**3GPP TSG RAN meeting #90e RP-20xxxx**

**Electronic Meeting, December 07 - 11, 2020**

## Status Report to TSG

**Agenda item:** 9.7.12

|  |  |
| --- | --- |
| **WI / SI Name** | **Study on supporting NR from 52.6 GHz to 71 GHz** |
| included in this status report | Study Item: Yes | Core part: No | Performance part:No | Testing part:No |
| **Acronym** | FS\_NR\_52\_to\_71GHz |
| **Unique ID** | 860037 |
| **TSG Tdoc of latest approved WI/SI description (if any)** | RP-201838 |
| **Target Completion Date****(indicate if changed)** | Study Item: 03/2021 | Core part: mm/yyyy | Performance part: mm/yyyy | Testing part: mm/yyyy |
| **Overall Completion level** | Study Item: 85 % | Core part: xx% | Performance Part: xx% | Testing part: xx% |

Note: Overall completion level percentage numbers should use one of the colors below:

* xx%: Normal progress, no RAN plenary action needed
* xx%: Progress behind schedule, may need RAN plenary intervention. If so, SR should clearly define requested action
* xx%: Progress critically behind, RAN plenary shall intervene. SR should define requested action

**Source:**

|  |  |
| --- | --- |
| **Leading WG** | RAN1 |
| **Rapporteur** | **Name** | Lee, Daewon (RAN1); Coan, Phil (RAN4) |
| **Company** | Intel Corporation; Qualcomm |
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## 1 Work plan related evaluation

|  |  |
| --- | --- |
| **Do you want to modify the time budget for this WI/SI compared to what was endorsed at the last RAN meeting?** | No |

*If you answered No: Then please remove the Excel file from the zip file of this status report.*

*If you answered Yes: Then please fill out the attached Excel template to request a modification of the time budgets for your WI /SI. The Excel table has to be filled out for all affected RAN WGs and up to the target date of the WI/SI. The basis are the endorsed time budgets of the last RAN meeting. Please highlight all changes of the values.
 One time unit (TU) corresponds to ~ 2 hours in the meeting.
 If this status report covers a WI with Core and Performance part, then please have one line for each in the attached Excel table.
 Note: If no Excel table is attached, then this means no time budget change.*

**Additional explanations/motivations for the time budget changes in the attached Excel table:**

## 2. Detailed progress in RAN WGs since last TSG meeting (for all involved WGs)

 NOTE: Agreements and Open issues impacted cross-TSG aspects shall be explicitly highlighted

### 2.1 RAN1

#### 2.1.1 Agreements

Agreement:

* R1-2007958 is endorsed with the “smallest of Z\_min” modifed to “smallest value of Z\_max” and setting Z\_min equal to 0 in Section A.3. Modifications to fix errors will be made as part of upcoming updates.

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

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* It was observed that amount of specification effort increases with the number of new numerologies enabled and supported for 52.6 GHz to 71 GHz frequency.
* In order to minimize specification effort while maximizing supported use cases and deployment scenarios applicable for 52.6 GHz to 71 GHz frequency, It is recommended to support 120 kHz subcarrier spacing with normal CP length, and at least one more subcarrier spacing. It is recommended to consider supporting at most up to three subcarrier spacings, including 120 kHz subcarrier spacing. Applicability of the supported subcarrier spacing to particular signals and channels should be further discussed in the corresponding WI phase.
* It is recommended that numerologies 240 kHz, 480 kHz, and 960 kHz are considered as candidates for additional numerologies in addition to 120 kHz, and numerologies outside this range are not supported for any signals or channels.
* In order to bound implementation complexity, it is recommended to limit the maximum FFT size required to operate system in 52.6 GHz to 71 GHz frequency to 4096 and to limit the maximum of RBs per carrier to 275 RBs.
* 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, accounting for what is already supported in Rel-15 and Rel-16 specifications.
* Some companies have noted that ability for a deployed system to operate with a single numerology for all channels and signals is beneficial, and some companies have further noted benefit remains even if SSB numerology is different. Some companies have noted mixed numerology operation is functional and is supported in Rel-15 and Rel-16 specifications (e.g. 240 kHz SSB subcarrier spacing with 120 kHz subcarrier spacing for PDCCH/PDSCH/PUSCH/PUCCH/PRACH in an initial BWP and activation of a dedicated BWP with SCS different than the initial BWP) and consideration of single numerology operation is not needed.

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

Overall implementation complexity for supporting a specific subcarrier spacing may need to consider the following, but not limited to:

* processing complexity for equalization including inter-carrier interference mitigation (if required to support higher modulation orders) and compensation, andFFT complexity per unit time for a given bandwidth,
* complexity associated with supporting multiple component carriers to reach a specific throughput
* complexity associated with supporting given reduced (in abosolute time) requirements on UE processing times (e.g. N1, N2, N3, Z1, Z2, Z3, etc) and UE PDCCH processing budget as a function of subcarrier spacing, if scheduling and monitoring unit is maintained to be one slot.
* supported features indicated by UE capability signaling or implemented by the gNB
* complexity associated with supporting required timing error tolerance which may need to considerinitial timing error, timing advance setting, TA granularity, MIMO TAE (TAE value will be defined by RAN4), multi-TRP timing alignment as a function of SCS, whether mixture or a single subcarrier spacing for signals is configured, and deployment scenarios.
* complexity associated with supporting higher sampling rates and with channel bandwidth larger than 2 GHz

Agreement:

* It is observed that for a single carrier with the same number of transmitted symbols, in general, smaller subcarrier spacing may potentially provide larger coverage due to use of smaller bandwidth and gears towards (but not limited to) coverage driven scenarios.
* It is observed that for a single carrier, 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) peak data-rate driven scenarios.

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* 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.
* 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 CORESET#0 offsets needed for supported channelization
* The following, which is not an exhaustive list, are some potential physical layer impact areas for each numerology:
	1. 120 kHz:
		1. Potential consideration of PTRS enhancement for CP-OFDM and DFT-s-OFDM, if needed
	2. 240 kHz:
		1. Potential consideration of PTRS enhancement for CP-OFDM and DFT-s-OFDM, if needed
		2. If common SSB/CORESET0 numerology (240/240) is supported, SSB patterns, and CORESET#0 configuration
		3. RO configuration
		4. Timelines for scheduling, processing and HARQ
		5. Potential enhancement to DM-RS, if needed
		6. PDCCH monitoring
	3. 480 kHz:
		1. If 480 kHz SSB is supported, SSB patterns, and CORESET#0 configuration
		2. Timelines for scheduling, processing and HARQ
		3. RO configuration
		4. Potential enhancement to DM-RS, if needed
		5. PDCCH monitoring
		6. Potential consideration of PTRS enhancement for CP-OFDM and DFT-s-OFDM, if neeeded
	4. 960 kHz:
		1. Potential consideration of ECP, if needed, depending on deployment scenarios
		2. If 960 kHz SSB is supported, SSB patterns, and CORESET#0 configuration
		3. Timelines for scheduling, processing and HARQ
		4. RO configuration
		5. Potential enhancement to DM-RS, if needed
		6. PDCCH monitoring
		7. Potential updates to smallest time unit, Tc, used in specifications depending on supported maximum carrier BW

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

Observations on the delay spread distribution:

* One source (R1-2007654, vivo) observed that for the delay spread distributions for the typical indoor scenarios evaluated, the delay spread of almost 80% of the users are less than 30 nsec.
* One source (R1-2007982, Ericsson) observed that Factory Scenario A (InF-DH) results in post-beamforming delay spreads that are a significant fraction of the CP duration for 960 kHz SCS.
* One source (R1-2007943, Intel) observed that 85% of the UE experience r.m.s delay spread small than CP length of 1.92 MHz subcarrier spacing (i.e. 36.6ns) in indoor, outdoor, and factory scenarios.
* One source (R1-2008615, Qualcomm) observed that for small range indoor hotspot deployment, the channel delay spread is not an issue with normal CP. For outdoor scenarios with larger ISD and at moderate to high SNR (this may be produced by higher EIRP or smaller BW), normal CP demonstrates SINR degradation compared to extended CP. However, for such large coverage, high EIRP, and small BW use cases, we can choose to use a small SCS, e.g., 120kHz, with NCP.
* One source (R1-2007790, Interdigital) observed that while each scenario experiences different amounts of r.m.s. delay spread, regardless of scenarios, most of UEs experience smaller r.m.s. delay spreads than normal CP of 960 kHz.
* One source (R1-2009062, Docomo) observed that the mean r.m.s. delay spread of 60 GHz system in Outdoor-B scenario is about 23 nsec and the 95%-tile delay spread value is about 80 nsec. More than half of UE experiences channels with delay larger than 20 ns, which should be referred to in the link performance evaluation with large delay configurations.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* Some companies have noted support of channelization that are aligned with IEEE 802.11ad and 802.11ay channelization is beneficial for coexistence. While some companies have noted alignment of channelization for coexistence is not necessary. Alignment of channelization between a NR channel and IEEE 802.11ad and 802.11ay channel in this context refers to a NR channel that is contained within one of the channels defined for IEEE 802.11ad and 802.11ay and NR channel bandwidth does not cross over channel boundaries of IEEE 802.11ad and 802.11ay.
* One company has evaluated misaligned NR wideband channels with 1.6 GHz and 2 GHz without LBT and have not identified coexistence issues between NR and NR.
* Some companies proposed that 2 GHz channel bandwidth should be supported andhave the raster points for 2 GHz channel bandwidth to be aligned with IEEE 802.11ad and 802.11ay channelization.
* Some companies proposed that 1.6 GHz should be the maximum channel bandwidth and channels do not necessarily need to be aligned with IEEE 802.11ad and 802.11ay channelizations.
* Some companies observed that support of channel bandwidth such as 200 or 400 MHz may enable efficient usage of available spectrum by 3GPP technology. Some companies observed that only supporting channelization that are alignemed with IEEE 802.11ad and 802.11ay channelization result in smaller number of supported channels for some regions of the world.
* Some companies have observed that channelization based on granularity of minimum supported channel BW would be benefitial and could provide efficient usage of available specturm. Other companies have observerd that support of channel BW such as 1.6 GHz or 2.4GHz would enable efficient usage of 5 GHz allocation in China and 5 GHz IMT allocation in Europe. Some companies have observed that smaller bandwidth (e.g. 1.6 GHz) allows for more channels (e.g., with 1.6 GHz, 3 channels instead of two) in these regions, easing frequency planning between operators at the cost of reduction in available channel bandwidth per carrier.
* Some companies proposed to support more than one channel bandwidths for a given SCS.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* Some companies noted SSB SCS selection should consider SCS of data/control channels and enablement of single subcarrier spacing operation.
* Some companies noted support and use of 120 kHz and/or 240 kHz SCS for SSB and 120 kHz subcarrier spacing for CORESET#0 in initial BWP and activation of dedicated BWP with an SCS for data/control different than the initial BWP may enable re-use of existing NR specification and minimize standardization effort.
* It was identified to further investigate considerations of SSB patterns, if needed, considering:
	1. unlicensed band operation if LBT is required for SSB, e.g. SSB cycling transmission within a DRS transmission window.
	2. Beam switching time between SSB,
	3. Coverage of SSB
	4. Multiplexing of SSB with CORESET and UL transmissions

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* 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.
* It is recommended to not support interlace design for PRACH for NR operating in 52.6 GHz to 71 GHz.
* It is recommended to further investigate whether or not to support configurations that enable non-consecutive RACH occasions in time domainto aid LBT processes if LBT is required.
* Some companies noted that PRACH SCS selection should consider SCS of data/control channels and enablement of single subcarrier spacing operation.
* 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 coverage perspective.
* It was identified that potential enhancements for PRACH should consider system coverage for PRACH with subcarrier spacing larger than 120 kHz, if supported.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* It was identified that the potential enhancements to PDCCH monitoring including potential limitation to UE PDCCH configuration,, multiple PDSCH/PUSCH scheduling with a single DCI (using existing DCI formats or new DCI format(s)), spatial relation management for GC-PDCCH, capability related to PDCCH monitoring, and PDCCH coverage should be further investigated for higher subcarrier spacings, including the need for such enhancements.
* It was observed that PDCCH processing capabilities per multiple slots for larger SCS (e.g. 480 or 960 kHz) can maintain scheduling framework same as for smaller SCS (e.g. 120 kHz) when the UE is configured to monitor the PDCCH every multiple slots.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* Some companies have noted that interlace transmissions for PUSCH do not provide benefit over non-interlaced uplink allocations currently supported by NR for NR operating in 52.6 GHz to 71 GHz, while some companies have noted support of sub-PRB or PRB interlace transmissions for PUSCH may improve transmit power and possibly meets OCB requirements (some companies note OCB requirements can be met without introducing interlacing) when necessary.
* It was identified that for new subcarrier spacing, if agreed, will at least require investigation on the need for enhacnments and 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, beamReportTiming, etc.)
	7. Timeline for multiplexing multiple UCI types
	8. Minimum of P\_switch for search space set group switching
	9. appropriate configuration(s) of k0 (PDSCH), k1 (HARQ), k2 (PUSCH),
	10. PDSCH processing time (N1), PUSCH preparation time (N2), HARQ-ACK multiplexing timeline (N3)
	11. CSI processing time, Z1, Z2, and Z3, and CSI processing units
	12. Any potential enhancements to CPU occupation calculation
	13. Related UE capability(ies) for processing timelines
	14. minimum guard period between two SRS resources of an SRS resource set for antenna switching
* It was identified that new subcarrier spacing, if agreed, may require further investigation of multi-PDSCH/PUSCH scheduling and standardization, if needed. The following aspects should be at least investigated for multi-PDSCH/PUSCH scheduling:
	1. whether to support a single TB and/or multiple TBs scheduled over multiple slots
	2. applicable DCI format(s) (including potential new formats, if needed) for multi-PDSCH and multi-PUSCH scheduling
	3. Enhancement on multiple beam indication and association with multiple PDSCH/PUSCH scheduling
	4. DM-RS enhancements such as DM-RS bundling, or changes to the time-domain pattern
	5. HARQ enhancements for multi-PDSCH
	6. Applicability of Rel-16 multi-PUSCH scheduling

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

It is recommended to further investigate potential enhancements to PUCCH to enable higher transmission power when regulatory limits apply. Further potential enhancements to spatial relation management for configured and/or semi-persistent UL signals/channels may be considered.

* Majority of the sources have identified PUCCH format 0, 1, and 4 as potential candidates for enahancement.
* Two sources has identified identified all PUCCH formats as potential candidates for enhancement.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* It is observed that in Rel-15 NR, absolute time for UE processing requirements generally decrease as subcarrier spacing increases. Some companies noted that introducing smaller UE processing time than Rel-15 and Rel-16, for larger subcarrier spacing, may lead to a more complex UE implementation. Some companies noted that per slot level monitoring for transmission and reception may not likely be the only mode of operation for higher subcarrier spacing, while some companies noted that per slot level monitoring for transmission and reception may be used as a mode of operation in scenarios that require lower latency.
* It is observed that, in general, larger subcarrier spacing may have benefit of short symbol/slot length to support lower latency requirements compared to what was supported for Rel-15 and Rel-16 NR, assuming slot-level monitoring subject to scheduling configurations and potentially UE processing capabilities.
* It is observed that, in general, channel access with shorter symbol duration may access channel earlier when LBT is passed, assuming slot-level monitoring and potentially subject to UE processing capabilities.
* It is observed that, in general, larger subcarrier spacing has higher resilience towards phase noise. Also, in general, the performance impact from phase noise may depend on various properties of the transmission, such as modulation order and coding rate, reception processing (e.g. CPE compensation), and phase noise profile of the UE and gNB.
* It is observed that, in general, maximum delay spread supported by a SCS is proportional to its CP length and larger subcarrier spacing reduces the budget for timing errors and beam switching, if beam switching delay within CP cannot be avoided by gNB (e.g. by allocating a time gap), due to shorter CP.
	1. CP needs to consider at least delay spread, timing errors (including Te), and timing alignment errors applicable for a deployment scenario.
	2. Minimum requirements on timing errors for new SCS values in > 52.6 GHz should be further studied in RAN4 when specifications are developed.
* Extended CP decreases the spectrum efficiency up to 14% compared to normal CP of the same subcarrier spacing.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* Some companies observed that the relationship between channel bandwidth and initial access aspects should be taken into account for the supported channel bandwidth(s), especially for minimum channel bandwidth. Some companies observed that a wider minimum channel bandwidth supported for a band may help to limit the number of synchronization raster entries in the band, if the same design principle for Rel-15 licensed bands applies (Minimum channel bandwidth and synchronization raster entries will be defined by RAN4).
* Available bandwidth within a given carrier for RMSI transmission for SSB and CORESET multiplexing pattern 2 and 3 is smaller than available bandwidth for multiplexing pattern 1. Some companies observed that the channel bandwidth supported for a band should be wide enough to enable multiplexing e.g. between SSB, CORESET0, and RMSI transmissions in multiplexing pattern 2 and 3. Some companies observed that depending on the supported carrier bandwidth and configured values of O and M, multiplexing pattern 1 can make available more time/frequency resources for RMSI PDSCH in a slot than pattern 2 and 3. Some companies observed that patterns 2 and 3 are more efficient than pattern 1 as it may potentially minimize the broadcast overhead in time.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* It is recommended to further investigate the need for DL and UL PT-RS enhancement for the subcarrier spacings to be supported in specifications. PT-RS enhancements, if needed, can consider the following:
	1. support of high MCS values,
	2. applicability of ICI compensation techniques,
	3. PT-RS sequence,
	4. time and frequency resources for PT-RS with OFDM and DFT-s-OFDM waveforms.
* It is recommended to further investigate the need for DL and UL DM-RS enhancements for the subcarrier spacings to be supported in specifications. DM-RS enhancements, if needed, can consider the following:
	1. coherence bandwidth and its impact to orthogonal codes used for DM-RS,
	2. frequency domain density and overhead,
	3. maximum number of DM-RS ports.
* Some companies noted LBT failure may prevent transmission of periodic reference signals, such as P-TRS, and negatively impact performance. Some companies noted deferral of periodic reference signals may be rare and may not significantly impact system performance. Some companies noted aperiodic reference signals could be used to negate the potential impact from LBT failure.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

It is recommended to investigate whether or not enhancements to CSI processing unit (CPU) availability check is needed when the UE is required to process CSI reports corresponding to multiple numerologies across active BWPs in different component carriers.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

It is recommended that both single and multi-carrier operation are supported to support higher data rates. Larger SCS may achieve larger aggregated bandwidth with multi-carrier operation given a maximum number of CCs.

Agreement:

Capture the following observations in the TR (Editorial modifications and changes to references can be made when capturing the observations in the TR):

* It is recommended to further investigate potential enhancements, if needed, to beam management at least considering one or more of potentially narrower beamwidths, CP duration, multiple beam indications for multi-PUSCH/PDSCH scheduling, triggering of reference signals for beam management, enhancements to beam management for random access procedure, intra- and/or inter-cell mobility, and adaptation to LBT failures.
* Minimum requirement on beam switching delay in > 52.6 GHz spectrum should be further studied by RAN4 when specification is further developed.

Agreement:

Capture the following for the conclusions of the TR:

------------------------------------- Begin ------------------------------------

Study of required changes to NR using existing DL/UL NR waveform to support operation between 52.6 GHz and 71 GHz was conducted. The study included study of applicable numerology including subcarrier spacing, channel BW (including maximum BW), and their impact to FR2 physical layer design to support system functionality considering practical RF impairments, and identification of potential critical problems to physical signal/channels, if any. Study of channel access mechanism, considering potential interference to/from other nodes, assuming beam-based operation, in order to comply with the regulatory requirements applicable to unlicensed spectrum for frequencies between 52.6 GHz and 71 GHz was also conducted.

As an outcome of the study, it is recommended to support 120 kHz subcarrier spacing with normal CP length, and at least one additional subcarrier spacings among 240 kHz, 480 kHz, and 960 kHz subcarrier spacing candidates. It is recommended to consider supporting at most up to three subcarrier spacings including 120 kHz. It is not recommended to consider support of only 240 kHz SCS for PDCCH/PDSCH/PUCCH/PUSCH in addition to 120 kHz. Subcarrier spacing outside 120 kHz to 960 kHz are not supported for any signals and channels. The applicability of the supported subcarrier spacing to particular signals and channels should be further discussed when specifications are developed. It is additionally recommended to limit the maximum FFT size required to 4096 and to limit the maximum of RBs per carrier to 275 RBs. The candidate supported maximum carrier bandwidth(s) for a cell should be between 400 MHz and 2160 MHz. Further investigation of the details of required changes to NR may be needed.

As an outcome of the channel access study, it is recommended to support both channel access with LBT mechanism(s) and a channel access mechanism without LBT for gNB and UE to initiate a channel occupancy. Further investigation of the details of the channel access mechanism may be needed.

---------------------------------------- End --------------------------------------------------

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

The following flavors of channel access schemes have been modeled.

* ‘No-LBT’: No LBT Dynamic TDD: NR operation with no restrictions on channel access mechanism.
* ‘TxED-omni’: Tx side ED Based LBT with Omnidirectional Sensing (‘Tx Omni LBT): Baseline LBT with sensing at the transmitter is expected to closely follow the ETSI En 302 567 based medium access procedure
* ‘TxED-Dir’, Tx Side ED Based LBT with Directional Sensing (‘Tx Directional LBT’)
* Rx Assisted LBT Flavors: Multiple flavors of Rx Assistance have been modelled
	+ RxA-1: [20, Ericsson], Receiver assisted LBT: the LBT procedure is evaluated at the receiver instead of transmitter. The LBT result is assumed to be available instantly at the transmitter without accounting any overhead for exchanging this information between the transmitter and the receiver
	+ RxA-2: [4, Huawei/HiSilicon] [40, Huawei/HiSilicon]: Receiver performs directional LBT but transmitter performs Omni LBT. Further details for RxA-2 are as follows. When UE is the receiver, UE receives a RTS from the gNB. Then, UE sends a “message B” to the gNB with CCA measurements results (dBm value of the measured interference) upon a successful LBT procedure. The latency from the reception of RTS to the transmission of “message B” is calculated equal to 4 slots for 120 kHz SCS and 22 slots for 960 kHz SCS. This includes the required time at the UE side for CCA. Then, gNB transmits PDSCH to the UE. The PDSCH processing time is calculated as 3 slots for 120 kHz and 13 slots for 960 kHz. A CAT4 LBT is performed at the gNB side before RTS transmission. When gNB is the receiver, first gNB performs energy measurement at the directions of the UEs that have UL data. Then, gNB selects the UE with the lowest interference level. After, gNB sends PDCCH to schedule PUSCH transmission of that UE. Finally, PUSCH is transmitted after a successful CAT2 LBT. In our simulations, we have considered the preparation time from PDCCH reception to PUSCH transmission equal to 4 slots for 120 kHz SCS and 22 slots for 960 kHz SCS. A processing time for PUSCH at gNB is not modelled. The transmissions are restricted to Rank 1 for DL as well as UL throughout.
	+ RxA-3: [4, Huawei/HiSilicon] [40, Huawei/HiSilicon]: Only Receiver performs directional LBT procedure. The procedure is similar to RxA-2 except that gNB does not perform any LBT before RTS transmission.
	+ RxA-4: [6, Vivo]: RTS and CTS type mechanism is deployed after winning contention before transmission. The RTS/CTS type exchange is between serving gNB and the served UEs. The transmitter sends a request, and the receiver feedbacks a confirmation if the request could be successfully decoded. Unlike RTS/CTS mechanism in 802.11ad, both the request and confirmation do not silence any other node. The processing delay for the RTS/CTS is assumed to be zero. There is no LBT before CTS.
	+ RxA-5: [36, Qualcomm]: Rx Assistance takes the form of protecting ongoing transmissions by silencing based on sensing at the transmitters and protecting intended transmission by silencing based on sensing at the receiver. The receiver also assists by sending silencing signals. Omni and directional sensing is applied at all nodes. In the simulated procedure, the ECCA is performed at the gNB followed by an exchange of request/response transmissions.
* Other LBT Flavors:
	+ ‘Dyn-RxA’: Dynamic [20, Ericsson], Dynamic LBT: a node operates without LBT unless the receiver experiences a failure in reception due to a drop in SINR, which reflects a presence of interferer. Only then, the node switches to LBT. Besides, when the LBT is switched on, the RAL described in section 2.1.4 of R1-2007983 is used

Agreement:

* Capture the tables in Section 3.3 of R1-2009626 in the TR with the following modifications:
	+ Change “DL:UL” to “DL:UL traffic ratio” in tables.
	+ Add “1:1” in Table 1 for vivo’s results in the “DL:UL traffic ratio” column
	+ Remove “No backoff” in Qualcomm’s results in Table 1

Agreement:

* At least when operating with LBT, MCOT is 5ms, including all the gaps inside.
* Note: Discussions related to further reductions in MCOT due to potential definition of CAPC will be handled separately.

Agreement:

* Use the CCA check procedure in EN 302 567 (per RAN1 understanding as from RAN1 #102-e) as the baseline for channel access for 60GHz band when LBT is applied. The following can be discussed further during normative work.
	+ Whether CAPC and contention window adjustment mechanisms are introduced
	+ Whether ED threshold change is needed, e.g., due to changes in bandwidth, beamforming gain etc.
	+ Whether contention window range needs to be adjusted

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* Comparison of No-LBT (NLBT) and Tx Side ED based Omnidirectional Sensing (TxED-Omni) for Indoor Scenerio A: 6 Companies have compared No-LBT with Tx Side ED based Omni sensing LBT
	+ Vivo, show tail and median benefits of using TxED-Omni LBT on DL, at high loading. In other cases, including all loads for UL and other loads for DL, TdxED-Omni LBT scheme shows losses. All results are at ED threshold -47.
	+ Intel shows gains for DL throughput at high loads with TxED-Omni LBT for all antenna configurations when BSs are ceiling mounted, and gains for 5%ile DL throughput at high loads when the BS are not ceiling mounted. Other cases including all UL cases show losses. All results are at ED threshold of -48.
	+ Ericsson, HW, Nokia, Qualcomm and Samsung show loss for TxED-Omni LBT with an EDT of -47 or -48 dB for all cases.

Agreement:

Capture the following in the TR:

On the LBT bandwidth (bandwidth over which a single contiguous LBT is performed) relative to channel bandwidth (as defined in RAN4), the following alternatives have been discussed. Further down-selection of one or more of these alternatives (if needed) should be further discussed when specifications are developed.

* Alt 1: LBT bandwidth equals channel bandwidth
* Alt 2: LBT bandwidth equals the minimum of channel bandwidth and the transmission bandwidth (number of RBs for a given transmission)
* Alt 3: LBT bandwidth can be wider than channel bandwidth
* Alt 4: LBT bandwidth can be narrower than the channel bandwidth, with multiple LBT subband within a channel
* Alt 5: LBT bandwidth equals with minimum supported channel bandwidth or multiples of the minimum supported channel bandwidth

Agreement:

Capture the following in the TR:

For operation where LBT is not required, it can be further discussed when specifications are developed

* If RAN1 should introduce additional conditions/mechanisms for no-LBT to be used, or leave it for gNB implementation
* When no-LBT mode is used, if RAN1 should introduce additional restrictions, such as DFS needs to be applied, ATPC needs to be applied, long term sensing needs to be applied, certain duty cycle limitation, certain transmit power limitation, MCOT limits, etc, or leave the restriction for gNB implementation
* When no-LBT mode is used, if RAN1 should introduce mechanism for the system to fallback to LBT mode, or leave it for gNB implementation

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

The following discussion refers to 5th percentile users as ‘tail’ users and 95th percentile users as ‘upper-tail’ users. Remarks mentioning ‘all users’ are applicable to tail, median and upper tail users at once.

* Comparison of No-LBT with directional LBT (TxED-Dir) for Indoor Scenario A: Vivo, Huawei, Nokia, Samsung, Intel, Ericsson provided results
* Vivo results show gain for directional LBT ((TxED-Dir) over No-LBT for DL, high load, for tail , median and upper tail users, and for UL, high load for tail users. For all other cases in this comparison, TxED-Dir underperforms No-LBT. (EDT -47 dBm)
* Nokia, for 100% DL presented low, medium and high load results. For all loads, their results show significant loss for both directional and omni-directional LBT for median and high-end users. Only the tail users may have some benefit from directional LBT (as compared to No-LBT), while omni-LBT provides loss also in this case (EDT -48 dBm).
* Ericsson results show No-LBT outperforms directional LBT with (EDT -47 dBm) and directional LBT with (ED -32 dBm for gNB, ED -41 dBm for UE)
* Samsung results show gain in medium and high loads for directional LBT over No-LBT at (EDT -47 dBm) for all users for DL as well as for UL. At low loads TxED-Dir underperforms No-LBT.
* Intel shows gains for DL throughput at high loads with TxED-Dir LBT for all antenna configurations when BSs are ceiling mounted, and gains for 5%ile DL throughput at high loads when the BS are not ceiling mounted. In other cases including all loads for UL, TdxED-Dir LBT scheme shows losses. All results are at ED threshold of -48
* Huawei largely shows loss for directional LBT over No-LBT for all loading levels and users, except DL, tail users at high loading where the results are comparable. Huawei’s TxED-Dir uses CW-Max of 127 with EDT of -47 dBm.

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* Comparison of Omni LBT (TxED-Omni) with directional LBT (TxED-Dir) for Indoor Scenario A: Vivo, ZTE, Nokia, Samsung, Intel, Qualcomm, Ericsson, and Huawei, provided results
* For Omni LBT (TxED-Omni) with directional LBT (TxED-Dir) have been done with using the same ED Threshold. Additionally, Ericsson simulated directional LBT with adjusted thresholds (ED -32 dBm for gNB, ED -41 dBm for UE). Multiple companies have evaluated adjustments to ED Threshold with directional sensing either implicitly or explicitly.
* Vivo results show that omni-directional is better than directional LBT in tail and median performance, and marginal difference in other cases. Both omni-directional and directional LBT use the same ED threshold of -47 dBm
* Samsung shows gain at all loading levels for directional LBT over omni-LBT (-47 dBm) for all users, for DL and UL traffic.
* Intel shows that for UL TxED-Dir LBT provides better performance relative to TxED-Omni for low ED thresholds (i.e., -55 and -65 dBm) but losses for high thresholds (i.e., -48 dBm). As for DL, TxED-Dir LBT provides consistently better performances than TxED-Omni. The gain of directionality increases with more directional UE beams.
* Qualcomm results show largely a comparable performance for omni and directional sensing using equal threshold, with small benefit of directionality under gNBs with narrower beams
* Ericsson results show that directional LBT with adjusted thresholds (ED -32 dBm for gNB, ED -41 dBm for UE) and directional LBT with ED -47 dBm, and omni-directional LBT with ED -47 dBm have comparable performance.
* For 100% DL traffic, Nokia results show that directional LBT TxED-Dir outperforms TxED-Omni at low as well as medium loads – for median, tail as well as upper tail users. The results use EDT -48~~7~~ dBm
* For 100% DL traffic, ZTE shows gains in directional LBT for tail usersand median users at ED threshold~~s~~ -68 dBm and -62 dBm. The gains are also present in DL+UL Traffic at ED threshold -68 dBm and -62 dBm.
* Coexistence: ZTE shows that an operator using directional LBT benefits in the presence of an operator using Omni LBT, relative to a deployment where both operators use Omni-LBT. The results use ED threshold -68 dBm.
* Huawei’s results show that directional LBT (TxED-Dir) does not outperform Omni LBT (TxED-Omni)

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* Comparison of No-LBT with receiver assisted LBT for Indoor Scenario A: Ericsson, Huawei, Vivo, provided results
* Different versions of receiver assistance modelled as presented earlier
* Ericsson results uses omni-sensing at receiver. The results do not show benefit for receiver assistance over No-LBT.
* Vivo’s results use an EDT -47 dBm, in the results, RxA-4-Omni gains in both DL and UL relative to No-LBT for tail users at high loads. RxA-4-Omni gains in DL but loses in UL relative to No-LBT for medium and high loads at all other user percentiles and mean.
* Huawei’s Receiver-only LBT (RxA-3) shows tail UPT and mean UPT gain compared to No-LBT in low, medium, and high traffic loads with InH Open Office channel model 40] and InH mixed channel model [40] in both UL and DL.
* In comparison with No-LBT, Huawei shows Receiver-assisted LBT (RxA-2) Tail UPT gain in DL with high traffic load for InH open office channel model and loss in other cases. Also, Huawei shows Receiver-assisted LBT Tail UPT gain in DL with low, moderate and high traffic load for InH mixed channel model and loss in other cases.

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* Comparison of receiver assisted LBT versions with Omni LBT (Tx-ED-omni), and directional LBT (TxED-dir) for Indoor Scenario A: Huawei, Qualcomm, Vivo and Ericsson provided results
* Ericsson results show similar performance of receiver assisted LBT (RxA-1) and omni- directional LBT (TxED-Omni). Nonetheless, the RxA-1 implementation does not model the overhead of information exchange between the transmitter and receiver. Hence, it is expected that the actual performance of RxA-1 is worse than the simulated one
* Huawei’s both flavors of receiver assistance, Rx-Assisted LBT (RxA-2), and Receiver Only LBT (RxA-3) outperform Tx-ED-Omi and Tx-ED-Dir at all loading levels and users percentiles, with larger benefits to tail users
* Qualcomm results show gains with receiver assisted LBT for DL and UL in the median as well as tail, primarily at higher loading levels. (A) The results show receiver assisted LBT RxA-5 Omni @EDT -67dBm and RxA-5 Dir@-67dBm 67dBm outperforms TxED-Omni and TxED-Dir as loading level increases. (B) Qualcomm results show comparable performance of RxA-5 Omni and RxA-5 Dir for the baseline gNB Antenna Configuration. (C) Further, as directionality increases at the gNB with more antenna elements, ( i.e. when gNB Configuration (Mg,Ng,M,N,P) = (1,1,4,8,2) is replaced with (Mg,Ng,M,N,P) = (1,1,8,16,2)) the relative benefits of Rx-Assistance are shown to be larger,. (D) Further as silencing Threshold is decreased from -67 to -72 dBm, the relative gains of Rx-Assistance increase. At 2 gHz BW, a silencing threshold of -72dBm is close to noise floor and may not be achieved as ED but may require a sequence detection mechanism.
* Vivo results show gains with receiver assisted LBT RxA-4-Omni relative to TxED-Omni primarily for uplink, at medium and high loads for all users. For DL, the performance is comparable between RxA-4 Omni and TxED-Omni, except at high load tail, where RxA-4-Omni underperforms.

Agreement:

Capture the following observations in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

For Indoor scenario A:

* Huawei shows Receiver-only LBT (RxA-3) tail UPT and mean UPT gain compared to receiver-assisted LBT (RxA-2) in low, medium, and high traffic loads with InH Open Office channel model [40] and InH mixed channel model [40].
* Ericsson’s results in Coexistence scenario with Operator A doing No-LBT and Operator B doing TxED-Omni LBT at -47 dBm EDT show that the operator B performance does not degrade (i.e. no losses observed) as compared to the case when Operator B coexists with another operator using LBT.
* Ericsson’s results for Dynamic LBT shows that the performance of the network can be improved when the decision to perform LBT is done dynamically per node, as compared to semi-statically operating all nodes with LBT.

Agreement:

Capture the following in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* One Company [Ericsson] submitted results for Indoor Scenario B, which is a smaller indoor scenario with 2 operators and 1 gNB each. Their observations for this case are in line with their observations for Indoor Scenario A.

Agreement:

Capture the following in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

* Comparison of No-LBT with omnidirectional LBT (TxED-Omni) for Indoor Scenario C: Ericsson and HW show loss for TxED-Omni LBT, Charter shows roughly comparable performance
* Ericsson’s results show worse performance for TxED-Omni LBT relative to No-LBT for both threshold -47dBm and -68 dBm. The loss is higher for EDT -68dBm.
* Charter’s low load DL:UL 50:50 results show loss for TxED-Omni LBT over No-LBT. Their medium load DL:UL 5:2 results show gains in DL tail user and UL median user, loss in UL tail user and comparable performance for other cases. Their high load results for DL:UL ~2:1, show small tail gain and median loss for DL and comparable performance for UL.
* Huawei’s results show loss for TxED-Omni LBT over No-LBT at -47dBm EDT for gNB and -32dBm EDT for UE.
* Comparison of omnidirectional LBT (TxED-Omni) with directional LBT (TxED-Dir) for Indoor Scenario C:
* In Huawei and Ericsson’s results, for equal ED threshold, Directional sensing, (TxED-Dir) and Omni sensing (Tx-ED-Omni) show comparable results.
* ZTE show gains for directional LBT in median users as well as tail users at -68 dBm ED threshold for 100% DL traffic
* Comparison of Rx-Assistance LBT schemes with others for Indoor scenario C
* Ericsson results show similar performance of Rx Assistance (RxA-1 -Omni) and TxED-Omni LBT but loss relative to no-LBT at both modelled ED thresholds. There is no benefit of using RxA-1 scheme over TxED-Dir LBT scheme for ED Threshold -47dBm.
* Another form of Rx-Assistance, referred as, Dyn-RxA is shown by Ericsson to provide similar performance as No-LBT for ED Threshold -47 dBm.
* Huawei’s results show consistent loss for receiver assistance scheme RxA-2 compared to No-LBT. RxA-2 is shown to outperform TxED-Omni and TxED-Dir for this scenario.

Agreement:

Capture the following in the TR. Editorial modifications and changes to references can be made when capturing the observations in the TR.

For Outdoor scenario B:

* Ericsson results show loss of TxED-Omni LBT schemes compared to No-LBT, for two ED thresholds (-47 and -68 dBm). TxED-Omni LBT with ED Threshold of -68 dBm dBm and -47 dBm has similar performance. HW shows loss for LBT schemes with respect to no-LBT for 1-site and 7 -site scenarios. Directional and omni LBT are comparable at -47dBm EDT for gNB and -32dBm EDT for UE.
* Huawei results show loss of TxED Omni LBT scheme compared to No-LBT for ED Threshold -47 dBm. TxED Omni and TxED-Dir are shown to have comparable performance. Receiver assisted LBT (RxA-2) is seen to improve tail performance and to a small extent median user performance at high loading levels compared to TxED-Omni, and in all other cases seen to have comparable performance. RxA-2 simulated underperforms No-LBT in all cases. These trends hold for 7-site as well as 1-site simulations.

Agreement:

* It can be further discussed when specifications are developed if and how the ED threshold provided by the ETSI BRAN 302 567 should be modified to account for aspects such as transmit power, LBT bandwidth, beamforming gain, coexistence etc.
	+ Note: There is no consensus that all of the aspects above need to be considered

Agreement:

* When LBT mode is used, it can be further discussed when specifications are developed if a responding device should use a Cat 2 LBT to share the COT, and if yes, how to define the Cat 2 LBT and if a maximum gap is to be introduced between the initiating device and responding device transmissions.

Agreement:

* Support of contention-exempt short control signalling transmission in 60GHz band for regions where LBT is required and short control signaling without LBT is allowed.
	+ Note: If regulations do not allow short control signaling exemption in a region when operating with LBT, operation with LBT for these short control signals should be supported
* Restrictions to the transmission, such as, on duty cycle (airtime measured over a relatively long period of time), content, TX power, etc. can be discussed when specifications are developed.

Agreement:

* It can be further discussed when specifications are developed if 3GPP specifications should define the relationship between the LBT beam and the transmission beam or leave it as implementation. If such relationship is defined, it can also be further discussed when specifications are developed if ED threshold should be adjusted by the choice of LBT beam and transmission beam.

Agreement:

* When LBT mode is used, spatial domain multiplexing of different beams is supported. The LBT requirement (if any) for spatial domain multiplexing of multiple beams can be further discussed when specifications are developed. At least the following can be considered while other LBT considerations are not excluded.
	+ Leave the LBT behaviour for implementation
	+ One LBT beam covers all transmission beams
	+ Multiple LBT beams cover multiple transmission beams

Agreement:

* When LBT mode is used, time domain multiplexing of DL/UL transmissions in different beams in the same COT is supported. The LBT requirement (if any) for time domain multiplexing of DL/UL transmissions in multiple beams can be further discussed when specifications are developed. At least the following can be considered while other LBT considerations are not excluded
	+ No additional LBT requirement defined and leave the LBT behaviour for implementation
	+ Perform directional or omni-directional LBT at the beginning of COT with sensing beam(s) that covers all TDM beams and with no LBT before each beam switching in the middle of COT.
	+ Perform directional or omni-directional LBT at the beginning of COT with sensing beam(s) that covers all TDM beams or the first transmission beam, and additional directional LBT with sensing beam that covers the next transmission beam for each beam switching in the middle of COT.

Agreement:

Capture the following in TR:

The following receiver assisted channel access and interference management schemes have been considered and can be further investigated when specifications are developed

* Class A. Receiver provides assistance information (signalling) to transmitter only. The following aspects of Class A can be further discussed when specifications are developed
	+ Applicability in the following potential channel access modes:
		- LBT is performed prior to transmission
		- No LBT is performed prior to transmission
	+ Details of assistance information (e.g., type, timing, content, how the assistance information is obtained etc.)
	+ Whether the assistance information can be obtained by LBT performed at the receiver prior to transmission
	+ Whether the assistance information can be obtained by existing layer 1 and layer 3 measurements with enhancements if needed
	+ If any specification changes are needed to support Class A

Also, the following receiver assisted channel access schemes have been considered, and considering the system performance and complexity tradeoff, these schemes will not be further investigated in Rel.17

* Class B. Receiver provides assistance information (signalling) to other NR nodes, including non-serving nodes
	+ In this case, cross RAT coexistence is based on ED
	+ Class B1. Intra-operator only
	+ Class B2. Also including inter-operator signalling
		- In this case, cross operator coexistence is based on ED
* Class C. Receiver provides assistance information (signalling) to other NR nodes and nodes from other RAT

Agreement:

* Capture observations in Section 3.4.8.4 of R1-2009760 in the TR (Section numbers and other references can be updated when incorporating into the TR)

Agreement:

* Support of only 240 kHz SCS for PDCCH/PDSCH/PUCCH/PUSCH in addition to 120 kHz should not be considered

Agreement:

* Summary observations #2a in Section 2.1.1.2 of R1-2009609 are agreed to supersede the previously agreed corresponding observations.

Agreement:

* Summary observations #2 in Section 2.1.3 of R1-2009609 are agreed to supersede the previously agreed corresponding observations.

Agreement:

* Summary observations #2a in Section 2.1.4 of R1-2009609 are agreed to supersede the previously agreed corresponding observations.

Agreement:

* Summary observations #2 in Section 2.1.5 of R1-2009609 are agreed to supersede the previously agreed corresponding observations.

Agreement:

* Summary observations #2 in Section 2.3 of R1-2009609 are agreed to supersede the previously agreed corresponding observations.

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

7 sources ([61, Ericsson], [26, Qualcomm], [56, vivo], [64, OPPO], [21, Apple], [25, NTT DOCOMO], [12, Intel]) reported evaluation results of PSS/SSS detection performance in terms of SINR in dB achieving cell ID detection probability of 90% by one-shot detection from PSS/SSS. 4 sources ([61, Ericsson], [26, Qualcomm], [56, vivo], [21, Apple]) reported PBCH performance in terms of SINR in dB achieving PBCH BLER target of 10%. 2 sources ([5, vivo], [14, 61, Ericsson]) compared link budget of SSB for different SCS.

* For PSS and SSS detection performance, all evaluated candidate SCSs (120, 240, 480 and 960 kHz) show comparable performances with the non-optional (non-optional to be replaced by references to channel model in Tables to be added when capturing in TR) channel models and delay spread values.
	+ The performance degrades as the increase of SCS.
	+ Note: The following references are used to derive the observations.
	+ 6 out of 7 sources reported minor performance difference (< or ~ 1 dB) between adjacent SCS for all evaluated candidate SCSs (120, 240, 480 and 960 kHz). The other source ([21, Apple]) reported more than 3 dB performance gap of 960 kHz SCS compared to other 120, 240 and 480 kHz SCS. It also reported that the gap of 960 kHz increases as the delay spread increases.
* For PBCH BLER performance, all evaluated candidate SCSs (120, 240, 480 and 960 KHz) show comparable performances with the non-optional (non-optional to be replaced by references to channel model in Tables to be added when capturing in TR) channel models and delay spread.
	+ The performance degrades as the increase of SCS.
	+ All 4 sources reported minor performance difference (< or ~ 1 dB) between adjacent SCS for all evaluated candidate SCSs (120, 240, 480 and 960 KHz).
	+ The performance gap between 120 and 960 kHz is up to ~ 1.8 dB.
* In terms of SSB link budget, smaller SCS have better coverage than larger SCS
	+ The MCL and MIL difference between 120 kHz SCS and 480 kHz SCS is about 5 dB. The MCL and MIL difference between 120 kHz SCS and 960 KHz SCS is about 8 dB.

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

8 sources ([61, Ericsson], [68, Huawei], [26, Qualcomm], [56, vivo], [60, ZTE], [64, OPPO], [25, NTT DOCOMO], [12, Intel]) reported evaluation results of PRACH preamble detection performance in terms of SINR in dB achieving PRACH preamble misdetection probability of 1% with evaluation assumptions and parameters as in Table A.1-1 of TR 38.808. Two sources ([14, 61, Ericsson], [19, OPPO]) compared link budget of PRACH for different SCS.

The following are observed.

* For PRACH preamble detection performances for the same PRACH format, all evaluated candidate SCSs (120, 240, 480 and 960 kHz) show comparable performances
	+ Note: The following references were used to derive the observations.
	+ 7 out of 8 sources reported minor performance difference (< or ~ 1 dB) between adjacent SCS for all evaluated candidate SCSs (120, 240, 480 and 960 kHz). The other source ([64, OPPO]) reported minor performances difference among all SCS for TDL-A with 5 and 10ns DS. It reported infinite SINR for 960 kHz SCS and comparable SINR for 120, 240 and 480 kHz SCS in TDL-A with 20ns DS using the metrics of preamble miss detection probability of 1% and the estimated timing error is within [-Tcp/2, Tcp/2].
* For PRACH link budget of the same PRACH format and the same sequence length, maximum isotropic loss (MIL) and maximum coupling loss (MCL) degrade as the subcarrier spacing is increased, negatively impacting coverage.
	+ Two sources ([14, 61, Ericsson], [19, OPPO]) reported that with UE power limitation of 25 dBm EIRP, the MCL/MIL difference between 120 KHz SCS and 480 KHz SCS is about 4 to 5 dB; the MCL/MIL difference between 120 KHz SCS and 960 KHz SCS is about 8 dB.
	+ One source ([14, 61, Ericsson]) reported that without UE power limitation of 25 dBm EIRP (but still under regulatory limits), the MCL difference between 120 kHz SCS and 480 kHz SCS is less than 2.5 dB; the MCL difference between 120 kHz SCS and 960 kHz SCS is less than 1 dB.
	+ One source ([14, 61, Ericsson]) reported that without UE power limitation of 25 dBm EIRPs (but still under regulatory limits), compared to short PRACH sequence length, longer PRACH sequence length improve MCL/MIL significantly for 120 kHz SCS due to wider bandwidth for a given SCS.

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

For CP-OFDM, the following are observed regarding the impact of DMRS to BLER performance.

* One source ([57, InterDigital]) reported performance improvement with increased number of DMRS symbols or increased DMRS density especially for higher modulation order for 960 kHz SCS in TDL-A (5 ns and 10 ns delay spread).
* One source ([14, Ericsson]) reported for 480 kHz SCS and below with large delay spread (TDL-A with 40 ns delay spread), the room for performance improvement with a change to the Rel-15 DMRS design is very limited.
* One source ([12, Intel]) reported a performance drop when frequency domain OCC is enabled especially for higher order modulation such as 64 QAM (MCS 22) for 960 kHz SCS in TDL-A (10ns and 20 ns delay spread) and 480 kHz SCS (20 ns delay spread). The performance gap increases when channel delay spread increases.
* One source ([26, Qualcomm]) reported performance improvement with a new DMRS pattern featured by high frequency density (i.e., every RE) and 2-FD-OCC across adjacent REs for 960 kHz SCS in TDL-A (20 ns and 40 ns delay spread)..
* One source ([10, Nokia]) reported that with Rel-15 DMRS type-1, different delay spread values (10ns and 20ns) have a negligible impact to the demodulation performance of PDSCH for a high SCS (such as 960 kHz).

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

7 sources ([61, Ericsson], [68, Huawei], [26, Qualcomm], [56, vivo], [64, OPPO], [10, Nokia], [21, Apple]) evaluated DFT-S-OFDM PUSCH BLER performance with different SCS.

* Compared to CP-OFDM when CPE-only compensation is enabled, DFT-s-OFDM is more robust under phase noise.
* For low and medium MCSs (QPSK and 16QAM), there’s minor performance difference among evaluated SCSs up to 960 kHz.
* With normal CP, for high MCS (64QAM), the performance improves as the increase of SCS, 120 kHz SCS shows up to ~2.0dB loss compared to other larger SCS.
	+ Note: the following are references when derive the observations.
	+ One source ([61, Ericsson]) reported a performance gap of 1.4~1.8 dB between 120 and 960 kHz SCS
	+ One source ([68, Huawei]) reported a performance gap of 1.3~2.5 dB between 120 and 960 kHz SCS
	+ One source ([26, Qualcomm]) reported a performance gap of 1.2~1.7 dB between 120 and 960 kHz SCS
	+ One source ([56, vivo]) reported a performance gap of ~1.4 dB between 120 and 960 kHz SCS
	+ One source ([10, Nokia]) did not report numerical SINR results in table but provided figures showing approximately similar performance difference (~ 2 dB) between 120 and 960 kHz SCS.
	+ One source ([21, Apple]) reported a performance gap of more than 7 dB performance gap between 120 kHz SCS and other SCS (240, 480 and 960 kHz) at TDL-A 5 ns DS. It also reported 120 kHz SCS cannot meet the BLER target of 10% at TDL-A 10ns DS and 960 kHz SCS cannot meet the BLER target of 10% at TDL-A 20ns DS.
	+ Another source ([64, OPPO]) reported 120 and 240 kHz SCS cannot meet the BLER target of 10% for all evaluated DS values.
* For high MCS (64QAM) at large delay spread (TDL-A 40ns or CDL-B 50ns DS), there’s error floor for 960 KHz SCS at least for BLER target 1%.
	+ Note: the following are reference when derive the observations.
	+ One source ([26, Qualcomm]) reported an error floor for 960 kHz SCS for BLER target 1%.
	+ One source ([56, vivo]) reported an error floor for 960 kHz SCS for BLER target 10%
	+ One source ([64, OPPO]) reported no error floor of 960 kHz SCS for the BLER target of 10% and 1% for CDL-B 50ns but an error floor for 960 kHz SCS at TDL-A 20ns for BLER target 1%

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

For CP-OFDM, with evaluation assumptions and parameters as in Table A.1-1 of TR 38.808, the following are observed when CPE-only compensation based on the existing Rel-15 NR PTRS structure is used for normal CP when delay spread is not large. The performance is measured in terms of SINR in dB achieving BLER target of 10% or 1%.

* For low MCS (QPSK) and medium MCS (16QAM), there is minor performance difference between different SCS values up to 960 kHz.
* For high MCS (64QAM), the performance improves in general as the increase of SCS
* For high MCS (64QAM), 13 sources ([61, Ericsson], [68, Huawei], [26, Qualcomm], [56, vivo], [60, ZTE], [64, OPPO], [10, Nokia], [2, 55, Lenovo], [21, Apple], [18, Samsung], [25, NTT DOCOMO], [12, Intel], [7, InterDigital]) compared performance of 120 and 240 kHz SCS in 400 MHz bandwidth
	+ for 10% BLER target, there is a performance gap between 120kHz and 240kHz SCS where 240 kHz SCS performs better.
		- Note: the following references are used when derive the observations.
		- One source ([61, Ericsson]) reported better performance of 240 kHz SCS in CDL-D. It also reported both SCS cannot meet 10% BLER target for other evaluated channel model.
		- 3 sources ([68, Huawei], [64, OPPO], [10, Nokia]) reported both SCS cannot meet 10% BLER target
		- 4 sources ([56, vivo], [60, ZTE], [21, Apple], [7, InterDigital]) reported 120 kHz SCS cannot meet 10% BLER target while 240 kHz SCS can
		- One source ([2, 55, Lenovo]) reported better performance of 240 kHz SCS at TDL-A 5 and 10ns. It also reported that both SCS cannot meet 10% BLER target for other evaluated cases.
		- One source ([12, Intel]) reported better performance of 240 kHz SCS in CDL-D. It also reported that both SCS cannot meet 10% BLER target for other evaluated cases.
		- 2 sources ([26, Qualcomm], [18, Samsung]) reported better performance of 240 kHz SCS
		- One source ([25, NTT DOCOMO]) reported comparable performance for both SCS in CDL-D. It also reported better performance of 120 kHz SCS for other evaluated channel model.
* For high MCS (64QAM), 13 sources ([61, Ericsson], [26, Qualcomm], [56, vivo], [60, ZTE], [64, OPPO], [10, Nokia], [2, 55, Lenovo], [21, Apple], [18, Samsung], [25, NTT DOCOMO], [12, Intel], [67, Charter], [7, InterDigital]) compared performance of 240 and 480 kHz SCS in 400 MHz bandwidth
	+ for 10% BLER target, there is a performance gap between 240kHz and 480kHz SCS where 480 kHz SCS performs better.
		- Note: the following references are used when derive the observations.
		- One source ([61, Ericsson]) reported better performance for 480 kHz SCS in CDL-D. It also reported 240 kHz SCS cannot meet 10% BLER target for other evaluated channel model.
		- 3 sources ([64, OPPO], [10, Nokia], [67, Charter]) reported 240 kHz SCS cannot meet 10% BLER target while 480 kHz SCS can
		- One source ([2, 55, Lenovo]) reported better performance of 480 kHz SCS at TDL-A 5 and 10ns. It also reported 240 kHz SCS cannot meet 10% BLER target for other evaluated cases.
		- One source ([12, Intel]) reported better performance of 480 kHz SCS in CDL-D. It also reported 240 kHz SCS cannot meet 10% BLER target for other evaluated cases.
		- 6 sources ([26, Qualcomm], [56, vivo], [60, ZTE], [21, Apple], [18, Samsung], [7, InterDigital]) reported better performance of 480 kHz SCS
		- One source ([25, NTT DOCOMO]) reported comparable performance for both SCS in CDL-D. It also reported better performance of 240 kHz SCS for other evaluated channel model.
* For high MCS (64QAM), 14 sources ([61, Ericsson], [68, Huawei], [26, Qualcomm], [56, vivo], [60, ZTE], [64, OPPO], [10, Nokia], [2, 55, Lenovo], [21, Apple], [18, Samsung], [25, NTT DOCOMO], [12, Intel], [67, Charter], [7, InterDigital]) compared performance of 480 and 960 kHz SCS in 400 MHz bandwidth
	+ for 10% BLER target, there is a performance gap between 480kHz and 960kHz SCS where 960 KHz SCS performs better.
		- Note: the following references are used when derive the observations.
		- 7 sources ([61, Ericsson], [60, ZTE], [64, OPPO], [10, Nokia], [2, 55, Lenovo], [67, Charter], [7, InterDigital]) reported a greater than 1 dB gain of 960 kHz SCS
		- 3 sources ([26, Qualcomm], [56, vivo], [18, Samsung]) reported a smaller than 1 dB performance gain of 960 kHz SCS
		- One source ([68, Huawei]) reported better performance of 480 kHz SCS for CDL-B 50ns and better performance of 960 kHz SCS for other evaluated cases. In all comparison, the difference is greater than 1 dB.
		- Two sources ([21, Apple], [12, Intel]) reported a better performance of 480 kHz SCS than 960 kHz SCS at 20ns DS in TDL-A where 960 kHz SCS cannot meet 10% BLER target and comparable performance for both SCS in all other evaluated cases
		- One source ([25, NTT DOCOMO]) reported comparable performance for both SCS in CDL-D. It also reported better performance of 480 kHz SCS in TDL-A 5ns and better performance of 960 kHz SCS in CDL-B 20ns.
	+ for 1% BLER target, the performance for 960kHz SCS is better than 480kHz SCS.
		- Among sources reported SINR values when both SCS can meet 1% BLER target, the absolute value of the performance gap between 480 kHz and 960 kHz SCS is larger than that for 10% BLER target.
* For high MCS (64QAM), 4 sources ([61, Ericsson], [56, vivo], [10, Nokia], [18, Samsung]) compared performance of 480 and 960 kHz SCS in 1600 or 2000 MHz bandwidth. 4 out of 4 sources reported performance gain around 4 ~ 5 dB of 960 kHz SCS for 10% BLER target. All 4 sources also reported that 480 kHz SCS cannot meet 1% BLER target.

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

For CP-OFDM, with evaluation assumptions and parameters as in Table A.1-1 of TR 38.808 (including optional delay spread value), the following are observed when CPE-only compensation based on the existing Rel-15 NR PTRS structure is used with respect to CP type and large delay spread.

* When delay spread is not large (< 40 ns in TDL-A), there is minor performance difference between normal and extended CP for SCS values up to 960 kHz when compared on the basis of equal MCS (code rate). If comparing on the basis of equal TBS (equal throughput), the performance of ECP is degraded due to higher overhead of ECP.
* Among 11 sources ([61, Ericsson], [68, Huawei], [26, Qualcomm], [56, vivo], [60, ZTE], [64, OPPO], [2, 55, Lenovo], [1, Futurewei], [25, NTT DOCOMO], [12, Intel], [7, InterDigital]) evaluated with large delay spread (i.e. 40 ns in TDL-A and/or 50ns in CDL) based on the existing Rel-15 NR PTRS structure for normal CP, 10 sources observed that for low MCS (QPSK) and medium MCS (16QAM), there is minor performance difference between different SCS values up to 960kHz for 10% BLER target
	+ The other source ([1, Futurewei]) evaluated SCS 960 kHz with CPE compensation at MCS16 with normal CP in TDL-A channel with 40ns DS. It reported that the BLER for SCS 960 kHz, MCS16, and Normal CP is not acceptable (cannot meet 10% BLER target) for 40ns DS.
* 10 sources ([61, Ericsson], [68, Huawei], [26, Qualcomm], [56, vivo], [60, ZTE], [64, OPPO], [2, 55, Lenovo], [25, NTT DOCOMO], [12, Intel], [7, InterDigital]) evaluated large delay spread (i.e. 40 ns in TDL-A and/or 50ns in CDL) with CPE compensation based on the existing Rel-15 NR PTRS structure with normal CP. Among 10 sources, 5 sources ([14, Ericsson], [68, Huawei], [5, 56, vivo], [2, 55, Lenovo], [25, NTT DOCOMO]) also evaluated extended CP at least for 960 kHz SCS with CPE compensation based on the existing Rel-15 NR PTRS structure.
	+ 9 out 10 sources observed that for high MCS (64QAM) with normal CP, larger SCS (480 and 960 kHz) performs better than smaller SCS (120 and 240 kHz) when only CPE compensation based on the existing Rel-15 NR PTRS structure is used. The other source ([25, NTT DOCOMO]) reported better performance of smaller SCS.
	+ 5 out 5 sources observed the performance of 960 kHz SCS with extended CP is significantly improved compared to with normal CP for large delay spread case when compared on the basis of equal MCS (code rate).
	+ 4 sources ([14, Ericsson], [68, Huawei], [5, vivo], [2, 55, Lenovo]) compared throughput of normal CP and extended CP at least for 960 kHz SCS with CPE compensation based on the existing Rel-15 NR PTRS structure. They all reported worse throughput of extended CP.

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

For CP-OFDM, the following are observed with respect to phase noise compensation and PTRS.

* Compared to no phase noise compensation, CPE compensation shows little gain at low and medium MCSs for all the evaluated SCS values; while significant gain is observed for high MCS (64QAM) for all the evaluated SCS values.
	+ Two sources ([57, InterDigital], [11, Mitsubishi])) reported that increased PTRS density in frequency domain based on Rel-15 configuration does not provide significant performance benefits.
* For a given SCS, the complexity of ICI compensation increases as the number of ICI filter tap increases
* For MCS 22 evaluation of the same SCS, performance gain of ICI compensation with additional complexity of multi-tap filtering compared to CPE-only compensation is observed when there is sufficient number of PTRS in the frequency domain for 120, 240 and 480 kHz SCS.
	+ Note: the following references are used when derive the observations.
	+ One source ([61, Ericsson]) showed performance gain of ICI compensation compared to CPE-only compensation for all evaluated SCS
	+ One source ([68, Huawei]) evaluated ICI compensation and compared with CPE-only compensation. It reported performance gain for all evaluated SCS.
	+ One source ([26, Qualcomm]) compared the performance of CPE and ICI compensation for 120 kHz SCS reported performance gain of ICI compensation.
	+ One source ([64, OPPO]) compared the performance of CPE and ICI compensation for all SCS. It reported performance gain of ICI compensation for 240 kHz and 480 kHz SCS. It reported performance gain of ICI compensation in CDL-B but a performance loss in TDL-A for 960 kHz SCS. It also reported that 120 kHz SCS still cannot meet 10% BLER target with ICI compensation.
	+ One source ([10, Nokia]) reported performance gain of ICI compensation for 120, 240 and 480 kHz SCS. It also reported performance gain of ICI compensation for 960 kHz SCS at 2GHz bandwidth and a performance loss of ICI compensation for 960 kHz SCS at 400MHz bandwidth.
	+ One source ([65, Apple]) evaluated ICI compensation for different SCS with a new PTRS pattern. It reported improvement of ICI compensation compared to CPE-only compensation.
	+ One source ([18, Samsung]) evaluated 120 kHz and 240 kHz SCS performance with ICI compensation based on some new PTRS pattern and reported performance improvement.
	+ One source ([1, Futurewei]) compared ICI performance among SCS. It reported performance gain of multi-tap ICI filter over CPE compensation for 120, 240 and 480 kHz SCS
	+ One source ([12, Intel]) evaluated performance of de-ICI method for MCS 22 with small RB allocations for 240, 480 and 960 KHz SCS. It is observed that the de-ICI method do not work when there isn’t sufficient number of PTRS tones in the frequency domain.
* For MCS 22 with normal CP when delay spread is not large, it is observed that ICI compensation of multi-tap filtering is required for 120, 240 and/or 480 kHz SCS to achieve comparable performance (< 1 dB difference) to that of 960 kHz SCS with CPE-only compensation for 10% BLER target
	+ Note: the following references are used when derive the observations.
	+ 2 sources ([61, Ericsson], [10, Nokia]) reported comparable performance of 480 kHz SCS with ICI compensation and 960 kHz SCS with CPE compensation in 1600 MHz bandwidth
	+ 2 sources ([64, OPPO], [10, Nokia]) reported comparable performance of 480 kHz SCS with ICI compensation and 960 kHz SCS with CPE compensation in 400 MHz bandwidth
	+ One source ([68, Huawei]) reported comparable performance of 240 kHz SCS with ICI compensation and 960 kHz SCS with CPE compensation in 400 MHz bandwidth
	+ One source ([26, Qualcomm]) evaluated and compared 120 KHz SCS with ICI compensation to larger SCS with CPE compensation. It reported that at MCSs 22 and 24, 120 kHz SCS with ICI compensation performs almost equal to 960 kHz SCS with CPE-only compensation in 400 MHz bandwidth.
	+ One source ([1, Futurewei]) reported comparable performance of 480 kHz SCS with ICI compensation and 960 kHz SCS with CPE compensation in TDL-A 5 and 10ns as well as in CDL-D 30ns in 400 MHz bandwidth.
* At very high MCS (e.g., MCS 26 or MCS 28), three sources ([12, Intel], [26, Qualcomm], [69, Huawei]) compared ICI and CPE compensation using the Rel-15 PTRS.
	+ Note: the following references are used when derive the observations.
	+ One source ([12, Intel]) evaluated the phase noise compensation performance with MCS 28 when delay spread is not large. It is observed that de-ICI technique with 3-taps filter for smaller subcarrier spacing (240 kHz) fails even though there are sufficient number of PTRS tones available for ICI covariance construction.
	+ One source ([26, Qualcomm]) compared the performance of CPE and ICI compensation and reported for MCS 26, 120kHz SCS with ICI compensation suffers from residual ICI and is outperformed by 960kHz SCS with CPE-only compensation when delay spread is not large.
	+ One source ([68, Huawei]) showed that for MCS 28, de-ICI technique with large number of taps (11, 9 and 7 taps for 120, 240 and 480 kHz SCS respectively) outperforms 960 kHz with CPE compensation only when delay spread is not large. For normal CP, it also reported that 960 kHz with 3-tap ICI compensation has comparable performance to other SCS with larger number of taps (11, 9 and 7 taps for 120, 240 and 480 kHz SCS respectively) for MCS 28 when delay spread is not large. It also reported that with large delay spread (50ns in CDL), ECP and ICI compensation with at least 3 taps filter are needed for 960 kHz SCS to reach 1% BLER target for MCS 26.
* For high MCS (64QAM) with normal CP when delay spread is large (TDL-A with 40 ns and/or CDL-B with 50ns), 4 sources compared performance of smaller SCS (120, 240 and/or 480 kHz) with ICI compensation to that of 960 kHz SCS with CPE compensation and reported worse performance of 960 kHz SCS with CPE compensation for 10% BLER target.
	+ Note: the following are references used when derive the observations.
	+ One source ([61, Ericsson]) reported a performance gain of 5 dB in TDL-A 40ns and 0.3 dB in CDL-B 50ns for 480 kHz SCS with ICI compensation compared to 960 kHz SCS with CPE compensation in 1600 MHz bandwidth
	+ One source ([68, Huawei]) reported a performance gain of 2.6 dB (for 240 kHz SCS) and 1.6 dB (for 120 kHz SCS) in CDL-B 50ns with ICI compensation compared to 960 kHz SCS with CPE compensation
	+ One source ([64, OPPO]) reported a performance gain of 1 dB in CDL-B 50ns for 480 kHz SCS with ICI compensation compared to 960 kHz SCS with CPE compensation. It also reported the performance of 120 kHz with ICI compensation cannot meet the 10% BLER target.
	+ One source ([1, Futurewei]) reported the performance of 960 kHz SCS with CPE compensation cannot meet the 10% BLER target. It also reported that the performance of 480 kHz SCS with ICI compensation cannot meet the 10% BLER target in TDL-A 40ns. With ICI compensation, it also reported comparable performance of 120, 240 and 480 kHz SCS in CDL-B 50ns and comparable performance of 120 and 240 kHz SCS in TDL-A 40ns.
* Multiple sources evaluated and compared ICI compensation schemes using the existing Rel-15 NR distributed PTRS structure and/or new PTRS patterns. The results from different sources are not aligned on whether new PTRS patterns perform better than existing Rel-15 PTRS structure when ICI compensation is used.
	+ Note: the following are reference used when derive the observations.
	+ One source ([11, Mitsubishi]) evaluated with 120 and 240 kHz SCS and reported that the PN compensation with block-based PTRS and cyclic sequence significantly outperforms in spectral efficiency both CPE compensation and de-ICI Wiener filtering with distributed PTRS, even when the density of the scattered pattern is increased above the Rel.15 defined density.
	+ One source ([14, Ericsson]) reported that 3-tap direct de-ICI compensation with Rel-15 PTRS outperforms ICI filter approximation approach with clustered PTRS. 3-tap direct de-ICI compensation with a clustered PTRS structure does not offer any performance advantage over the existing Rel-15 NR distributed PTRS structure.
	+ One source ([23, MediaTek]) reported that with a 3-tap BLS ICI equalizer, a clustered PTRS structure does not offer any performance advantage over the existing Rel-15 NR distributed PTRS structure.
	+ One source ([62, LG]) reported that the performance of clustered PTRS allocation is worse than that of Rel-15 PTRS based ICI compensation scheme and further showed that the performance of subcarrier nulling allocation is similar or superior (up to 2 dB gain especially in the scenarios with low PTRS overhead, K=4) to that of Rel-15 PTRS based ICI compensation scheme.
	+ Two sources ([18, Samsung], [65, Apple]) evaluated the performance with some new PTRS patterns (e.g. chunk based PTRS pattern to allow adjacent PTRS symbols in frequency) and reported that the performance with ICI compensation based on new PTRS patterns is better than the Rel-15 pattern with CPE compensation only.
	+ One source ([26, Qualcomm]) reported that for the same ICI compensation algorithm, the legacy PTRS pattern outperforms the block PTRS pattern. It showed that for ICI compensation (direct de-ICI filtering) with the legacy PTRS pattern, the performance improves with the increasing number of de-ICI filter taps (3 to 5 taps). It also observed that with a fixed transport block size, the performance improves as the PTRS overhead decreases (the performance loss due to increased effective code rate is more pronounced at higher MCSs) and with a fixed effective code rate, the performance slightly improves as the PTRS overhead increases.
* For high MCS (64QAM) with normal CP, 2 sources ([61, Ericsson], [10, Nokia]) compared performance of 480 and 960 kHz SCS in 1600 MHz bandwidth when ICI compensation is used based on Rel-15 PTRS.
	+ When delay spread is not large, both sources reported a smaller than 1 dB performance gain of 960 kHz SCS for both 10% and 1% BLER target in TDL-A. One source ([61, Ericsson]) reported that for CDL-B, there is up to 1.1 dB gain at 1% BLER target for 960 kHz SCS.
	+ When delay spread is large (TDL-A with 40 ns DS), one source ([61, Ericsson]) reported 480 kHz SCS performed 3.6 dB better than 960 kHz SCS at 10% BLER target and 960 kHz SCS cannot meet the 1% BLER target.

Agreement:

Capture the following observations in the TR (updates to references and other editorial modifications can be made for inclusion in the TR):

For CP-OFDM, two sources ([14, 61, Ericsson], [68, Huawei]) evaluated PDSCH BLER performance with optional PN models in addition to PN model in Table A.1-1 of TR 38.808. Note that such optional PN models are not confirmed and/or recommended by RAN4 at the time of RAN1#103-e (These observations can be updated if RAN4 input is available).

* When CPE-only compensation is used with an optional PN model at the UE or at BS and UE, it is observed by both sources that there is significantly less dependence of BLER performance on SCS compared to the PN model in Table A.1-1 of TR 38.808. For all test cases, no error floor is observed for smaller SCS with TDL-A or CDL-B/CDL-D for 1% BLER target. There is around 1 to 2 dB performance difference between consecutive SCSs for 1% BLER target.
* However, multiple sources expressed concerns on the validity of such optional PN models given no confirmation and/or recommendation from RAN4. In consequence, there’s a concern on whether and how the observations based on such optional PN models can be used given no RAN4 input on these optional PN models.

Agreement:

* Update BS Antenna Pattern in Table A.2-1 of TR 38.808 as the following.

|  |  |
| --- | --- |
| BS Antenna Pattern | For outdoor scenarios:- Antenna power pattern given in Table 7.3-1 of TR38.901(with exception of antenna element gain)For indoor~~/factory~~ scenarios:- Antenna power pattern given in Table A.2.1-7 of TR38.802 for ceiling mount(with exception of antenna element gain)For factory scenarios:Companies to provide information on the antenna orientation and pattern used. |

Agreement:

* Update the indoor A description as follows:

Office box 120m x 50 m, 12 BS per operator, 2 operator, BS height at 3m (ceiling), UE height 1m, x-axis ISD = 20m and y-axis ISD = 25m, where ISD is define by the distance between two adjacent 10m x 10m virtual box, BS randomly deployed within 10m x 10m virtual box, minimum distance between BS of different operators is 2m.”



Agreement:

* Section 2 of R1-2009356 is endorsed for inclusion in the TR (formatting and other minor errors can be corrected when including in the TR).

Agreement:

* TR38.808 v0.1.0 in R1-2009713 is endorsed.

#### 2.1.2 Remaining Open issues

None.

### 2.2 RAN2

#### 2.2.1 Agreements

#### 2.2.2 Remaining Open issues

### 2.3 RAN3

#### 2.3.1 Agreements

#### 2.3.2 Remaining Open issues

### 2.4 RAN4

#### 2.4.1 Agreements

Agreement (R4-2017832)

* WF#1: Minimum channel bandwidth for 52-6 – 71 GHz NR operation: both 50MHz and 400MHz channel bandwidths are considered as conclusion of RAN4 part of SI and as inputs to the followup WI discussions.
* WF#2: Maximum channel bandwidth for 52-6 – 71 GHz NR operation: depends on the decision on the max SCS in RAN1 (i.e. both 480 and 960 kHz SCS under consideration) and further RAN4 discussion in followup WI.
* WF#3: Carrier aggregation is considered to be used for NR operation in 52.6 – 71GHz range. Decision on intra/inter band operation in contiguous/non-contiguous allocation is out of scope of this SI.

Agreement Nov 6 Go to Webinar meeting

* RAN4 agreed 120 kHz SCS minimum
* RAN4 will consider 480 or 960 kHz SCS max, pending the outcome of RAN1 valid SCS

Agreement (R4-2016926)

* RAN4 to continue to discuss PN models during the WI phase

Agreement (R4-2016998)

* BS and UE Transient period will be discussed during WI phase
* BS and UE Measurement BW will be discussed during WI phase
* RAN4 will not specify multi-cluster operation
* RAN4 will continue to discuss regulatory status in the next meeting

Agreement (R4-2016927)

A text proposal shall be drafted capturing the content in the WF into TR 38.808

Agreement (R4-2016928)

Reply LS on PN models to RAN1

Agreement (R4-2016995)

A skeleton and text proposal for TR 38.808 BS RF aspect

#### 2.4.2 Remaining Open issues

Study of required changes to NR using existing DL/UL NR waveform to support operation between 52.6 GHz and 71 GHz

* Study of applicable numerology including subcarrier spacing, channel BW (including maximum BW), and their impact to FR2 physical layer design to support system functionality considering practical RF impairments [RAN4].

### 2.5 RAN5

#### 2.5.1 Agreements

#### 2.5.2 Remaining Open issues

#### 2.5.3 Remaining Open issues with cross-WG dependencies

### 2.6 RAN6

#### 2.6.1 Agreements

#### 2.6.2 Remaining Open issues

## 3. Detailed progress in SA/CT WGs since last TSG meeting (for all involved WGs)

NOTE: This section only needs to be filled in for WI/SIs where there is a corresponding relevant WI/SI in SA/CT.

## 3.1 SAx/CTs

#### 3.1.1 Agreements with cross-TSG impacts

#### 3.1.2 Remaining Open issues with cross-TSG impacts

NOTE: This section should also flag any critical dependencies that need TSG attention.

## 4. References

NOTE: This can be e.g. a list of all related Tdocs in the affected WGs since last TSG, references to LSs, produced TRs/TSs, the work/study item description or status reports of previous TSGs.

1. R1-2007549 "Further discussion on B52 numerology" FUTUREWEI
2. R1-2007550 On channel access modes in 60GHz FUTUREWEI
3. R1-2007558 Discussion on physical layer impacts for NR beyond 52.6 GHz Lenovo, Motorola Mobility
4. R1-2007559 Discussion on channel access for NR beyond 52.6 GHz Lenovo, Motorola Mobility
5. R1-2007560 Additional evaluations for NR beyond 52.6GHz Lenovo, Motorola Mobility
6. R1-2007604 PHY design in 52.6-71 GHz using NR waveform Huawei, HiSilicon
7. R1-2007605 Channel access mechanism for 60 GHz unlicensed operation Huawei, HiSilicon
8. R1-2007642 Physical layer design for NR 52.6-71GHz Beijing Xiaomi Software Tech
9. R1-2007643 Channel access mechanism for NR on 52.6-71 GHz Beijing Xiaomi Software Tech
10. R1-2007652 Discussion on requried changes to NR using existing DL/UL NR waveform vivo
11. R1-2007653 Discussion on channel access mechanism vivo
12. R1-2007654 Evaluation on different numerologies for NR using existing DL/UL NR waveform vivo
13. R1-2007785 Consideration on required changes to NR using existing NR waveform Fujitsu
14. R1-2007790 Consideration on supporting above 52.6GHz in NR InterDigital, Inc.
15. R1-2007791 On Channel access mechanisms InterDigital, Inc.
16. R1-2007792 Evaluation results for above 52.6 GHz InterDigital, Inc.
17. R1-2007847 System Analysis of NR opration in 52.6 to 71 GHz CATT
18. R1-2007848 Channel Access Mechanism in support of NR operation in 52.6 to 71 GHz CATT
19. R1-2007883 Required changes to NR using existing DL/UL NR waveform TCL Communication Ltd.
20. R1-2007884 Channel access mechanism TCL Communication Ltd.
21. R1-2007918 Channel access mechanisms for NR from 52.6-71GHz AT&T
22. R1-2007926 Required changes to NR using existing DL/UL NR waveform Nokia, Nokia Shanghai Bell
23. R1-2007927 Design of NR channel access mechanisms for 60 GHz unlicensed band Nokia, Nokia Shanghai Bell
24. R1-2007928 Simulation Results for NR from 52.6 GHz to 71 GHz Nokia, Nokia Shanghai Bell
25. R1-2007929 On phase noise compensation for NR from 52.6GHz to 71GHz Mitsubishi Electric RCE
26. R1-2007941 Discussion on Required Changes to NR in 52.6 – 71 GHz Intel Corporation
27. R1-2007942 Channel Access Procedure for NR in 52.6 - 71 GHz Intel Corporation
28. R1-2007943 Considerations on performance evaluation for NR in 52.6-71GHz Intel Corporation
29. R1-2007958 Draft TR 38.808 v002: Study on supporting NR from 52.6 GHz to 71 GHz Intel Corporation
30. R1-2007965 On the required changes to NR for above 52.6GHz ZTE, Sanechips
31. R1-2007966 On the channel access mechanism for above 52.6GHz ZTE, Sanechips
32. R1-2007967 Simulation results for NR above 52.6GHz ZTE, Sanechips
33. R1-2007982 On NR operations in 52.6 to 71 GHz Ericsson
34. R1-2007983 Channel Access Mechanism Ericsson
35. R1-2007984 Evaluation results for NR in 52.6 - 71 GHz Ericsson
36. R1-2008045 Consideration on required physical layer changes to support NR above 52.6 GHz LG Electronics
37. R1-2008046 Considerations on channel access mechanism to support NR above 52.6 GHz LG Electronics
38. R1-2008047 Considerations on phase noise compensation to support NR above 52.6 GHz LG Electronics
39. R1-2008076 Discussion on required changes to NR using existing DL/UL NR waveform in 52.6GHz ~ 71GHz CMCC
40. R1-2008082 Study on the numerology to support 52.6 GHz to 71GHz NEC
41. R1-2008091 Discussion on channel access mechanism for above 52.6GHz Spreadtrum Communications
42. R1-2008156 Design aspects for extending NR to up to 71 GHz Samsung
43. R1-2008157 Channel access mechanism for 60 GHz unlicensed spectrum Samsung
44. R1-2008158 Evaluaton results for extending NR to up to 71 GHz Samsung
45. R1-2008250 Discusson on required changes to NR using DL/UL NR waveform OPPO
46. R1-2008251 Discussion on channel access OPPO
47. R1-2008252 Discussion on other aspects OPPO
48. R1-2008353 Considerations on required changes to NR from 52.6 GHz to 71 GHz Sony
49. R1-2008354 Channel access mechanism for 60 GHz unlicensed spectrum Sony
50. R1-2008457 A Discussion on Physical Layer Design for NR above 52.6GHz Apple
51. R1-2008458 Views on Channel Access Mechanisms  for Unlicensed Access above 52.6 GHz Apple
52. R1-2008459 Evaluation results for Physical Layer Design for NR above 52.6GHz Apple
53. R1-2008493 Discussions on required changes on supporting NR from 52.6GHz to 71 GHz CAICT
54. R1-2008494 Discussions on channel access mechanism on supporting NR from 52.6GHz to 71 GHz CAICT
55. R1-2008501 On required changes to NR using existing DL/UL NR waveform for operation in 60GHz band MediaTek Inc.
56. R1-2008516 On NR operation between 52.6 GHz and 71 GHz Convida Wireless
57. R1-2008517 On Channel Access Mechanism and Interference Handling for Supporting NR from 52.6 GHz to 71 GHz Convida Wireless
58. R1-2008547 Evaluation Methodology and Required Changes on NR from 52.6 to 71 GHz NTT DOCOMO, INC.
59. R1-2008548 Channel Access Mechanism for NR in 60 GHz unlicensed spectrum NTT DOCOMO, INC.
60. R1-2008549 Potential Enhancements for NR on 52.6 to 71 GHz NTT DOCOMO, INC.
61. R1-2008563 Discussion on channel access mechanism ITRI
62. R1-2008615 NR using existing DL-UL NR waveform to support operation between 52p6 GHz and 71 GHz Qualcomm Incorporated
63. R1-2008616 Channel access mechanism for NR in 52p6 to 71GHz band Qualcomm Incorporated
64. R1-2008630 Channel access mechanism for NR in 52p6 to 71GHz band Qualcomm Incorporated
65. R1-2008717 Discussion on channel access mechanism for 52.6 to 71GHz unlicensed band Potevio
66. R1-2008726 Discussion on physical layer aspects for NR beyond 52.6GHz WILUS Inc.
67. R1-2008769 Waveform considerations for NR above 52.6 GHz Charter Communications
68. R1-2008770 Further aspects of channel access mechanisms Charter Communications
69. R1-2008771 Performance evaluations for NR above 52.6 GHz Charter Communications
70. R1-2008779 Link level and System level evaluation for NR system operating in 52.6GHz to 71GHz Huawei, HiSilicon
71. R1-2008805 Discussion on Required Changes to NR in 52.6 – 71 GHz Intel Corporation
72. R1-2008806 Channel Access Procedure for NR in 52.6 - 71 GHz Intel Corporation
73. R1-2008872 Design aspects for extending NR to up to 71 GHz Samsung
74. R1-2008873 Evaluaton results for extending NR to up to 71 GHz Samsung
75. R1-2008889 Channel access mechanism for NR in 52p6 to 71GHz band Qualcomm Incorporated
76. R1-2008890 FL Summary of system level evaluation results for NR from 52.6GHz to 71GHz Moderator (Qualcomm)
77. R1-2008976 Channel access mechanism for 60 GHz unlicensed operation Huawei, HiSilicon
78. R1-2009062 Evaluation Methodology and Required Changes on NR from 52.6 to 71 GHz NTT DOCOMO, INC.
79. R1-2009111 Summary of link level evaluation results and related issues on supporting NR from 52.6 GHz to 71 GHz Moderator (vivo)
80. R1-2009157 Performance evaluations for NR above 52.6 GHz Charter Communications, Inc
81. R1-2009312 Design of NR channel access mechanisms for 60 GHz unlicensed band Nokia, Nokia Shanghai Bell
82. R1-2009313 Issue Summary for physical layer changes for supporting NR from 52.6 GHz to 71 GHz Moderator (Intel Corporation)
83. R1-2009344 FL summary for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
84. R1-2009352 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #1 Moderator (Intel Corporation)
85. R1-2009355 Discussion summary #1 for [103-e-NR-52-71-Evaluations] Moderator (vivo)
86. R1-2009356 Collection of evaluation results on supporting NR from 52.6 GHz to 71 GHz Moderator (vivo, Qualcomm)
87. R1-2009362 Channel access mechanism for NR in 52.6 to 71GHz band Qualcomm Incorporated
88. R1-2009363 FL summary#2 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
89. R1-2009368 FL summary#3 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
90. R1-2009377 Discussion summary #2 for [103-e-NR-52-71-Evaluations] Moderator (vivo)
91. R1-2009379 Discussion on Required Changes to NR in 52.6 – 71 GHz Intel Corporation
92. R1-2009380 Channel Access Procedure for NR in 52.6 - 71 GHz Intel Corporation
93. R1-2009392 Discussion summary #3 for [103-e-NR-52-71-Evaluations] Moderator (vivo)
94. R1-2009403 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #1 Moderator (Intel Corporation)
95. R1-2009408 FL summary#4 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
96. R1-2009450 Simulation results for NR above 52.6GHz ZTE, Sanechips
97. R1-2009459 Link level and System level evaluation for NR system operating in 52.6GHz to 71GHz Huawei, HiSilicon
98. R1-2009521 FL summary#5 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
99. R1-2009524 Discussion summary #4 for [103-e-NR-52-71-Evaluations] Moderator (vivo)
100. R1-2009540 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #2 Moderator (Intel Corporation)
101. R1-2009572 FL summary#6 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
102. R1-2009609 Discussion summary #5 for [103-e-NR-52-71-Evaluations] Moderator (vivo)
103. R1-2009610 Link level and System level evaluation for NR system operating in 52.6GHz to 71GHz Huawei, HiSilicon
104. R1-2009615 Discussion on other aspects OPPO
105. R1-2009626 FL summary#7 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
106. R1-2009653 Consideration on required physical layer changes to support NR above 52.6 GHz LG Electronics
107. R1-2009667 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #3 Moderator (Intel Corporation)
108. R1-2009668 Summary of 38.808 TR Text Proposal Discussion Moderator (Intel Corporation)
109. R1-2009675 FL summary#8 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
110. R1-2009688 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #4 Moderator (Intel Corporation)
111. R1-2009713 Draft TR 38.808 v010: Study on supporting NR from 52.6 GHz to 71 GHz Intel Corporation
112. R1-2009717 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #5 Moderator (Intel Corporation)
113. R1-2009718 [103-e-NR-52-71-Waveform-Changes] Discussions Summary #6 Moderator (Intel Corporation)
114. R1-2009724 FL summary#9 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
115. R1-2009760 FL summary#10 for channel access of 52.6GHz to 71GHz band Moderator (Qualcomm)
116. R1-2009779 Summary#2 of 38.808 TR Text Proposal Discussion Moderator (Intel Corporation)
117. R4-2014382 Further discussion on numerology and CBW for above 52.6 GHz CATT
118. R4-2014401 Discussion on the BS requirements for 52.6-71GHz CATT
119. R4-2014737 Bandwidth and numerology for NR in 52.6GHz CMCC
120. R4-2014892 Further considerations on the numerology and channel bandwidth sizes for the 60GHz frequency range Apple Inc.
121. R4-2014893 Futher considerations on the phase noise for the 60GHz frequency range Apple Inc.
122. R4-2014894 Regulatory overview and input for the 60GHz frequency range Apple Inc.
123. R4-2014974 Further discussion on channel bandwidths and numerology for B52.6G vivo
124. R4-2014975 Further discussion on PA model for B52.6G vivo
125. R4-2014976 TP to TR 38.808: On 52.6 to 71 GHz phase noise characteristics, TP to TR and draft LS to RAN1 Ericsson
126. R4-2014977 TP to TR 38.808: Addition of technical background information for base station in clause 2 and sub-clause 4.2.6 Ericsson
127. R4-2014980 TP to TR 38.808: Addition of general RAN4 structure to sub-clause 4.2 Ericsson
128. R4-2015200 TP to TR 38.808 BS RF for NR beyond 52.6 GHz Nokia, Nokia Shanghai Bell
129. R4-2015206 Numerology and channel bandwidth discussion for NR beyond 52.6 GHz Nokia, Nokia Shanghai Bell
130. R4-2015307 Channel bandwidth and subcarrier spacing for 52.6 GHz to 71GHz NEC
131. R4-2015443 Draft LS: Phase noise and RF impairment considerations Nokia, Nokia Shanghai Bell
132. R4-2015444 UE RF for NR beyond 52.6 GHz Nokia, Nokia Shanghai Bell
133. R4-2015563 On numerology and channel bandwidth in 52.6 - 71 GHz Intel Corporation
134. R4-2015564 On 60 GHz Phase noise and RF impairments Intel Corporation
135. R4-2015700 Discussion on 52.6 GHz to 71 GHz SI Huawei, HiSilicon
136. R4-2015727 On 52.6 to 71 GHz numerology evaluation and channel bandwidths Ericsson
137. R4-2015728 Discussion on PTRS for 52 beyond Ericsson
138. R4-2015886 Views on numerologies above 52 GHz Sony
139. R4-2015947 TP to TR 38.808: BS architecture and BS classes for 52-71 GHz range Huawei
140. R4-2015948 TP to TR 38.808: PA trends and typical Noise Figure values Huawei
141. R4-2015984 On power amplifier aspects for UE in the 52.6-71 GHz range Ericsson
142. R4-2016000 TP to TR 38.808: Timing considerations for operation between 52.6 and 71 GHz Nokia, Nokia Shanghai Bell
143. R4-2016036 TP for NR Rel-17 TR 38.808: Time and synchronization impact Ericsson
144. R4-2016110 Further discussion on numerology and BW for 52.6GHz-71GHz ZTE Corporation
145. R4-2016298 Phase noise and PTRS Qualcomm Incorporated
146. R4-2016299 Subcarrier spacing and minimum channel bandwidth Qualcomm Incorporated
147. R4-2016371 A Survey on Memory Based PA Models Huawei, HiSilicon
148. R4-2016533 on PN model for 60GHz+reply LS RAN1 Huawei, HiSilicon
149. R4-2016642 Email discussion summary for [97e][140] FS\_NR\_52\_to\_71GHz\_Part\_1 Moderator (Qualcomm)
150. R4-2016643 Email discussion summary for [97e][141] FS\_NR\_52\_to\_71GHz\_Part\_2 Moderator (Intel)
151. R4-2016925 WF on Min and Max Channel Bandwidths in 52 to 71 GHz Huawei
152. R4-2016926 WF on Phase noise mask and PTRS Qualcomm
153. R4-2016927 WF on timing text proposal to TR Nokia
154. R4-2016928 LS on PN models RAN4
155. R4-2016981 Email discussion summary for [97e][140] FS\_NR\_52\_to\_71GHz\_Part\_1 Moderator (Qualcomm)
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157. R4-2016995 TP to TR 38.808 BS RF for NR beyond 52.6 GHz Nokia, Nokia Shanghai Bell
158. R4-2016998 WF on FS 52 to 71 GHz Intel
159. R4-2017812 Email discussion summary for [97e][140] FS\_NR\_52\_to\_71GHz\_Part\_1 Moderator (Qualcomm)
160. R4-2017832 WF on Min and Max Channel Bandwidths in 52 to 71 GHz Huawei

 20.04.2020 minor adaptations for RAN #88e

 18.02.2020 minor adaptations for RAN #87e

 14.11.2019 minor adaptations for RAN #86

 18.08.2019 minor adaptations for RAN #85

 12.05.2019 minor adaptations for RAN #84

 27.02.2019 minor adaptations for RAN #83

 21.11.2018 completion levels with colours added (for RAN #82)

v04.81 31.07.2018 simplification of template and addition of cross-TSG aspects (for RAN #81)

v04.80 21.05.2018 minor adaptations for RAN #80

v04.79 26.02.2018 minor adaptations for RAN #79

v04.78 18.11.2017 minor adaptations for RAN #78

v04.77 06.08.2017 minor adaptations for RAN #77

v04.76 15.05.2017 minor adaptations for RAN #76

v04.75 31.01.2017 minor adaptations for RAN #75

v04.74 28.10.2016 minor adaptations for RAN #74

v04.73 01.09.2016 adaptations for RAN #73 (time units in extra Excel table, RAN6 reporting included)

v04.72 26.05.2016 adaptations for RAN #72 (introduction of NR & GERAN TUs)

v04.71 10.02.2016 minor adaptations for RAN #71

v04.70 30.10.2015 minor adaptations for RAN #70

v04.69 12.08.2015 minor adaptations for RAN #69

v04.68 21.05.2015 minor adaptations for RAN #68

v04.67 01.02.2015 minor adaptations for RAN #67

v04.66 16.11.2014 minor adaptations for RAN #66

v04.65 16.08.2014 minor adaptations for RAN #65

v04.64 22.05.2014 minor adaptations for RAN #64

v04.63 24.01.2014 restructuring for RAN #63 to cover Core & Perf. in one doc file

v03.62 11.11.2013 section 1.2.3 adapted for RAN #62

v03 11.08.2013 section 1.2.3 added on time budget

v02 07.05.2010 history added, some spelling corrections

v01 13.11.2009 First version of the template