduling feature introduced in Rel-16 to the scheduling of multiple PDSCH using one DCI in Rel-17
	+ Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz, it is beneficial to reduce the FDRA fields size by supporting larger RBG sizes.
	+ Capture the following observation in TR 38.808: For operation in the 52.6 – 71 GHz band, consider gNB initiated polling approach for UL traffic management to reduce UL data latency.
* From [15]:
	+ Proposal #8: Consider to support multi-PDSCH scheduling by a single DCI.
* From [20]:
	+ Proposal 3: Multi-PDSCH/PUSCH scheduling by one DCI should be supported for NR above 52.6 GHz.
	+ Observation 5: Multi-PUSCH scheduling introduced in Rel-16 NR-U can be reused for NR above 52.6 GHz.
* From [21]:
	+ Proposal 15: Support frequency domain scheduling enhancements, time domain scheduling enhancements and updates to the Scheduling request for NR operation above 52.6 GHz.
* From [26]:
	+ Proposal 5: Multi-slot-based UE capabilities can be considered for new SCSs with short slot lengths.
	+ Observation 9: The span-based UE capability in Rel-16 can be a baseline for multi-slot-based UE capability for high SCSs.
* From [28]:
	+ Proposal 1: Consider enhanced multi-carrier operation where a single DCI can schedule multiple cells, including SCells with a dormant BWP, for energy-efficient and low-latency NR performance.
* From [29]:
	+ Proposal 10: When a large subcarrier spacing is defined, multi-TTI based scheduling can be considered to relax scheduler implementation and higher layer processing burden.
* From [30]:
	+ Proposal 8: RAN1 shall study more flexible resource allocation in both time and frequency domain for different scenarios, including increasing the time-domain scheduling unit to be larger than one symbol, multi-PDSCH scheduling by one DCI, one TB mapped to multiple slots and subcarrier bundling/sub-PRB.
* From [31]:
	+ Proposal 7: How to allocate resource for data in frequency domain needs to be considered especially for higher SCS if introduced.
		- PDSCH/PUSCH allocated on more than 14 symbols would be beneficial.
		- In 60 GHz unlicensed band, the necessity of interlaced PUCCH/PUSCH would be questionable.
		- Enhancements on RB allocation for PUCCH format 0/1 should be considered.
	+ Observation 11: The current granularity in time/frequency domain in Rel-15/16 may be too fine, assuming less opportunity for FDM between UEs due to narrower beam width and larger number of symbols required for coverage performance.

### 2.6.2 PUSCH Interlace Transmission - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 13: For supporting NR beyond 52.6 GHz in unlicensed band in Rel. 17, study the enhancement of PRB/sub-PRB interlacing designs for NR with higher SCS, if agreed to be supported.
* From [3]:
	+ Observation 12: Sub-PRB based resource allocation for PUSCH is not necessary due to an increased channel estimation complexity and a higher payload for FDRA.
	+ Proposal 12: PRB based interlace resource mapping for PUSCH/PUCCH/SRS should be studied further in NR-U-60.
* From [9]:
	+ Observation 4: Due to very wide BW, the number of PRBs per interlace will increase significantly.
	+ Proposal 5: RAN1 shall study the possibility to assign NR-U PUCCH onto partial interlaces for high BW channels.
* From [10]:
	+ Observation 28: OCB requirement or PSD limitation does not require interlaced UL allocation on 60 GHz unlicensed band.
	+ Proposal 24: No interlaced transmission is defined for 60 GHz unlicensed band.
* From [13]:
	+ Proposal 11: It may not be necessary to support interlaced uplink transmission for unlicensed operation in 52.6~71 GHz band.
* From [14]:
	+ PRB-based interlacing is not beneficial for SCS ≥ 120 kHz
	+ Sub-PRB interlacing is not beneficial for SCS ≥ 960 kHz
	+ Both PRB and sub-PRB interlacing is not beneficial for large frequency resource allocations
	+ Capture the following observation in TR 38.808: Neither PRB or sub-PRB interlacing is beneficial for the expected large frequency resource allocations applicable for NR operation in 52.6 – 71 GHz spectrum. The support of UL interlace allocation is not considered for NR operation in 52.6 – 71 GHz.
* From [19]:
	+ Observation 10: interlace seems not necessary in 60GHz unlicensed operation, due to the OCB requirement does not need to be constantly met and the power boosting benefit seems disappear with wider RB bandwidth envisioned in 60GHz.
* From [20]:
	+ Proposal 4: Sub-PRB based interlace design should be supported for 60 GHz unlicensed spectrum.
* From [22]:
	+ Proposal 4: In order to meet the requirements of minimum OCB, some enhancement on interlace design with unregular RB number might be considered.
* From [23]:
	+ Proposal 4: PRB and sub-PRB Interlace are not supported for UL transmission in 60 GHz band.
* From [30]:
	+ Proposal 9: RAN1 shall study sub-PRB level interlace for UL transmission.

### 2.6.3 Transmission Rank - Observations and Proposals from Contributions

* From [10]:
	+ Proposal 11: Consider supporting rank-2 SU-MIMO for DFT-s-OFDM in 60GHz band.
* From [14]:
	+ Do not further discuss Rank-2 transmission for DFT-s-OFDM in the 52.6 – 71 GHz SI/WI. This should be addressed under a MIMO SI/WI.
* From [28]:
	+ Proposal 2: It is beneficial to allow higher UL throughput without sacrificing power efficiency by enabling more than 1 spatial layer with UL transform precoding.

### 2.6.4 HARQ Processes - Observations and Proposals from Contributions

* From [4]:
	+ Proposal 6: HARQ-ACK feedback mechanism for multi-TTI scheduling should be studied.
* From [5]:
	+ Proposal 11: The default set of PDSCH-to-HARQ\_feedback timing indicator should be adapted to the SCS of PDSCH.
* From [14]:
	+ Because of larger processing latencies, the numbers of DL and UL HARQ processes may need to be increased. Otherwise, physical layer specification and implementation changes compared to Rel-15 may be needed to sustain high data throughput.

### 2.6.5 Processing Timelines - Observations and Proposals from Contributions

* From [3]:
	+ Proposal 11: Reuse the processing timeline for FR2 for 120 kHz. If a new SCS is supported, reusing processing timeline for FR2 based on a fixed time unit defined as a slot duration of 120 kHz can be considered with slot bundling within the fixed time unit for PDSCH/ PUSCH resource allocation, mapping, and PDCCH monitoring.
* From [4]:
	+ Proposal 2: For PUSCH scheduled by RAR or by the fallback RAR, Δ value should also be considered for new SCS if agreed.
	+ Proposal 3: Specify different default K1 value sets for different SCS, and each K1 set with a maximum number of 8 values to keep the K1 bit field in DCI 1-0 unchanged.
	+ Proposal 4: Configure different K1 value sets for different SCS, and each K1 set with a maximum number of 8 values to keep the K1 bit field in DCI 1-1/DCI 1-2 unchanged.
	+ Proposal 5: Impacts on PDSCH/PUSCH processing time(N1/N2) should be considered if defining maximum number of BDs/CCEs for PDCCH monitoring per multiple slots.
* From [7]:
	+ Proposal 8: Study required UE processing time for higher frequencies considering the differences on antenna/panel structure, beam width, BWP size and new subcarrier spacings.
	+ Observation 6: Existing processing time determination methods are based on worst case scenarios and may require more redundant processing time for higher frequencies.
	+ Proposal 9: Study application of different processing time requirements based on parameters which contribute UE processing time.
* From [13]:
	+ Proposal 14: If introducing new numerology, the impacts on processing time and scheduling operation should be considered.
* From [14]:
	+ UE processing timelines for SCS > 120 kHz need to be further tightened vis-à-vis those for 120 kHz SCS to enable high performance NR operation in 52.6 to 71 GHz.
	+ The times provisioned for UE processing grow exponentially with the numerology. Large processing latencies restrict the achievable throughputs, defeating the purpose of enabling large bandwidths with large sub-carrier spacings.
	+ Capture the following observation in TR 38.808: For selection of suitable SCS for the 52.6 – 71 GHz frequency range, the expected increases in processing latencies and decreases in processing capabilities associated with large SCS are important factors. To enable high performance NR operation in 52.6 to 71 GHz, UE processing timelines and capabilities for SCS > 120 kHz need to be further tightened. Such issues put pressure to define SCS(s) as low as possible preferably leveraging existing SCS(s) in the current spec, i.e., ≤480 kHz.
	+ Add the following aspects to the list of processing timelines for new SCS (if agreed) that are not currently supported,
		- Processing capability for PUSCH scheduled by RAR UL grant
		- Dynamic SFI and SPS/CG cancellation timing
		- Timeline for HARQ-ACK information in response to a SPS PDSCH release/ dormancy.
		- Minimum time gap for wake-up and SCell dormancy indication (DCI format 2\_6)
		- BWP switch delay
		- Multi-beam operation timing (timeDurationForQCL, beamSwitchTiming, beam switch gap, etc.)
		- Timeline for multiplexing multiple UCI types
	+ RAN1 should investigate the different factors that contribute to the PDSCH processing time and consider possible latency reduction opportunities.
* From [21]:
	+ Proposal 11: To reduce the timing constraints due to increasing the SCS, modify the UE timing parameter values and their associated signaling.
	+ Proposal 12: To accommodate timeline changes from the increased number of slots due to a possible increase in the SCS , increase the number of HARQ processes and/or increase the number of slots a HARQ codebook is tied to.
* From [29]:
	+ Proposal 8: When a large subcarrier spacing is defined, processing time related aspects, including PDSCH/PUSCH processing time, CSI computation time, etc., need to be investigated.
* From [30]:
	+ Proposal 6: RAN1 shall study proper value for processing timing for new numerology, and enhancement for relevant procedures and signaling with the consideration of UE complexity, latency and signaling overhead.
* From [31]:
	+ Proposal 10: For higher SCS, the appropriate configuration of k0, k1, k2 need to be discussed to meet UE minimum processing timeline.
		- If the current candidate values don’t meet UE processing limitation, extending, limiting or shifting the range of k0, k1, k2 may be necessary.

### 2.6.6 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* Some companies notes some interlace operations may be needed. Some companies commented to study PRB and sub-PRB interlace design, while some companies comments sub-PRB interlace design is not need and some companies commented interlace transmission is not needed altogether.
* Some companies suggested to support rank 2 transmission for DFT-s-OFDM. It should noted that some companies have commented that this design should be conducted under MIMO SI/WI.
* Some companies have commented HARQ feedback mechanism if multi-TTI scheduling is supported require further study.
* A company noted that processing latencies requirements tend to decrease with increase in SCS and may pose challenges to implementation.
* A company noted that following processing timelines for new SCS (if agreed) needs to be defined:
	+ Processing capability for PUSCH scheduled by RAR UL grant
	+ Dynamic SFI and SPS/CG cancellation timing
	+ Timeline for HARQ-ACK information in response to a SPS PDSCH release/ dormancy.
	+ Minimum time gap for wake-up and SCell dormancy indication (DCI format 2\_6)
	+ BWP switch delay
	+ Multi-beam operation timing (timeDurationForQCL, beamSwitchTiming, beam switch gap, etc.)
	+ Timeline for multiplexing multiple UCI types

##### Company Comments on PDSCH/PUSCH scheduling aspects:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei  | Support multi-PDSCH and multi-PUSCH scheduling with a single DCI |
| Lenovo/Motorola Mobility | Agree with Futurwei to consider supporting single DCI that can schedule both multi-PDSCH and multi-PUSCH. This would allow for reduced PDCCH monitoring, longer scheduling units for both PDSCH and PUSCH, and avoid long continuous transmissions for either PDSCH or PUSCH |
| InterDigital | As mentioned above, time-domain scheduling enhancement should be considered for both PDSCH and PUSCH.  |
| Qualcomm | We support multi-PDSCH/PUSCH scheculing. Two different aspects can further be discussed: a single DCI scheduling multiple TBs (one TB per slot, similar to Rel-16 NR-U UL) or a single TB mapped to multiple slots. Also, related to the multi-PDSCH/PUSCH scheduling, the followings can furhter be discussed:* HARQ-ACK feedback enhancement (see Section 2.6.4)
* DMRS enhancement: e.g., DMRS bundling/skipping
* DCI piggyback on PDSCH

Furthermore, due to the overlapping scope of multi-TTI scheduling with CE and UE power saving discussions, inter-WI alignment would be necessary. |
| Apple | Support multi-PDSCH/multi-PUSCH scheduling. Also support scheduling over a group of slots i.e. longer scheduling units. Unlike in R-16 NR-U, the multi-PDSCH scheduling does not have to be for a continuous set of transmissions.  |
| vivo | Support multi-PDSCH/PUSCH scheduling.  |
| Nokia, NSB | Support multi-PDSCH/PUSCH scheduling with a single DCI. |

##### Company Comments on PUSCH interlace transmissions:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Sub-PRB interlace may not be beneficial at lower SCS (240 kHz) |
| Qualcomm | There is no OCB issue in 60GHz operation and power boosting is not applicable with both 120KHz and 960kHz SCS. So interlacing is not necessary. For 120KHz SCS, sub-PRB level interlace may increase transmit power under PSD limitation, but the associated spec impact is too high. |
| vivo | We didn’t see strong motivation to support interlace |
| Nokia, NSB | OCB requirement or PSD limitation does not require interlaced UL allocation on 60 GHz unlicensed band. Hence, interlaced transmission is not needed for 60 GHz unlicensed band. |

##### Company Comments on Transmission Rank:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | The rank discussion for DFT-s-OFDm belongs to MIMO SI/WI |
| InterDigital | We also think that rank-2 transmission can be considered as rank-2 transmission can be supported with by utilizing X-pol antennas in LOS channel. In addition, we are not sure that the discussion belongs to MIMO SI/WI as we are discussing specification for 52.6 – 71 GHz while delegates in MIMO SI/WI is discussing MIMO operations in FR1 and FR2. |
| Qualcomm | We support rank-2 DFT-s-OFDM. Although we agree with the view of [14] and Futurewei, rank-2 DFT-s-OFDM is an issue of particular interest in the 52.6-71GHz SI/WI. Therefore, it could be addressed in the 52/6-71GHz SI/WI. |
| vivo | Agree with Futurewei |
| Nokia, NSB | Agree with Qualcomm |

##### Company Comments on HARQ Processes:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Qualcomm | We support HARQ enhancement in the following aspects:* HARQ supporting multi-PDSCH/PUSCH scheduling
	+ Joint feedback in a single or multiple PUCCHs for a single DCI-scheduled SCHs
* Increased number of HARQ processes
 |
| Apple | The number of HARQ processes may need to be increased. In addition, we support creating HARQ slot groups i.e. inverse of the HARQ-sub-slots in Rel-16. |
| vivo | Support HARQ enhancement regarding multi-PDSCH/PUSCH scheduling |

##### Company Comments on Processing Timelines:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Having a single SCS of 240 kHz would not require re-evaluating the processing timelines already supported. We may reuse the FR2 timelines. |
| Qualcomm | We should simply acknowledge the fact that, in terms of the number of symbols, the processing timeline will be longer for higher SCSs. The detailed numbers and related capabilities can be left for WI phase. |
| Nokia, NSB | Agree with Qualcomm |

##### 2nd round of Discussion:

Moderator has provided some suggestion for conclusion/observation to be captured for the TR. Please provide further comments on the suggestion and if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

1. Some companies have noted that interlace transmissions for PUSCH do not provide benefit over uplink allocations currently supported by NR for NR operating in 52.6 GHz to 71 GHz, while some companies have noted support of interlace transmissions for PUSCH may be needed to improve transmit power and possibly to meet OCB requirements when necessary.
2. RAN1 identifies that for new subcarrier spacing, if agreed, will require standardization of the following processing timelines:
	1. Processing capability for PUSCH scheduled by RAR UL grant
	2. Dynamic SFI and SPS/CG cancellation timing
	3. Timeline for HARQ-ACK information in response to a SPS PDSCH release/ dormancy.
	4. Minimum time gap for wake-up and SCell dormancy indication (DCI format 2\_6)
	5. BWP switch delay
	6. Multi-beam operation timing (timeDurationForQCL, beamSwitchTiming, beam switch gap, etc.)
	7. Timeline for multiplexing multiple UCI types

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Nokia, NSB |  Adding 3) RAN1 identifies that for new subcarrier spacing, if agreed, will require standardization of multi-PDSCH scheduling? |
| Lenovo, Motorola Mobility | Agree with Nokia’s proposed addition and further additions on similar point as follows:1. RAN1 identifies that for new subcarrier spacing, if agreed, will require standardization of multi-PDSCH/PUSCH scheduling and at least following specification enhancements should be considered:
	1. Single TB and multiple TB scheduling over multiple slots
	2. New single DCI format for multi-PDSCH and multi-PUSCH scheduling
	3. Multiple beam indication (multiple TCI states) and corresponding validity in time
	4. DM-RS enhancements such as DM-RS bundling, time-domain pattern.
 |
| Futurewei | Agree with Moderator’s proposal. We support multi-PDSCH and multi-PUSCH scheduling.  |
| Qualcomm | We agree with Nokia and Lenovo, Motorola Mobility’s view. We can further add HARQ enhancement for multi-TTI scheduling. |
| InterDigital | We are fine with Moderator’s proposal and adding multi-PDSCH scheduling and correponding HARQ enhancement. |

## 2.7 Reference Signals

### 2.7.1 PT-RS - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 4: For supporting NR operation between 52.6GHz and 71GHz in Rel. 17, no PT-RS configuration should also be supported, depending up on the MCS range, if higher subcarrier spacing values are agreed to be supported.
* From [3]:
	+ Observation 11: Block PTRS enables low complexity ICI compensation for smaller SCSs such as 120 kHz and 240 kHz and helps the smaller SCS to perform even better than a larger SCS such as 960 kHz. A new PTRS pattern with more PTRS groups within one DFT-s-OFDM symbol should be considered.
* From [5]:
	+ Proposal 10: DM-RS/PT-RS enhancement should be further studied to solve the problem caused by RF impairment such as phase noise, I-Q imbalance and PA non-linear work range.
* From [10]:
	+ Observation 8: For ICI compensation, two approaches are discussed,
		- Enhanced PT-RS design (e.g. localized/block PT-RS)
		- Implementation-based method (e.g. data-aided direct filtering.)
	+ Proposal 7: Support ICI compensation for NR beyond 52.6GHz, and study and compare different ICI compensation schemes with respect to performance as well as implementation complexity.
	+ Proposal 9: Consider defining new PTRS configurations for DFT-s-OFDM.
* From [11]:
	+ Proposal 1: Support block-based PT-RS patterns for OFDM waveform.
	+ Proposal 2: Support cyclic PT-RS sequence for OFDM waveform.
	+ Proposal 3: A PT-RS sequence for OFDM waveform composed of KP samples includes a cyclic prefix of floor(KP/2) samples.
	+ Proposal 4: Support density extension of current Rel.15 PT-RS for DFTsOFDM waveform.
* From [14]:
	+ Capture the following observation in TR 38.808: Clustered PT-RS structure can frequently collide with existing NR reference symbols (such as CSI-RS and TRS) with no simple avoidance solution.
	+ Capture the following observation in TR 38.808: A clustered PT-RS structure does not offer any performance advantage over the existing Rel-15 NR distributed PT-RS structure.
	+ Retain the same Rel-15 distributed PT-RS structure for OFDM for NR operation in 52.6 to 71 GHz.
* From [15]:
	+ Proposal #5: Investigate the necessity to enhance the structure of DM-RS for data as well as control DL/UL channels and that of PT-RS for DFT-s-OFDM considering UE multiplexing and efficient data transmission.
* From [19]:
	+ Observation 8: with legacy PTRS pattern, phase noise impact is more visible for MCS 22.
	+ Observation 9: the ICI compensation can further reduce the BLER floor compared with simple CPE compensation, but displays a 2~2.5 dB gap to phase noise off performance.
* From [21]:
	+ Observation 2: The total PN increases when compared to below 52.6 GHz operation.
	+ Observation 3: By using PN ICI compensation, we can reduce the maximum SCS selected when compared with CPE compensation only.
	+ Proposal 3: Consider the use of a new PTRS and/or Phase Noise ICI compensation to improve performance to limit need for specifying higher SCS.
	+ Proposal 9: Support an update to Rel-15 PTRS to enable improved ICI compensation.
* From [26]:
	+ Proposal 2: As PTRS enhancement for assisting ICI compensation, increasing the frequency domain PTRS density for small RB allocation can be considered. New PTRS patterns other than the Rel-15 design, such as the block PTRS pattern is not necessary.
* From [30]:
	+ Proposal 11: RAN1 shall study the enhancement to reference signals (e.g. chunk based PT-RS pattern) for the new carrier frequency range to mitigate the impact of ICI, taking into consideration of the impact from the new numerology.

### 2.7.2 DM-RS - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 5: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, new DM-RS configurations should be considered with following criterion:
		- High frequency density of the DM-RS for high SCS for better channel estimation when channel coherence bandwidth is less than the configured SCS
		- Reduced number of DM-RS ports as the performance gain of high rank MIMO channels is expected to be limited in high FR2
* From [5]:
	+ Proposal 10: DM-RS/PT-RS enhancement should be further studied to solve the problem caused by RF impairment such as phase noise, I-Q imbalance and PA non-linear work range.
* From [7]:
	+ Observation 5: The performance loss from channel estimation error gets reduced as DM-RS density increases especially when a higher modulation order is used.
	+ Proposal 6: Study enhanced DM-RS designs for a larger subcarrier spacing for PDSCH and PUSCH.
* From [10]:
	+ Observation 30: Existing Rel-15 DMRS type-1 is a feasibile solution for 480kHz and 960kHz sub-carrier spacing options.
	+ Observation 31: Existing Rel-15 DMRS type-1 is also feasible solution with higher transmission ranks (e.g. rank 2) for 480kHz and 960kHz sub-carrier spacing options.
	+ Proposal 26: Use existing Rel-15 DMRS type-1 for 480 kHz and 960 kHz sub-carrier spacing options. No need to design any new DMRS structure for 480 KHz and 960 sub-carrier options in Rel-17.
* From [14]:
	+ Capture the following observation in TR 38.808. For 480 kHz SCS and below with large delay spread, the room for performance improvement with a change to the Rel-15 DMRS design is very limited.
* From [15]:
	+ Proposal #5: Investigate the necessity to enhance the structure of DM-RS for data as well as control DL/UL channels and that of PT-RS for DFT-s-OFDM considering UE multiplexing and efficient data transmission.
* From [21]:
	+ Proposal 10: To account for transmission with large SCSs in low coherence BW channels,
		- turn on or off the FD-OCC based on the scenario the channel is in
		- configure the UE with a DMRS pattern robust to frequency selective fading
* From [25]:
	+ Proposal 3: For DMRS enhancement for high SCSs, higher DMRS RE density and new multiplexing patterns should be studied.
* From [29]:
	+ Proposal 6: For subcarrier spacing 480 kHz and 960 kHz, PDSCH (and potentially PUSCH) reception performance is impacted by frequency domain OCC in DMRS, and therefore we suggest that RAN1 further investigate on frequency domain OCC for DMRS.
* From [31]:
	+ Proposal 6: How to allocate resource for RS (e.g. DMRS, PTRS) in frequency domain needs to be considered for higher SCS if introduced
		- DMRS density in frequency domain may not be sufficient
		- DMRS ports multiplexing may not work well

### 2.7.3 TRS - Observations and Proposals from Contributions

* From [10]:
	+ Observation 32: For P-TRS transmissions in the cell, it would be beneficial to have a mechanism to be able to transmit P-TRSs dropped due to LBT failure.

### 2.7.5 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* Some companies provided suggestions for enhanced PTRS design that may improve to combat phase noise by enabling ICI compensation.
* A companies noted that one of the enhanced PTRS design being proposed by some companies, block PT-RS design, may collide with other NR reference signals.
* Some companies noted enhancements for DMRS may be needed for larger SCS and noted frequency domain OCC is being impacted by frequency selectivity for larger SCS.
* Some companies noted that existing DMRS does not exhibit issues and existing design is suitable.
* A company noted P-TRS transmission may be dropped do to LBT failure and RAN1 may need to investigate further into this issue.

##### Company Comments on PT-RS:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | New PTRS design may not be necessary. The time density of PTRS signal may be increased.  |
| Qualcomm | New PTRS pattern, such as a block PTRS pattern, is not needed if a proper ICI cancallation scheme (e.g., direct de-ICI filtering) is used. |
| CATT | No new PTRS pattern is needed |
| Intel | Prefer to keep current PTRS patterns. |
| Mitsubishi | Current PTRS pattern is not sufficient and needs to be improved. Block PTRS with cyclic sequencs shows significant performance improvement over both CPE and de-ICI filtering applied onto the legacy Rel.15 PTRS pattern. Disagree with Futurewei on the possibility of increasing the time density, the higher layer parameter *timeDensity* can already be set to *LPT-RS* = 1 (every OFDM symbol not carrying DMRS) in the current specification. At least two companies show that increasing the current PTRS density in the frequency domain does not procure significant performance improvement either. In our evaluations we observed significant performance improvement when passing from a block PTRS structure with “ordinary” random sequence to a block PTRS structure with cyclic structure. The receiver of the block PTRS structure with cyclic sequence is less complex than the de-ICI filter for block structure with random sequence as explained in our contribution. Our contribution did not explicitly show the results of block PTRS with random structure because they were close to de-ICI filtering onto legacy PTRS sequence (plotted in our contribution), with an identical 5-tap receiver.  |
| vivo | No new PTRS pattern is needed |
| Nokia/NSB |  For 960kHz SCS, CPE compensation is enough to support higher MCS, while additional ICI compensation is required for SCS lower than 960kHz. For low complexity indoor device, higher SCS with CPE compensation is beneficial without having complex ICI compensation. For coverage extension, lower SCS with ICI compensation is applicable. For ICI compensation, it is required to study possible enhancement of PT-RS with the consideration of complexity and the performance for both CP-OFDM and DFT-s-OFDM.   |
| InterDigital | We agree that no new PTRS pattern may not be needed |

##### Company Comments on DM-RS:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | New DM-RS design for SCS less or equal to 480 kHz may not be necessary |
| Lenovo/Motorola Mobility | New DM-RS design should be considered to increase the frequency density for improved channel estimation performance with higher SCS, while also reducing the number of DM-RS ports compared to exiting DM-RS configurations |
| Qualcomm | For higher SCS, such as 960kHz, higher DMRS RE density and a new DMRS port multiplexing pattern can be investigated to compensate the channel estimation performance degradation. |
| CATT | No new DM-RS pattern is needed |
| Intel | Modification to current DM-RS might be needed especially for high SCS to prioritize FDM of DM-RS ports over CDM. |
| Apple | May need to modify the DMRS (e.g. the FD OCC) in the case of a high SCS and small coherence BW. |
| Nokia/NSB | For CP-OFDM, no new DM-RS pattern is required. Current DM-RS configuration supports upto 2 ports without FD-OCC by scheduling DM-RS port {0,2}. For UL DFT-s-OFDM, in order to reduce PAPR and cross-correlation between sequences, DM-RS pattern without Comb (as used for PUCCH format 3/4) can be considered for PUSCH DMRS.   |
| InterDigital | For high SCS, enhancement on higher DMRS density and DMRS port multiplexing patterns can be investigated.  |

##### Company Comments on TRS:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
|  |  |

##### 2nd round of Discussion:

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Nokia, NSB | LBT failure may prevent transmission of P-TRS that is the main QCL source for different signals and channels. Thus, UE may not have up to date QCL source for coming signals/channels to be received (or to be transmitted) and that would impact negatively on the downlink performance but as well the uplink performance. It would be beneficial to have a mechanism to be able to transmit P-TRSs dropped due to LBT failure. |
| Lenovo, Motorola Mobility | Generally, agree with Nokia’s view on periodic RS transmission as QCL source in case of LBT failure. Could be more generic and instead of P-TRS, periodic CSI-RS should be considered |
| InterDigital | We additionally shared our views for 1st round discussions.  |

## 2.8 PUCCH

### 2.8.1 PUCCH - Observations and Proposals from Contributions

* From [7]:
	+ Proposal 7: Study channel estimation performance impact of PDCCH and PUCCH with a larger subcarrier spacing.
* From [9]:
	+ Proposal 4: RAN1 shall study high BW formats, up to 2.16 GHz, for NR-U PUCCH in 60 GHz band.
	+ Observation 5: Due to increased BW, Rel16 NR-U PUCCH format would have a very low spectral efficiency in the 60GHz band (down to less than 1%)
	+ Proposal 5: RAN1 shall study the possibility to assign NR-U PUCCH onto partial interlaces for high BW channels.
* From [10]:
	+ Observation 29: There is need to enhance PUCCH Format 0 and 1 transmissions to achieve higher transmit power when PSD limits apply.
	+ Proposal 25: Support contiguous multi-PRB allocation for PUCCH format 0 and format 1 or use of PUCCH format 2 and format 3 for SR and before dedicated PUCCH configuration for 1 or 2 bit payloads.
* From [14]:
	+ Capture the following observation in TR 38.808: it is beneficial to enhance PUCCH format 0 and 1 to span multiple RBs to allow larger transmit power.
* From [23]:
	+ Proposal 5: Potential enhancements for PUSCH/PUCCH transmissions to achieve higher transmit power should be considered in WI, e.g., PUCCH repetition in time/frequency domain.

### 2.8.2 SR - Observations and Proposals from Contributions

* From [14]:
	+ Proposal 49 Capture the following observation in TR 38.808: For operation in the 52.6 – 71 GHz band, consider enhancements to SR (PUCCH) resource configuration and spatial relation management to reduce UL data latency

### 2.8.3 PUCCH Interlace Transmission - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 13: For supporting NR beyond 52.6 GHz in unlicensed band in Rel. 17, study the enhancement of PRB/sub-PRB interlacing designs for NR with higher SCS, if agreed to be supported.
* From [3]:
	+ Proposal 12: PRB based interlace resource mapping for PUSCH/PUCCH/SRS should be studied further in NR-U-60.
* From [9]:
	+ Observation 4: Due to very wide BW, the number of PRBs per interlace will increase significantly.
	+ Proposal 5: RAN1 shall study the possibility to assign NR-U PUCCH onto partial interlaces for high BW channels.
* From [10]:
	+ Observation 28: OCB requirement or PSD limitation does not require interlaced UL allocation on 60 GHz unlicensed band.
	+ Proposal 24: No interlaced transmission is defined for 60 GHz unlicensed band.
* From [13]:
	+ Proposal 11: It may not be necessary to support interlaced uplink transmission for unlicensed operation in 52.6~71 GHz band.
* From [14]:
	+ PRB-based interlacing is not beneficial for SCS ≥ 120 kHz
	+ Sub-PRB interlacing is not beneficial for SCS ≥ 960 kHz
	+ Both PRB and sub-PRB interlacing is not beneficial for large frequency resource allocations
	+ Capture the following observation in TR 38.808: Neither PRB or sub-PRB interlacing is beneficial for the expected large frequency resource allocations applicable for NR operation in 52.6 – 71 GHz spectrum. The support of UL interlace allocation is not considered for NR operation in 52.6 – 71 GHz.
* From [19]:
	+ Observation 10: interlace seems not necessary in 60GHz unlicensed operation, due to the OCB requirement does not need to be constantly met and the power boosting benefit seems disappear with wider RB bandwidth envisioned in 60GHz.
* From [20]:
	+ Proposal 4: Sub-PRB based interlace design should be supported for 60 GHz unlicensed spectrum.
* From [22]:
	+ Proposal 4: In order to meet the requirements of minimum OCB, some enhancement on interlace design with unregular RB number might be considered.
* From [23]:
	+ Proposal 4: PRB and sub-PRB Interlace are not supported for UL transmission in 60 GHz band.
* From [30]:
	+ Proposal 9: RAN1 shall study sub-PRB level interlace for UL transmission.

### 2.8.3 Discussion on PUCCH

##### Moderator Summary of observations and proposals from Contributions:

* Some companies notes some interlace operations may be needed. Some companies commented to study PRB and sub-PRB interlace design, while some companies comments sub-PRB interlace design is not need and some companies commented interlace transmission is not needed altogether.
* Some companies noted that PUCCH Format 0 and 1 may be limited in transmit power when regulatory PSD limitation apply and suggest supporting enhancements for PUCCH format 0 and 1.
* A company noted enhancements to SR to improve UL data latency may be needed.

##### Company Comments on PUCCH:

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| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Potential enhancements for PUSCH/PUCCH transmissions to achieve higher transmit power should be considered |
| Lenovo/Motorola Mobility | Agree with Futurewei’s comments |
| Qualcomm | Enhancement of PUCCH format 0/1 to support wider bandwidth may be needed for better coverage. |
| Nokia, NSB | There is need to enhance PUCCH Format 0 and 1 transmissions to achieve higher transmit power when PSD limits apply. |

##### Company Comments on SR:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Nokia, NSB | Consider potential enhancements for SR, CG-PUSCH and GC-PDCCH spatial relation updating mechanisms. |

##### Company Comments for PUCCH interlace transmission:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Some per PRB interlace may be considered to achieve a mode with minimum OCB |
| Qualcomm | There is no OCB issue in 60GHz operation and power boosting is not applicable with both 120KHz and 960kHz SCS. So interlacing is not necessary. For 120KHz SCS, sub-PRB level interlace may increase transmit power under PSD limitation, but the associated spec impact is too high. |
| vivo | No need for interlace |
| Nokia, NSB | OCB requirement or PSD limitation does not require interlaced UL allocation on 60 GHz unlicensed band. Hence, interlaced transmission is not needed for 60 GHz unlicensed band. |

##### 2nd round of Discussion:

Moderator has provided some suggestion for conclusion/observation to be captured for the TR. Please provide further comments on the suggestion and if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

1. RAN1 recommends to further investigate on potential enhancements to PUCCH Format 0 and 1 to enable higher transmission power when regulatory PSD limits apply.

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Nokia, NSB | Agree with Moderator views |
| Lenovo, Motorola Mobility | Agree |
| Futurewei | Agree |
| Qualcomm | Agree |
| InterDigital | Agree |

## 2.9 Measurements

### 2.9.1 RLM and RRM - Observations and Proposals from Contributions

* From [3]:
	+ Proposal 13: Study the use of aperiodic CSI-RS for BFR procedure in NR-U-60.
	+ Proposal 14: RSSI measurement with directional reception should be studied in NR-U-60.
* From [14]:
	+ Scheduling restrictions during RRM, RLM and beam management procedures are the responsibility of RAN4 and thus need not to be discussed further in RAN1.

### 2.9.2 CSI Processing Timelines - Observations and Proposals from Contributions

* From [2]:
	+ Proposal 8: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then potential enhancements should be considered on how to efficiently utilize UE’s limited processing capability to reduce latency and efficiently handle processing/preparation of CSI reports associated with multiple numerologies in parallel:
		- Same reference symbols duration (possibly the shortest duration corresponding to maximum supported SCS value) could be used for checking CPU availability corresponding to different CSI reports associated with different SCS values

### 2.9.3 Discussion on Measurements

##### Moderator Summary of observations and proposals from Contributions:

* Some company suggested areas in measurements for further study. The following are some areas for further study:
	+ Aperiodic CSI-RS for BFR
	+ RSSI measurements with directional reception
	+ Processing/preparation of CSI report to enable lower latency

##### Company Comments on RLM and RRM:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
|  |  |

##### Company Comments on CSI processing timelines:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Lenovo/MotorolaMobility | Consider CSI processing timeline enhancements for better availability for CPUs for multiple CSI reports associated with different numerologies. |

##### 2nd round of Discussion:

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

|  |  |
| --- | --- |
|  **Company** | **Comments** |
|  |  |

## 2.10 TDD Configuration and Transition Time

### 2.10.1 Observations and Proposals from Contributions

* From [3]:
	+ Observation 9: Overhead caused by DL/UL switching (14 μs) is large under SCS of 480 kHz (half a slot) and 960 kHz (almost a full slot).
* From [14]:
	+ TDD switching time requirements for the 52.6 – 71 GHz band are the responsibility of RAN4 and thus do not need to be further discussed in RAN1.

### 2.10.2 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* A company noted that current FR2 DL/UL switching time period may be large for 480 and 960 kHz SCS.

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

##### Company Comments:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Nokia, NSB | Overhead caused by DL/UL switching depends on the the switching periodicity. The granularity to adjust the switching gap increases with the increasing SCS. Based on that, with given switching peridicity, a high SCS has opportunities for smaller GP overhead compared to a low SCS. |
| Qualcomm | In our view, the discussion point about DL/UL switching for a high SCS is a new UE capability, such as extending the UE capability ”tdd-MultiDL-UL-SwitchPerSlot”. |

## 2.11 Multi-Carrier Operations

### 2.11.1 Observations and Proposals from Contributions

* From [13]:
	+ Proposal 13: Multi-carrier operation (carrier aggregation and bonding) can be considered to achieve a wider bandwidth, e.g. 2.16 GHz if it should be supported.
* From [14]:
	+ For operation in the 52.6 – 71 GHz band, it is beneficial to support both single and multi-carrier operation to achieve wideband operation as is already supported in Rel-15/16. The maximum carrier bandwidth still requires further discussion.
* From [15]:
	+ Proposal #10: Consider carrier-group based operation for NR unlicensed band in frequency range above 52.6 GHz, with consideration of multi-RAT coexistence as well as control signalling efficiency.
* From [24]:
	+ Proposal 4. The signaling overhead for scheduling large number of aggregated carriers should be studied for NR operation from 52.6 to 71 GHz.

### 2.11.2 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* Some companies noted that multi-carrier operation should be considered to achieve wideband operation and to support higher data rates.
* Some companies noted that multi-carrier operation may need to consider multi-RAT coexistence, and may need to consider control signaling efficiency.

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

##### Company Comments:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Support multi-carrier operation for wider bandwidth |
| Convida Wireless | Support multi-carrier operation for enabling wider bandwidth. |
| Qualcomm | Support multi-carrier operation for wider bandwidth |
| CATT | CA should be supported |
| Apple | Support CA for wider bandwidth operation. |
| vivo | Support multi-carrier operation |
| Nokia, NSB | Support CA within a 2.16 GHz channel, and between 2.16 GHz channels |
| InterDigital | Agree |

*Moderator note: Most companies if not all seems to support enablement of multiple carriers. However, this would be something bit odd to state in the TR since moderator expect CA, which is one of the fundamental features for NR to be not supported if not stated otherwise. Therefore, moderator thinks may not have much value to capture such statement.*

## 2.12 Beam Management

### 2.12.1 Beam Management - Observations and Proposals from Contributions

* From [7]:
	+ Observation 9: Due to the narrow beamwidth in higher frequencies, UE may experience reliability issue to recover dynamic blockage via the existing BFR operation.
	+ Proposal 12: Enhanced BFR operation to provide better reliability and efficiency should be studied for higher frequencies.
* From [10]:
	+ Proposal 22: Consider potential enhancements for SR, CG-PUSCH and GC-PDCCH spatial relation updating mechanisms.
	+ Proposal 28: If new subcarrier spacing is introduced the UE shall provide timeDurationForQCL for that subcarrier spacing.
* From [14]:
	+ Capture the following text in TR 38.808: For operation in the 52.6 – 71 GHz band, due to the large number of beams expected to be used, it is beneficial to enhance triggering of aperiodic CSI-RS and SRS resources to support flexible multi-slot triggering with a single DCI.
* From [15]:
	+ Proposal #9: Study potential enhancements for beam management CSI-RS or SRS considering beam switching time and coverage loss for large SCS.
* From [21]:
	+ Proposal 16: Support multiple non-periodic A-CSI-RS to mitigate the problem of LBT failure or allow for gNB scheduling flexibility in BFD.
	+ Proposal 17: Support modification of the hypothetical PDCCH used in BFD in the case that the RS for BFD is not sent by the gNB.
	+ Proposal 18: Support modification of the following capabilities/concepts based on the SCSs selected and the need for symbol level beam switching:
		- BeamSwitchTiming, BeamReportTiming, TimeDurationforQCL, maxNumberRxTxBeamSwitchDL, tdd-MultiDL-UL-SwitchPerSlot, SFI Pattern
* From [23]:
	+ Proposal 6: Aperiodic CSI-RS should not be used for BFR purpose.
* From [30]:
	+ Proposal 10: RAN1 shall consider the beam adjustment mechanism in initial access procedure to alleviate the beam alignment delay.
* From [31]:
	+ Observation 10: SSB beam may not be narrow enough for subsequent transmissions considering large propagation loss.
	+ Proposal 8: Coverage enhancements for transmissions during initial access should be discussed.
	+ Proposal 9: BFR procedure enhancement needs to be considered with at least following points
		- The number of candidate beams included in set
		- The minimum time gap to apply new beam configuration after receiving BFR response from gNB
		- Simultaneous update of beam configuration for multiple SCells
		- Monitoring aperiodic transmissions for beam failure detection

### 2.12.2 Beam Switching - Observations and Proposals from Contributions

* From [2]:
	+ Observation 14: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, beam switching issue would appear between the contiguous transmissions (such as SSB beams) since the CP length would not be enough for beam switching, and an extra gap such a might be needed to prevent performance degradation.
	+ Proposal 10: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then to allow the beam switching between contiguous transmissions, ECP or a symbol gap could be applied before beam switching, otherwise NCP is applied to all other symbols
	+ Observation 15: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then to increase the possibility of periodic RS transmissions for LBT based channel access in unlicensed bands, it is not resource efficient to schedule a burst of resources within RS period
	+ Proposal 11: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17 in unlicensed bands, if higher subcarrier spacings (numerologies) are adopted and directional LBT is supported, then potential enhancements related to periodic transmissions of RS such as periodic/semi-persistent CSI-RS should be considered to deal with LBT failure:
		- RAN1 could study on the potential dynamic switching of beam for periodic RS transmission on same time-frequency resources after consecutive LBT failures on one of the configured beams
* From [10]:
	+ Proposal 27: No beam switching gap handling is needed for the signals and channels for which 960 kHz or lower subcarrier spacing is applied.
	+ Proposal 29: If new subcarrier spacing is introduced the UE shall provide beamSwitchTiming for the A-CSI-RS triggering for that subcarrier spacing.
* From [14]:
	+ Capture the following text in TR 38.808: For operation in the 52.6 – 71 GHz band, Rel-15/16 already supports functionality to configure gaps between CSI-RS and SRS resources for beam management. Furthermore, for SCS <= 480 kHz, the CP duration is sufficient for beam switching which typically requires < 100 ns.
* From [31]:
	+ Proposal 11: Whether to introduce beam switching gap (i.e., whether guard period is necessary for beam switching between transmissions/receptions with different beam directions) should be discussed for potential high SCS.

### 2.12.2 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* Some companies noted that improvement for BFR operation, spatial relation update mechanism, triggering of CSI-RS and SRS resources may be needed.

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

##### Company Comments on Beam Management:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | Balanced coverage between SSB beam and the beam for data transmission should be considered |
| Lenovo/MotorolaMobility | Beam-management related work in MIMO WI in Rel-17 would be applicable to B52.6GHz as well, so only very specific enhancement needed for higher SCS could be considered here. |
| Convida Wireless | Coverage enhancement for SSB beam could be considered and discussed. |
| InterDigital | We don’t think that beam management in MIMO can be fully applicable for 52.6-71GHz. As a system in 52.6-71GHz supports generally narrower beams than FR2, the system requires dramatically increased number of beams to maintain the coverage. Given that, in our view, beam related enhancements should be considered.  |
| Qualcomm | Beam-management in FR2 should be the baseline. Other than LBT-related issues, we think the BM enhancement should be in the MIMO WI. |
| CATT | Beam management enhancement should be considered  |
|  |  |
| Apple | Beam management should account for the possible loss of periodic CSI-RS due to LBT failure in BFD. Solutions include using an A-CSI RS, creating additional CSI-RS transmissions and enabling a modification of the BFI\_counter in the case that the failure was due to a non-transmission as opposed to poor performance. |
| Nokia, NSB | In general, we share the view from Qualcomm. One LBT-related issue is LBT failure on P-TRS transmission that is the main QCL source for different signals and channels.  |

##### Company Comments on Beam Switching:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| Futurewei | For lower SCS of 240 kHz beam switching gap is not necessary |
| Lenovo/Motorola Mobility | For higher SCS, beam switching should be investigated for supporting contiguous transmissions on different beams |
| Qualcomm | For higher SCS, the necessity of the beam switching gap should be discussed. |
| Apple | The effect of beam switching should be discussed for higher SCS. Also, any associated capabilities need to be modified. |
| Nokia, NSB | We consider that assumption for the beam switching time is << 70 ns meaning that normal cyclic prefix length of 960 kHz subcarrier spacing is long enough to handle beam switching and no explicit beam switching gap is needed (e.g. between successive SSB blocks). |

## 2.13 Issues with RF impairments

### 2.13.1 Observations and Proposals from Contributions

* From [5]:
	+ Observation 8: The impact of I/Q imbalance needs to be evaluated by RAN4 to decide whether it is necessary to consider additional design on standard to mitigate the side effect.
	+ Observation 9: The PA model for frequencies above 52.6GHz and the PAPR performance need further evaluation by RAN4 to decide whether it is necessary to consider additional design on standard to mitigate the side effect.
* From [10]:
	+ Proposal 12: Send an LS to RAN4 on updating the MIMO TAE minimum requirements.
* From [14]:
	+ Capture the following in TR 38.808: Link evaluation based on phase model Ex 2, with characteristics not reflecting realistic devices or current state of the technology, can lead to pessimistic assessment of smaller sub-carrier spacings. It is important for 3GPP to adopt more suitable phase noise models in the discussion and system designs for NR operation in 52.7 – 71 GHz range.

### 2.13.2 Discussions

##### Moderator Summary of observations and proposals from Contributions:

* A company noted that impact of I/Q imbalance requires to be evaluated and depending on the severity RAN1 may need to address the issues.
* A company noted that MIMO TAE may need to be looked into for NR operating in 60 GHz band.
* A company noted that phase noise model from TR 38.803 may not reflect state of art technology and provide pessimistic assessment of suitable subcarrier spacings.

Moderator has yet to provide some suggestion for agreement for this topic. Moderator plans to suggestions later. Meanwhile, if companies have suggestions on what RAN1 may be able to agree to and capture to the TR, please comment further.

##### Company Comments:

|  |  |
| --- | --- |
|  **Company** | **Comments** |
| InterDigital | As RAN1 is not the expert group on phase noise, we still prefer to have an agreed phase noise assumption if RAN1 needs to consider new phase models.  |

# Summary of Conclusions

To be filled once agreements/conclusions are made in RAN1.

Agreement:

Numerologies below 120 kHz or above 960 kHz are not supported for any signal or channel.

Agreement:

For operation in 52-71 GHz:

* 120 kHz should be supported
* Up to two additional SCS may be considered and at least one should be supported
* FFS: Applicability of additional SCS to particular signals and channels

# Reference

1. R1-2007549, “Further discussion on B52 numerology,” FUTUREWEI
2. R1-2007558, “Discussion on physical layer impacts for NR beyond 52.6 GHz,” Lenovo, Motorola Mobility
3. R1-2007604, “PHY design in 52.6-71 GHz using NR waveform,” Huawei, HiSilicon
4. R1-2007642, “Physical layer design for NR 52.6-71GHz,” Beijing Xiaomi Software Tech
5. R1-2007652, “Discussion on requried changes to NR using existing DL/UL NR waveform,” vivo
6. R1-2007785, “Consideration on required changes to NR using existing NR waveform,” Fujitsu
7. R1-2007790, “Consideration on supporting above 52.6GHz in NR,” InterDigital, Inc.
8. R1-2007847, “System Analysis of NR opration in 52.6 to 71 GHz,” CATT
9. R1-2007883, “Required changes to NR using existing DL/UL NR waveform,” TCL Communication Ltd.
10. R1-2007926, “Required changes to NR using existing DL/UL NR waveform,” Nokia, Nokia Shanghai Bell
11. R1-2007929, “On phase noise compensation for NR from 52.6GHz to 71GHz,” Mitsubishi Electric RCE
12. R1-2007941, “Discussion on Required Changes to NR in 52.6 – 71 GHz,” Intel Corporation
13. R1-2007965, “On the required changes to NR for above 52.6GHz,” ZTE, Sanechips
14. R1-2007982, “On NR operations in 52.6 to 71 GHz,” Ericsson
15. R1-2008045, “Consideration on required physical layer changes to support NR above 52.6 GHz,” LG Electronics
16. R1-2008076, “Discussion on required changes to NR using existing DL/UL NR waveform in 52.6GHz ~ 71GHz,” CMCC
17. R1-2008082, “Study on the numerology to support 52.6 GHz to 71GHz,” NEC
18. R1-2008156, “Design aspects for extending NR to up to 71 GHz,” Samsung
19. R1-2008250, “Discusson on required changes to NR using DL/UL NR waveform,” OPPO
20. R1-2008353, “Considerations on required changes to NR from 52.6 GHz to 71 GHz,” Sony
21. R1-2008457, “A Discussion on Physical Layer Design for NR above 52.6GHz,” Apple
22. R1-2008493, “Discussions on required changes on supporting NR from 52.6GHz to 71 GHz,” CAICT
23. R1-2008501, “On required changes to NR using existing DL/UL NR waveform for operation in 60GHz band,” MediaTek Inc.
24. R1-2008516, “On NR operation between 52.6 GHz and 71 GHz,” Convida Wireless
25. R1-2008547, “Evaluation Methodology and Required Changes on NR from 52.6 to 71 GHz,” NTT DOCOMO, INC.
26. R1-2008615, “NR using existing DL-UL NR waveform to support operation between 52p6 GHz and 71 GHz,” Qualcomm Incorporated
27. R1-2008726, “Discussion on physical layer aspects for NR beyond 52.6GHz,” WILUS Inc.
28. R1-2008769, “Waveform considerations for NR above 52.6 GHz,” Charter Communications
29. R1-2008805, “Discussion on Required Changes to NR in 52.6 – 71 GHz,” Intel Corporation
30. R1-2008872, “Design aspects for extending NR to up to 71 GHz,” Samsung
31. R1-2009062, “Evaluation Methodology and Required Changes on NR from 52.6 to 71 GHz,” NTT DOCOMO, INC.
32. R1-2009313, “Issue Summary for physical layer changes for supporting NR from 52.6 GHz to 71 GHz,” Moderator (Intel Corporation)