3GPP TSG-RAN WG4 Meeting #116bis R4-2514508

Prague, Czech Republic, Oct 13 – 17, 2025

**Agenda item:** 8.1

**Source:** Feature lead (Huawei, HiSilicon)

**Title:** Feature lead summary for [116bis][101] 6G system parameter

**Document for:** Information

# Introduction

This is the first meeting in RAN4 to start the 6G study.

This document provides feature lead summary for 6GR system parameters. The scope includes waveform, modulation, CBW, FFT, numerology, spectrum utilization, synchronization signal and raster, irregular channel bandwidth, #Rx, #Tx, device types, etc.

It is noted that the aspects related to the interim milestone should be prioritized according to the guidance of RAN4 chair.

Before we commence the significant journey of the RAN4 study into 6G system parameters, it would be helpful to better understand its relationship with the ongoing RAN and RAN1 studies on similar topics. Below are the relevant objectives regarding system parameters, excerpted from the RAN-led Study on 6G Scenarios and Requirements (RP-250810) and the working group level Study on 6G Radio (RP-251881), respectively.

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| --- |
| **RAN level 6G SI**This study item aims to * investigate a candidate set of items for minimum TPRs based on the Recommendation ITU-R M.2160, and, where applicable, the associated target values and key assumptions for the identified minimum TPRs.
	+ The outcome is expected to be shared by LS with ITU-R WP5D, as suitable, and used as a baseline for the subsequent study 6G in RAN
* Identify typical and practical deployment scenarios defined by attributes such as carrier frequency, inter-site distance, user density, maximum mobility speed, and other relevant factors.
* Develop 3GPP requirements for 6G Radio for improvement of existing services and for new services.
* Determine the applicability of legacy services to 6G Radio, and define radio requirements for these, as appropriate.
* Develop 3GPP requirements for 6G Radio for these practical deployment scenarios to ensure substantial gains in all relevant bands: overall performance, user experience, TCO reduction including at least:
	+ Ensure appropriate set of functionalities, minimize the adoption of multiple options for the same functionality, avoid excessive configurations, excessive UE capabilities and UE capabilities reporting
	+ Energy efficiency and energy saving: both for network and device
	+ Enhanced spectral efficiency
	+ Enhanced overall coverage, focus on cell-edge performance and UL coverage
	+ **Wider channel bandwidth** (at least 200MHz) support for 6G deployments at least above 2 GHz, around 7 GHz
	+ Re-use of existing 5G mid-band (~3.5GHz) site grid for 6G deployments in at least around 7 GHz and targeting comparable coverage to 5G mid-band
	+ Target scalable and forward compatible design for **diverse device types**
	+ **Improved spectrum utilization** and operations taking into account diverse spectrum allocations
	+ Aim at using common 6G Radio design, which meets mobile broadband service requirements as high priority, to also meet vertical needs
	+ Aim at a harmonized 6G Radio design for TN and NTN, including their integration
	+ System simplification, including reducing configuration complexity, enabling more efficient Cell/UE management, etc.
* Define a time plan and steer work as appropriate for the RAN WGs during the 6G WG SI to deliver high-level decisions at least on the following areas:
	+ Fundamental 6G radio design aspects: **waveform**, **numerology**, channel coding, etc…
	+ Overall high-level aspects of 5G to 6G migration
	+ RAN architecture and interfaces, including RAN-Core interface
	+ Coordination of 6G AI/ML framework

**WG level 6G SI**The detailed objectives of the study are:1. Single technology framework based on a stand-alone architecture (Note1) to support the agreed existing and new services, and to satisfy the usage scenarios, requirements, deployment scenarios and design principles with acceptable performance/complexity trade-off, as determined by the RAN requirements in [RP-250810] and [TR38.914], including: [RAN1], [RAN2], [RAN3], [RAN4]
2. Physical Layer structure for 6GR,
	1. **Waveforms (OFDM-based) and modulations**. 5G NR Waveforms and modulation should be considered for 6GR and is also the benchmark for other potential proposals. [RAN1, RAN4]
	2. Frame structure, including compatibility with 5G NR to allow for efficient 5G-6G Multi-RAT Spectrum Sharing (MRSS). [RAN1]
	3. Channel coding, using LDPC and Polar Code as baseline, considering applicable extensions to satisfy 6G requirements and characteristics with acceptable performance/complexity trade-off [RAN1]
	4. **Channel Bandwidth (at least minimum and maximum)**, **Numerology**, avoiding multiple numerologies for the same band / sub-range (e.g., enabling synergies among frequency bands in the ~7GHz range) [RAN1, RAN4]
	5. Physical layer control, data scheduling and HARQ operation [RAN1, RAN2]
	6. MIMO operation [RAN1, RAN4]
	7. Duplexing improvements [RAN1, RAN4]
	8. **Initial access** [RAN1, RAN2, RAN4]
		* Studies on **synchronization signal and raster**, broadcast signals/channel and physical random access channel [RAN1, RAN4]
		* Studies on **initial access procedure**, random access procedures, system information and paging [RAN2, RAN1, RAN4]
	9. **6GR spectrum utilization** and aggregation. [RAN1, RAN2, RAN4]
	10. Other physical layer signals, channels and procedures [RAN1, RAN2, RAN4]
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According to the SI objectives set at both the RAN and working group levels, the primary objective of the RAN4 study on system parameters is to apply its unique expertise. This focuses on rigorous, implementation-aware evaluations that ensure the final defined parameters fulfill all target usage scenarios, requirements, deployment scenarios, and design principles, and to deliver a viable performance-complexity trade-off. It is important to note that this work is conducted through close coordination among RAN4, RAN and RAN1.

# Companies’ contribution summary

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| **TDoc** | **Title** | **Source** |
| [**R4-2513020**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513020.zip) | Qualcomm views on 6G System parameters | Qualcomm Incorporated |
| [**R4-2513026**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513026.zip) | Improving 6G UL throughput performance | Charter Communications, Inc |
| [**R4-2513035**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513035.zip) | On 6G system parameters | Apple |
| [**R4-2513043**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513043.zip) | Discussion on system parameters for 6GR | Samsung |
| [**R4-2513061**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513061.zip) | Overview of 6GR System Parameters | InterDigital, Europe, Ltd. |
| [**R4-2513075**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513075.zip) | Views on 6G system parameters | MediaTek inc. |
| [**R4-2513078**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513078.zip) | Discussion on 6G FR1 CBW | China Telecom |
| [**R4-2513114**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513114.zip) | Inputs to RAN4 6G study on system parameters | Skyworks Solutions Inc. |
| [**R4-2513116**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513116.zip) | System parameter considerations for 6G | Ericsson |
| [**R4-2513122**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513122.zip) | Initial views on system parameters of 6GR | Sony |
| [**R4-2513132**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513132.zip) | Discussion on system parameters for 6GR study | CMCC |
| [**R4-2513144**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513144.zip) | 6GR System parameters | Nokia |
| [**R4-2513147**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513147.zip) | Views on 6G system parameters | Spreadtrum,UNISOC |
| [**R4-2513240**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513240.zip) | Discussion on system parameters for 6G study | CATT |
| [**R4-2513250**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513250.zip) | Discussion on 6G System parameters | vivo |
| [**R4-2513256**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513256.zip) | Initial views on 6G system parameters | LG Electronics |
| [**R4-2513269**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513269.zip) | Views on 6G system parameter | ZTE Corporation,Sanechips |
| [**R4-2513272**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513272.zip) | Overview for 6G system parameter design | Xiaomi |
| [**R4-2513290**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513290.zip) | 6G RAN4 Study on system parameter | NTT DOCOMO, INC. |
| [**R4-2513304**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513304.zip) | Consideration on system parameters for 6G | Huawei, HiSilicon |
| [**R4-2513315**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513315.zip) | On 6GR system parameter | OPPO |
| [**R4-2513330**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513330.zip) | Views on 6G system parameters | CSCN |
| [**R4-2513351**](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513351.zip) | Discussion on 6G system parameters | Google Korea LLC |

# Topic #1: Waveform

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

The primary objective of this meeting is to identify a clear RAN4 scope to be investigated in parallel with RAN1 on the same topic.

The agreements already reached in RAN1 are provided below for reference.

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| ***Waveform*****RAN1#122**[**R1-2506550**](file:///C%3A%5CUsers%5Cqiu%20haijie%5CAppData%5CLocal%5CTemp%5CDocs%5CR1-2506550.zip) **Feature Lead summary #1 on 6GR waveform Moderator (Nokia)**From Wednesday sessionAgreement (first agreement for 6G!!)CP-OFDM and DFT-s-OFDM waveforms as defined in 5G NR are supported as the basis for 6GR for uplink* Enhancements/modifications on CP-OFDM/DFT-s-OFDM will be studied as potential additions
* Other OFDM based waveforms are not precluded.

[**R1-2506595**](file:///C%3A%5CUsers%5Cqiu%20haijie%5CAppData%5CLocal%5CTemp%5CDocs%5CR1-2506595.zip) **Feature Lead summary #2 on 6GR waveform Moderator (Nokia)**From Friday sessionAgreementCP-OFDM waveform as defined in 5G NR is supported as the basis for 6GR for downlink* Enhancements/modifications on CP-OFDM will be studied as potential additions
* DFT-s-OFDM or any other OFDM-based waveform will be studied as a potential additional waveform for downlink

Note: proponents to identify at least the target use cases, signals/channels to use the waveform, and how the proposal is intended (if applicable) to support multiplexing with CP-OFDM, including MRSS, and how multi-user multiplexing is supported, etc. |

## Observations and Proposals/Options

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Baseline waveform consensus in RAN1: There is an agreement in RAN1 to use 5G NR waveforms (CP-OFDM for DL, both CP-OFDM and DFT-s-OFDM for UL) as the baseline for 6G. However, other OFDM-based waveforms are not precluded from study.
	+ Waveform performance and impact:
		- High PAPR is recognized as a critical issue as it decreases PA efficiency and reduces maximum output power.
		- Some specific techniques like frequency-domain mapping truncation for π/2 BPSK can achieve spectral efficiency similar to QPSK with higher output power.
		- Introducing DFT-s-OFDM in the DL could provide coverage and receiver sensitivity gains, but would increase UE implementation complexity, and there is no conclusion in RAN1 yet
		- Enabling multi-rank UL for DFT-s-OFDM will have minimal impact on RAN4 specifications
* Main proposals
	+ Close collaboration with RAN1
		- RAN4 must work closely with RAN1 to define evaluation methodologies, assumptions, and a common PA model for simulations.
		- Some proposals suggest postponing detailed RAN4 waveform discussions until 2026, after RAN1 has made sufficient progress.
	+ Key Performance Indicators (KPIs)
		- Waveform evaluation should include KPIs like PAPR, Cubic Metric (CM), SEM, ACLR, OBE, EVM, implementation complexity, and compatibility with 5G band combinations.
	+ Evaluation metric
		- Propose using "Net Gain" as a starting point for evaluating low-PAPR schemes.
	+ Specific studies include:
		- Study Low-PAPR techniques: Investigate both transparent and non-transparent techniques (like CFR-SE) to reduce PAPR and assess their impact on RF requirements.
		- Explore new waveforms for new use cases: Study the feasibility and impact of supporting DFT-s-OFDM in the DL (e.g., for massive IoT) and new waveforms for Integrated Sensing and Communications (ISAC).
* Recommended WF
	+ The primary purpose of RAN4 study on waveform is to evaluate candidate waveforms and potential PAPR reduction techniques based on agreements and inputs from RAN1
	+ To establish the foundational evaluation framework in RAN4 firstly when no solid progress and inputs from RAN1
		- Identify the main affected requirements for waveform evaluations, such as ACLR, SEM, SE, EVM and MPR.
			* The existing 5G NR requirements could be served as the baseline, which are subject to future updates based on RAN4's 6G UE RF discussions.
		- Align on the evaluation assumptions, such as frequency bands, power class, channel bandwidth, RF impairments, etc.
		- Align on the PA model for consistent evaluations on the waveforms, which could be discussed together with the topic of UE RF.
			* This agreed model should also be provided to RAN1 to align their studies.
		- Decide on the evaluation metric, e.g., whether to adopt ‘Net Gain’ metric for low PAPR evaluation
	+ Model and evaluate the RF performance of different waveform candidates and PAPR reduction techniques pending on RAN1 inputs
		- Evaluation cases could be selected step-by-step, based on RAN1 progress
		- Whether to investigate RF impacts of DL DFT-s-OFDM pending on RAN1 agreement

# Topic #2: Modulation

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

The primary objective of this meeting is to identify a clear RAN4 scope to be investigated in parallel with RAN1 on the same topic.

The agreements already reached in RAN1 are provided below for reference.

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| ***Modulation*****RAN1#122**[**R1-2506579**](file:///C%3A%5CUsers%5Cqiu%20haijie%5CAppData%5CLocal%5CTemp%5CDocs%5CR1-2506579.zip) **FL summary#2 for 6GR modulation, joint channel coding and modulation Moderator (Qualcomm)**From Friday sessionAgreement* For 6GR DL, 5G NR uniform QPSK, 16QAM, 64QAM, 256QAM and 1024QAM are supported as basis for study for data channel
	+ FFS: Enhancements and other modulation schemes
* For 6GR UL, 5G NR uniform QPSK, 16QAM, 64QAM, and 256QAM are supported as basis for study for CP-OFDM for data channel
	+ FFS: Enhancements and other modulation schemes
* For 6GR UL, 5G NR pi/2 BPSK, uniform QPSK, 16QAM, 64QAM, and 256QAM are supported as basis for study for DFT-s-OFDM for data channel
	+ FFS: Enhancements and other modulation schemes
 |

## Observations and Proposals/Options

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Baseline and direction for modulation:
		- There is a consensus to use 5G NR modulation orders as a baseline, with enhancements under discussion in RAN1.
		- The initial expected upper limits are 1024QAM for DL and 256QAM for UL.
		- Studies for even higher-order modulations, such as 4096QAM for DL and 1024QAM for UL, are being considered for 6G, potentially with AI-assisted receivers.
	+ Performance and feasibility of higher-order modulations:
		- Introducing higher-order modulations (e.g., UL 1024QAM) requires significant study in RAN4, including MPR, required SNR, throughput, and coverage impacts.
		- New technologies like AI/ML, advanced semiconductor (SiC/GaN), and digital pre-distortion (DPD) at the UE, as well as advanced channel estimation at the base station side, are seen as enablers for these high-order modulations.
		- Non-uniform constellations (Geometric Shaping) and Probabilistic Shaping can provide link budget gains ~1 dB, but their impact on RF requirements needs evaluation.
	+ Device type considerations:
		- Modulation support should be tailored to device types: low-order (e.g., 64QAM) for massive IoT, and high-order for broadband devices (e.g., 256QAM/1024QAM UL/DL).
* Main proposals
	+ Supported modulation order:
		- Support QPSK to 1024QAM for DL and π/2 BPSK/QPSK to 256QAM for UL as the baseline for “Day One” 6G specifications.
		- Study the feasibility of optional higher-order modulations, specifically 1024QAM for UL and 4096QAM for DL.
	+ Early involvement:
		- RAN4 should be involved early to validate the feasibility of any new modulation schemes agreed upon by RAN1.
		- Some proposals suggest postponing detailed RAN4 discussions on waveform/modulation until sufficient progress is made in RAN1 (e.g., starting in Q2 2026).
	+ Studies for enabling higher-order modulations:
		- Conduct studies on MPR, required SNR, throughput, and coverage for high-order modulations.
		- Study advanced UE techniques (like DPD) and sNB (tentatively used ^^) techniques (like advanced channel estimation) to enable UL 1024QAM.
		- Use 5G EVM requirements as a starting point but define more realistic and appropriate requirements for 6G.
* Recommended WF
	+ To establish the foundational evaluation framework in RAN4 firstly when no solid progress and inputs from RAN1
		- Identify the main affected requirements for modulation evaluations, such as EVM and MPR.
			* The existing 5G NR requirements will serve as the baseline, which are subject to future updates based on RAN4's 6G UE RF discussions.
		- Align on the evaluation assumptions, such as frequency bands, power class, channel bandwidth, RF impairments, etc.
		- Align on the PA model for consistent evaluations on the modulation, which could be discussed together with topic of UE RF.
			* This agreed model should also be provided to RAN1 to align their studies.
		- RF evaluation could be done firstly for 5G supported modulations with new assumptions for 6G study, such as assumed new spectrum, CBW, new PA models, etc. Co-ordination with 6G UE RF study is needed.
		- Both link-level and system-level simulations should be performed as usual for high-order modulations study done by RAN4 in prior releases, pending on the progress of RAN1.
	+ Model and evaluate the RF performance of higher-order modulations and/or new constellations pending on RAN1 inputs
		- Evaluation cases could be selected step-by-step, based on RAN1 progress

# Topic #3: Channel bandwidth

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

The primary objective of this meeting is to identify a clear RAN4 scope to be investigated in parallel with RAN1/RAN on the same topic.

The agreements already reached in RAN1 / RAN are provided below for reference.

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| ***Minimum Channel Bandwidth*****RAN#109**In RP-252873, proposal 1 is endorsed**Proposal 1:** Endorse the following two RAN1 agreements (with the clarification that the 2nd agreement is applicable to FR1). Companies are invited to bring contributions regarding the minimum spectrum allocation in RAN#110, while RAN1 is requested to continue the study on both the minimum spectrum allocation and the smallest maximum UE bandwidth from the 6GR design perspective. Revisit in RAN#110.Agreement* For the study of RAN1 6GR design, consider the minimum spectrum allocation in which 6G can operate, subject to further discussion and confirmation in RAN.
	+ Note: RAN4 involvement is necessary.

 Agreement* Study the following smallest maximum supported RF and BB UE BW without spectrum aggregation for at least one low-tier device type supported by 6GR framework from physical layer perspective, subject to further discussion and confirmation in RAN
	+ Opt1: 3MHz
	+ Opt2: 5MHz
	+ Opt3: 10MHz
	+ Opt4: 20MHz
	+ FFS: the UL bandwidth may be different to the DL bandwidth
	+ FFS: the bandwidth value may be different for different SCS, duplex modes, and bands.

FFS: whether RF and BB UE BW are same or different***Numerology*****RAN1#122 and RAN#109 agreements****Agreement*** Regarding the RAN1 agreement below, the following is agreed:
* Keep using “around 7GHz” instead of using detailed frequency range definition in RAN1’s and RAN4’s study.

**Agreement*** 6GR takes the following SCS as start point for discussion for all the signals/channels except PRACH.
	+ For sub 6GHz
		- The following subcarrier spacing is at least supported
			* 15kHz SCS for FDD, 30kHz SCS for TDD
		- FFS: 30kHz SCS for FDD for around e.g., 1-2.5GHz
		- FFS: 7.5kHz SCS for sub1GHz (FDD)
		- ~~Whether to discuss the FFS will be subject to RANP decision.~~
	+ For around 7GHz
		- The following subcarrier spacing options can be studied
			* 30kHz, 60kHz
	+ FFS: For around 15GHz
		- The following subcarrier spacing options can be studied
			* 30kHz, 60kHz, 120kHz
		- ~~Whether to discuss it will be subject to RANP decision~~
	+ For between 24.25GHz - 52.6GHz
		- Subcarrier spacing 120kHz is supported
	+ FFS whether to allow using additional subcarrier spacing for SSB
* FFS subcarrier spacing for PRACH and up to initial access discussion.

***Spectrum utilization*****RAN#109**In RP-252950, proposal 1 is agreed**Proposal 1: 6GR aims to support improved spectrum utilization and operations over one or more carriers/bands, compared to 5G NR.** |

## Observations and Proposals/Options

### Sub-topic 3-1: Max Channel Bandwidth

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Spectrum availability and regulatory constraints:
		- Current 5G FDD bands have limited contiguous spectrum (e.g., the largest is 90MHz in n65). This directly constrains the practical maximum CBW.
		- Higher frequency ranges (e.g., around 7 GHz, 15 GHz, and FR2-1) offer wider contiguous blocks, making larger CBWs like 200 MHz, 400 MHz, and 800 MHz technically plausible from a spectrum allocation standpoint.
	+ Technical feasibility and implementation complexity:
		- FFT size as a key enabler: Supporting wider CBWs is contingent upon larger FFT sizes. For instance, a 400 MHz CBW with 30 kHz SCS is noted to require a 16K FFT, while an 8K FFT can support 200 MHz (30 kHz SCS) or 800 MHz (120 kHz SCS).
		- UE complexity and power consumption: There is a clear trade-off where larger CBWs increase UE implementation complexity and power consumption.
		- BS vs. UE asymmetry: An alternative to mandating wide CBWs for UEs is to specify them for BS only, using CA to provide equivalent bandwidth to UEs.
		- Device-type differentiation: A distinction is made between device categories, e.g., Massive IoT devices may have a very low max CBW, while broadband and ultra-broadband devices would support progressively larger CBWs.
* Main proposals
	+ Frequency-range specific max CBW proposals:
		- Sub-6 GHz (FDD): 50 MHz or 100 MHz (using 15 kHz/[30kHz] SCS and 4K/8K FFT).
		- Sub-6 GHz (TDD): 200 MHz (using 30 kHz SCS and 8K FFT).
		- Upper mid-bands (approx. 6-24 GHz): 200 MHz or 400 MHz (using 30/60 kHz SCS and 8K/16K FFT).
			* Several proposals further split above frequency range with different sub-frequency ranges for consideration on max CBW and numerology selection e.g.
				+ 6425MHz ~ 7125MHz
				+ 7125MHz ~ 8.4GHz
				+ ~15GHz around
		- FR2-1 (24-52 GHz): 800 MHz (using 120 kHz SCS and 8K FFT).
	+ Implementation and feasibility studies:
		- Study wideband RF impact: Propose that RAN4 studies the RF implications of wide CBWs (200 MHz, 400 MHz, 800 MHz) on requirements like EVM, ACLR, SEM and receiver sensitivity.
		- Study UE implementation paths: For a 400 MHz CBW, study different UE baseband architectures (e.g., single 16K FFT vs. two 8K FFTs vs. two-component carrier aggregation).
	+ Flexible and asymmetric support:
		- Different UL/DL CBW: Propose supporting different maximum channel bandwidths for Uplink and Downlink.
		- BS vs. UE asymmetry: Propose introducing wide CBWs (e.g., 400 MHz) only for base stations, not for UEs, to manage UE complexity.
* Recommended WF

In the absence of RAN1 agreements, RAN4 could conduct preliminary assessments of the RF feasibility for the candidate maximum channel bandwidths.

* + RF performance evaluation with proposed max CBW
		- Identify the prioritized max CBW scenarios (e.g., TDD/FDD, frequency ranges) for evaluation
		- From transmitter perspective, evaluate the feasibility of meeting out-of-band emission requirements with assumed spectrum utilization
		- From receiver perspective, study the impact on UE reference sensitivity, blocking, and ACS when receiving these wide carriers
		- 5G NR requirements could be considered as baseline for the evaluation
	+ Phased evaluation of UE and BS implementation complexity
		- Study the need of specifying large CBW from RAN4 perspective
		- Assess the implementation complexity and power consumption for the different proposed UE types in relation to their target max CBWs, which could rely on the progress of discussion for device types in RAN
		- Compare implementation options, e.g., for challenging cases like 400 MHz, evaluate the RF performance and implementation trade-offs of the different proposed UE architectures (e.g., single 16K FFT vs. multi-FFT vs. CA). Obviously, the evaluation cases also depend on the discussion in RAN1.
	+ Collaborate with RAN1 on feasibility findings
		- Provide early feedback to RAN1 with RAN4's initial findings on the RF feasibility and trade-offs of the most prominent max CBW/SCS/FFT combinations.

### Sub-topic 3-2: Min Channel Bandwidth

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ The min CBW values from 5G NR serve as a key reference. Initially, 5 MHz for 15 kHz SCS and 10 MHz for 30 kHz SCS were agreed upon for FR1. Subsequently, 3 MHz was introduced in 3GPP Release 19 for a total of 12 bands, demonstrating a trend towards supporting narrower bandwidths for specific use cases.
	+ The primary driver for considering min CBW values smaller than 5 MHz (notably 3 MHz) is to accommodate operators with fragmented spectrum holdings or limited spectrum resources (as small as 3 MHz), ensuring efficient utilization.
	+ Defining the min CBW also need to consider factors such as initial access requirements, the specific spectrum status of different bands, and overall spectrum utilization efficiency.
* Main proposals
	+ Specific min CBW values proposals:
		- General baseline: Multiple proposals suggest establishing 5 MHz as a general baseline, following the NR approach.
		- Narrowband support: Several companies support for also standardizing 3 MHz as the min CBW, particularly for specific bands or scenarios (e.g., for initial access, FDD bands, or where operator spectrum is fragmented).
		- SCS-dependent framework: Several proposals link min CBW directly to the SCS, suggesting a scalable framework (e.g., 3/5 MHz for 15 kHz, 10 MHz for 30 kHz, 20 MHz for 60 kHz, 50/100 MHz for 120 kHz).
	+ Flexible and granular definition proposals:
		- Band-specific definition: A key proposal is to define min CBW on a per-band basis rather than a per-frequency-range basis. This would allow for larger min CBWs in most legacy bands while enabling smaller min CBWs only in bands where operators truly have fragmented spectrum.
		- Device-type specific definition: Another forward-looking proposal is to explore defining different min CBWs for different device types operating on the same band (e.g., a larger min CBW for high-tier devices and a smaller one for massive IoT devices).
* Recommended WF
	+ Compare options of defining min CBW on a per-band basis or a per-frequency-range or per sub-frequency range basis, considering pros and cons
	+ Study the following aspects from RAN4 perspective, meanwhile tracking RAN1/RAN progress
		- Whether 5MHz could be considered as a general baseline while 3MHz is allowed for particular bands
		- SCS-dependent framework
		- Other aspects are not precluded
	+ Provide early feedback to RAN1 with RAN4's initial findings on min CBW from implementation and spectrum perspective.

### Sub-topic 3-3: FFT size

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ FFT size as an enabler for wider bandwidths:
		- The primary driver for larger FFT sizes (like 8K) is to support wider channel bandwidths (e.g., 200 MHz, 400 MHz, 800 MHz) efficiently.
		- A specific observation notes that an 8K FFT is considered a baseline in RAN1 for processing channels up to 200 MHz, while a 16K FFT would be needed to support a 400 MHz channel with a 30 kHz SCS.
	+ Device capability differentiation:
		- There is a recognition that FFT size requirements could be tailored to device capabilities. Massive IoT devices could use smaller FFTs (2K/4K), while higher-capability devices would use larger ones (8K or more).
* Main proposals
	+ FFT size and CBW combination proposals:
		- Baseline FFT size: Several companies suggested to take 8192 (8K) FFT as the maximum size while a few companies brought up the need to further consider even 16K FFT to potentially cover 400MHz Channel BW.
		- FR1 (Sub-6 GHz / <5GHz): Proposals suggest 4K FFT for up to 100 MHz (with 15/30 kHz SCS) and 8K FFT for up to 200 MHz (with 30 kHz SCS).
		- Upper Mid-Bands (around 7GHz up to 15.35 GHz): Proposals suggest 8K FFT or even up to 16K FFT for up to 400 MHz (with 30/60 kHz SCS).
		- FR2-1 (24-52 GHz): Proposals suggest 4K FFT for 400 MHz and 8K FFT for 800 MHz (with 120 kHz SCS).
	+ Feasibility study:
		- Multiple proposals recommend studying the feasibility of 8K FFT with associated SCS, especially for wide CBWs in frequencies above 2.4 GHz and in new frequency range higher than 7125MHz.
* Recommended WF
	+ Consider FFT size, maximum Channel Bandwidth and numerology as a framework to have feasibility study from implementation perspective, especially for the feasibility of 8K or 16K FFT size considering the associated SCS and also the frequency ranges
	+ Provide RAN1 with early RAN4 feedback on the RF feasibility and trade-offs of the proposed FFT/CBW/SCS combinations to help guide their decisions.

### Sub-topic 3-4: Numerology

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Lessons from 5G NR deployment: A key observation is that while 5G NR specified multiple SCS options per band and allowed different SCS for SSB and data, these features are not typically used in real-world deployments. This complexity has yielded limited practical benefit.
	+ For refarmed FR1 bands, using the same SCS as 5G is considered beneficial for MRSS and smoother migration
* Main proposals
	+ "Single numerology" proposals:
		- Most companies prefer to adopt a single SCS per operating band or frequency sub-range for 6G. This aims to drastically simplify specification, implementation, and network management.
		- This principle extends to using the same numerology for both SSB and data channels within a band, simplifying initial access and receiver design.
	+ Frequency-range specific SCS values proposals:
		- FR1 (Sub-6 GHz): 15 kHz for FDD bands and 30 kHz for TDD bands are the most proposed values.
		- Upper Mid-Bands (~7-24 GHz): 30 kHz and 60 kHz are the primary candidates, while 30 kHz being favored for the lower part of this range (e.g., around 7 GHz) with several proposals.
		- FR2-1 (24-52 GHz): 120 kHz SCS is universally proposed as the baseline for these mmWave frequencies.
	+ Framework linking SCS, CBW, and FFT size:
		- Integrated design: Multiple proposals present a unified framework where SCS, max CBW, and FFT size are defined together. For example:
			* 30 kHz SCS + 8K FFT => 200 MHz CBW
			* 30 kHz SCS + 16K FFT => 400 MHz CBW
			* 120 kHz SCS + 8K FFT => 800 MHz CBW
		- Band group based SCS: Proposals suggest grouping bands by certain frequency range (e.g., "below 2.4 GHz", "FDD bands < 1.6 GHz", etc.) and assigning a single SCS and FFT size combination to each group.
	+ Exceptions and special cases proposals:
		- NTN and ISAC: While a single numerology is the baseline, studies are proposed for supporting multiple SCS for special use cases like NTN and ISAC.
		- Asymmetric UL/DL: The possibility of supporting different SCS for Uplink and Downlink is also noted for further study.
* Recommended WF
	+ Consider FFT size, maximum Channel Bandwidth and numerology as a framework to have feasibility study from implementation perspective, especially for the feasibility of 8K FFT or 16K FFT size considering the associated SCS and also the frequency ranges
	+ Evaluate the following proposals regarding numerology from RAN4 perspective
		- "Single numerology" proposal
		- Frequency sub-range/Band specific SCS values proposal
			* Compare perf gain and implementation complexity for different SCS with same frequency range or specific band
		- Whether single numerology as baseline is viable if other scenarios are considered as well, like NTN and ISAC
		- Whether asymmetric numerology for UL/DL could be considered
		- Other proposals not presented in this meeting are not precluded
	+ Provide RAN1 with early RAN4 feedback on the RF feasibility and trade-offs of the proposed FFT/CBW/SCS combinations to help guide their decisions.

### Sub-topic 3-5: Spectrum utilization

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ 5G status and 6G objective:
		- 5G Baseline: 5G NR serves as the starting point, with a basic principle of carrier spectrum utilization above 90% compared to E-UTRA. However, SU for FR1 smaller channel bandwidths (e.g., ≤20 MHz) and FR2-1 are often less than or equal to 95%.
		- 6G Objective: There is a clear objective and consensus in RAN to achieve improved spectrum utilization in 6G compared to 5G.
	+ Observations from 5G:
		- SCS vs. SU: It is noted that for the same channel bandwidth, a higher SCS leads to lower SU, and a lower SCS leads to higher SU.
		- Guard band impact: Issues like non-monotonic guard bands (where a smaller CBW has a larger guard band than a larger CBW) can cause network access difficulties.
		- Interdependent factors: SU is not isolated, which is deeply intertwined with waveform, modulation, and RF requirements (SEM, ACLR, EVM), as well as PA models and implementation complexity.
	+ 6G enhancements and constraints:
		- Spectral confinement: Advanced spectral confinement techniques are identified as a key enabler for improving SU by allowing more RBs within the same channel bandwidth.
		- Requirement relaxation: A precedent was set in 5G where relaxations of ACLR/SEM/EVM requirements were traded for improved MPR, suggesting a similar trade-off could be explored for SU in 6G.
* Main proposals
	+ Foundational principles and framework:
		- Propose to adopt the 5G NR design philosophy of a unified spectral emission mask as a baseline for SU evaluation, but evolve it for 6G.
		- Propose that 6G SU shall not be smaller than 5G NR. Specifically, for the same channel bandwidth, lower SCS should have higher SU than higher SCS.
		- Propose that the guard band for a given SCS and channel bandwidth should not be larger than that of all larger channel bandwidths for the same SCS.
	+ Specific studies and evaluations:
		- Study SU enhancement techniques: Study the benefits and RF trade-offs of techniques to enhance SU, such as using larger NRB and advanced spectral confinement.
		- Evaluate SU systematically: Conduct a comprehensive evaluation of SU, considering the trade-offs between improved SU, RF performance (OOBE, EVM, ACLR), and UE/BS complexity under detailed parameter assumptions (PA model, I/Q imbalance, phase noise, etc.).
			* For existing channel bandwidths (e.g.,≤100 MHz), reusing 5G SU as starting point.
			* Study enhanced SU for the existing CBWs, and prioritize enhancing SU for smaller channel bandwidths where it is currently low (<95%).
			* For newly introduced larger channel bandwidths (e.g., 200MHz), a new SU evaluation is necessary.
		- Investigate requirement relaxation: Study the relaxation of ACLR, SEM, and EVM requirements as a method to improve SU.
* Recommended WF
	+ Agree on a set of common simulation assumptions for SU evaluation, including PA models, RF impairments (e.g., carrier leakage, I/Q imbalance, phase noise, etc.), and baseline RF requirements (e.g., SEM, ACLR, EVM).
		- 5G NR channel bandwidth, requirements can be considered as starting point for the SU evaluation with new assumptions for 6G
	+ Evaluate the RF performance impact (complying with the affected requirements) of advanced spectral confinement techniques (e.g., better filtering, windowing) to understand how many additional RBs can be safely enabled
		- Considering trade-offs between SU, RF performance, and UE/BS complexity
		- Channel bandwidth and SCS with smaller SU should be prioritized
		- SU for larger channel bandwidth shall be evaluated based on standard progress on CBW
		- The potential of relaxing ACLR/SEM/EVM can be considered together with the 6G study on UE RF. Study how much SU gain can be achieved with relaxed a requirement
		- Closely coordinate with RAN1 on different waveform candidates and SCS configurations.

### Sub-topic 3-6: Asymmetric channel bandwidths

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Asymmetric channel bandwidth for DL and UL is not a new concept. It was already specified in 5G NR, where UEs must explicitly signal their capability to support it.
* Main proposals
	+ All bands can apply symmetric/asymmetric CBW in downlink and uplink in 6G day one.
* Recommended WF
	+ RAN4 to check whether the proposal is viable for 6G, meanwhile, take the identified issues for asymmetric CBW in 5G into consideration to establish a framework for both FDD and TDD bands

# Topic #4: Channel arrangement

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

## Observations and Proposals/Options

### Sub-topic 4-1: Channel raster

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ 5G NR already introduced a more flexible 10 kHz "enhanced" channel raster to replace the 100 kHz raster from LTE. For higher frequencies, it also defined SCS-based rasters to support wider bandwidths, establishing a clear evolutionary trend.
	+ It is observed that 5 kHz serves as the Greatest Common Divisor (GCD) of key numerologies (10 kHz, 15 kHz) and is already used in the NR-ARFCN global frequency raster, making it a technically sound candidate for a unified approach.
	+ A critical consideration is ensuring seamless coexistence and MRSS, especially for spectrum refarmed from 5G NR and LTE, where legacy raster definitions must be accommodated.
* Main proposals
	+ The SCS-based raster as baseline: A dominant proposal is to adopt an SCS-based channel raster as the primary or baseline method for 6G, especially for new bands and frequencies above ~3 GHz.
	+ Unified and finer-granularity rasters: For lower frequencies (typically below 3 GHz), there is a push for rasters finer than 100 kHz to increase channel placement flexibility:
		- 10 kHz raster: Proposed as a baseline for refarmed bands below 2.4/3 GHz, continuing the 5G "enhanced raster" approach.
		- 5 kHz raster: Proposed as a unified "common channel raster" for all refarmed FR1 bands, considering it provides maximum flexibility and is a GCD of common SCS values.
	+ Migration and co-existence approaches:
		- Band-specific hybrid approach: Many proposals recommend a dual or hybrid strategy: using a finer raster (5/10 kHz) for refarmed low-band spectrum and an SCS-based raster for new and higher-frequency bands.
		- Raster shifting: Suggesting the use of a fixed frequency shift to align a new 6G SCS-based raster with existing 5G raster points, easing coexistence.
		- Study migration paths: Explicitly proposing to study the migration of existing NR bands from a 100 kHz raster to an SCS-based model.
* Recommended WF
	+ Study co-existence and MRSS scenarios with legacy NR bands
		- Note that NR bands could have 100kHz channel raster or SCS based channel raster
	+ Investigate the interaction between the channel raster and the synchronization raster (especially for SSB placement)
	+ Study the listed main proposals especially for the migration and co-existence approaches
		- Other options not presented in this meeting are not precluded
	+ Provide early feedback to RAN1 with RAN4's analysis on the RF coexistence performance and potential implementation complexity associated with the various proposed channel raster options (5 kHz, 10 kHz, SCS-based).

### Sub-topic 4-2: Sync raster

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Issues of 5G NR design:
		- Over-engineering: The 5G NR sync raster is widely observed as being "over-designed" and "high-density," with a vast number of raster points that are never used in real deployments. This superfluous density increases UE processing overhead and significantly extends initial cell search time and power consumption, especially in wideband scenarios.
		- Rigid periodicity: The default 20ms SSB periodicity in 5G is seen as a constraint that limits network operators' ability to dynamically optimize for energy efficiency.
	+ Key design drivers and dependencies:
		- The sync raster design is fundamentally dependent on several parameters defined by RAN1, including the SSB bandwidth, minimum channel bandwidth, and the SS/PBCH block (SSB) design itself.
		- A core observation is the inherent trade-off between sync raster density (which provides SSB placement flexibility for operators) and UE performance (impacting search time, complexity, and power consumption).
	+ Considerations for 6G:
		- It is noted that aligning the sync raster with a coarser grid, such as a "1RB reference channel raster" can avoid the need for complex frequency shifts (K\_ssb) and greatly simplify UE implementation.
		- The sync raster must be designed considering MRSS, with proposals suggesting non-overlapping or sufficiently separated raster points from 5G to avoid interference.
* Main proposals
	+ The "Sparser is Better" principle:
		- Coarser step sizes: The predominant proposal is to design a sparser, coarser-grained sync raster for 6G. This involves using larger step sizes and basing the design on larger assumed channel bandwidths to reduce the total number of raster points.
		- Minimize raster entries: A key goal is to explicitly minimize the number of sync raster entries defined per operating band.
	+ Enhanced flexibility and efficiency:
		- Adaptive SSB periodicity: Propose supporting longer and adaptive SSB periodicities (e.g., 40ms, 80ms, 160ms) to enable significant network energy saving, with the possibility of a dual raster (sparse and dense) for different deployment scenarios.
		- Decouple data and sync carriers: A forward-looking proposal suggests studying the feasibility of "pure data channels" that do not contain an SSB, allowing the sync raster to be optimized solely for initial access.
	+ Simplified and unified design:
		- Unified Framework: Propose a unified sync raster design that works across different bands, min CBW values, and SCS configurations to avoid the fragmentation seen in 5G.
		- Leverage coarser reference grids: Specifically propose using a "1 RB reference channel raster" to achieve RB-level alignment and eliminate K\_ssb, leading to a significant reduction in sync raster points.
		- Consistent SSB design: Advocate for a consistent SSB design across bands to facilitate harmonized deployment and avoid risk of deployment delays.
	+ Prudent timeline and collaboration:
		- Postpone for RAN1 input: Several proposals recommend postponing detailed RAN4 sync raster discussion until after RAN1 has made sufficient progress on the fundamental SSB and initial access design.
		- Early RAN4 involvement: It is also proposed by companies that RAN4 should be involved early in any study related to initial access performance to provide RF and implementation perspectives.
* Recommended WF
	+ Evaluation on sync raster from RAN4 perspective:
		- Investigate the interaction between the channel raster and the synchronization raster (especially for SSB placement)
		- Study the listed proposals regarding
			* Enhanced flexibility and efficiency
			* Simplified and unified design
			* Other aspects if identified are not precluded
	+ Collaboration and planning:
		- Proactively collaborate with RAN1 to ensure that the evolving SSB design considers the practical RF and implementation constraints related to the sync raster from the outset.
		- Develop a flexible evaluation framework in RAN4 that can quickly assess different sync raster proposals once key parameters (like final SSB bandwidth and min CBW) are stabilized by RAN1.

### Sub-topic 4-3: Channel spacing

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ There is a recognition that 6G is likely to move beyond the traditional concept of intra-band Carrier Aggregation towards new multi-carrier transmission schemes. However, the fundamental need to define carrier spacing and the concepts of contiguous and non-contiguous carriers remains essential.
	+ A key observation is that the 5G NR method for defining contiguous vs. non-contiguous aggregation, based on a fixed "nominal channel spacing," can be too rigid. It may fail to accommodate certain real-world, fragmented operator spectrum allocations, hindering flexible and efficient deployment.
* Main proposals
	+ Simplify the nominal channel spacing framework for 6G by not designing it to support simultaneous mixed numerologies (i.e., different SCS on adjacent carriers).
	+ Study in 6GR to develop a proper definition of channel spacing for intra-band CA to support flexible operator deployment scenarios.
* Recommended WF
	+ Further study in RAN4 with the observations and proposals regarding channel spacing
		- Other issues relevant to channel spacing if identified are not precluded

# Topic #5: Irregular channel bandwidth

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

## Observations and Proposals/Options

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ A primary driver for irregular CBW is that many operators hold irregular spectrum blocks (e.g., from refarmed GSM/CDMA bands) that do not align with standard 3GPP channel bandwidths.
	+ Supporting a vast number of irregular CBWs is infeasible from a UE implementation and test coverage perspective. Only a finite set is practical.
	+ Major challenges for current 5G solutions exist in aligning component carriers, channel rasters, and ensuring sufficient overlapping bandwidth for critical signals (SSB) if BS and UE support different CBWs, especially for small irregular bandwidths.
	+ It is considered more acceptable for the BS to support irregular CBWs for specific bands.
	+ It is noted that many RF requirements are either scalable with bandwidth or unrelated to it, which provides a foundation for a flexible framework.
* Main proposals
	+ Study and establish a scalable and efficient framework for supporting irregular bandwidths from 6G "Day 1," avoiding the proliferation of specified CBWs.
	+ Use 5G solutions and specific concepts from TR 38.844 (like overlapping UE CBW and larger CBW) as a starting point. Other options could also be considered, such as:
		- Option 1 (Define a limited set): Standardize a specific, limited set of irregular CBWs (e.g., up to 10 or 20MHz) just like regular bandwidths.
		- Option 2 (Scaling-based approach): Specify RF requirements for a baseline (min/max CBW) and define scaling factors for other bandwidths.
		- Option 3 (BWP-like approach): A more radical proposal to define RF requirements based on the actual configured/activated bandwidth (e.g., on a per-RB basis or BWP-like basis) rather than the total channel bandwidth.
	+ Investigate whether solutions like single-cell multi-carrier operation or Carrier Aggregation can help utilize irregular spectrum.
	+ Consider initially enabling irregular CBW only in the Downlink where RF requirements are easier to define.
	+ Carefully examine and limit the set of CBWs to balance UE design/test complexity with the flexibility for operators to fully utilize their spectrum.
	+ Further study the signaling design and channel raster rules to guarantee flexible CBW works properly.
	+ How to reduce test burden is also an important aspect to be studied
* Recommended WF
	+ With inputs from operators, to check whether limited set of irregular CBWs could be specified for 6G, like specific channel BW of 7MHz and 6MHz defined in 5G-A
	+ Using 5G concepts from TR 38.844 as starting point to study a more generic solution for 6G
		- The listed main proposals and identified issues should be taken into account for the following study of irregular/flexible/scalable channel bandwidths
		- Other options not presented in this meeting are not precluded

# Topic #6: Number of Tx and Rx

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

## Observations and Proposals/Options

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Performance vs. complexity trade-off: A key observation from 5G RAN4 discussions highlights that increasing the number of UE antennas is the critical trade-off between performance gains and practical implementation complexity, cost, and power consumption.
	+ 5G NR as a baseline: The current state of the art in 5G NR serves as a reference point. For FR1 handheld devices, the maximum practical capability is noted as 3Tx and 6Rx, while reduced-capability devices (RedCap) are standardized with 1T1R or 1T2R configurations. For FWA UE, the maximum practical capability is noted as 4Tx and 8Rx.
* Main proposals
	+ Device-type and frequency-dependent scaling: Proposals define baseline configurations by linking the number of Tx/Rx chains directly to the device type and the operating frequency band/frequency sub-range. The following are just some examples.
		- Massive IoT: A baseline of 1T1R is proposed.
		- Reduced capability UE / Wearable device / Scalable UE: 1T2R
		- Smartphone / Normal UE (Handheld):
			* Low Bands (< 3 GHz): 1T2R or 1T4R.
			* Mid/High Bands (3-7 GHz): 2T4R or 2T6R.
			* Around 7GHz: 2T4R or 2T6R or 4T8R.
		- FWA / Advanced UE: Higher configurations are proposed, with baselines of 2T8R or 4T8R or 8T8R in FR1 or ~7GHz, and even 8Tx/16Rx for new bands, leveraging their relaxed form factor.
	+ Architectural evolution and enhanced capabilities:
		- Higher maximum limits: Proposals suggest supporting up to 4Tx and 8Rx/16Rx for capable UEs, scaling beyond 5G's limits from the start.
		- Advanced MIMO and beamforming: There are proposals to support higher-order MIMO (e.g., 8x8 DL, 4x4 UL) and improved digital beamforming with finer granularity.
		- Enhanced architectures: Some proposals study feasibility of unique configurations like "6Rx only" for high frequency range to optimize for downlink-heavy traffic.
	+ Specification and requirement framework:
		- Scalable RF requirements:
			* Study scalable requirement versus #antennas based on antenna correlation, antenna coupling and beamforming impairments for UE multi-Tx/Rx and MIMO support
			* Study how to define scalable requirements for different numbers of Rx chains per band.
		- Unified power management: consider MPR specification based on cumulative power across all antenna connectors, independent of Tx chain count
* Recommended WF
	+ Study the number of Tx/Rx chains and device types as an integrated framework, given their tight coupling.
	+ Evaluate proposed configurations from both a performance and implementation complexity perspective.
	+ Consider the listed main proposals as a basis for discussion, while remaining open to new technical aspects.

# Topic #7: Device types

## Open issues summary

*Before Meeting, moderators shall summarize list of open issues, candidate options and possible WF (if applicable) based on companies’ contributions.*

The primary objective of this meeting is to identify a clear RAN4 scope to be investigated in parallel with RAN on the same topic.

The agreements already reached in RAN are provided below for reference.

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| --- |
| ***Device types*****RAN#109**In RP-252873, proposal 3 & 4 are endorsed for RAN only (no WG discussion)**Proposal 3:** To investigate further:* Motivations/justifications behind the proposed diverse device types, which should be a limited set
* Whether/how to have one or more device types for eMBB or 6G IoT
* Whether/how to have other device types for, e.g., XR/immersive experiences, FWA, VUE, wearables/RedCap, sensing, NTN-specific, AI agents, collaborative robots, etc.
* Whether/how to explicitly standardize device types
* Ensuring forward compatibility
* Minimizing/avoiding potential market fragmentation

Note: the terminology “device type” is subject to further discussion and possible refinement.  **Proposal 4**: In terms of diverse device types, study further:* Possible parameters/factors, e.g.:
	+ Number of Tx antennas/chains
	+ Number of Rx antennas/chains
	+ Power classes
	+ Maximum UE bandwidth (DL/UL)
	+ Peak data rate (DL/UL)
	+ Maximum MIMO layers (DL/UL)
	+ Duplex mode
	+ Max modulation order (DL/UL)
	+ CA/spectrum aggregation (DL/UL)
	+ UE processing capabilities
	+ Coverage
	+ Energy efficiency
	+ Mobility/speed
	+ Sensing
	+ AI

Note: some of the above parameters/factors may be related with form factorNote: aim to have a focused/limited set of parameters/factors for a device type* + The value(s) for the identified parameters for a device type
 |

## Observations and Proposals/Options

*Sub-topic description*

The main observations and proposals are based on the inputs for this meeting.

* Main observations
	+ Lessons from past generations: A key observation from LTE and NR is that while classifying UEs into high-level categories is helpful for performance benchmarking and feature definition, creating too many fragmented device types leads to "over-design" and market complexity.
	+ The need for a structured framework: There is a clear consensus that 6G requires a more structured approach. Device types should represent a common set of assumptions about UE hardware capabilities (e.g., CBW, number of antennas, TX power, MIMO layers) rather than being based solely on form factor or usage scenario.
	+ Balancing commonality and differentiation: A fundamental challenge is identified, i.e., how to define a common mandatory baseline functionality set for all 6G devices to ensure basic interoperability, while also allowing for scalable, device-type-specific capabilities to cater to diverse performance, cost, and power consumption targets.
* Main proposals
	+ Category of Device Types: There is common view to define a limited set of device types from 6G "Day One" to avoid market fragmentation. The most frequently proposed categories are (may not cover all diversified proposals):
		- Massive IoT/Type C: For sensors, low-end wearables; characterized by low complexity, 1T1R, 3-20 MHz CBW, and basic modulation.
		- Reduced-Capability/Wearable/Scalable UE/ Type B: For smartwatches, XR; with moderate capabilities (e.g., 1T2R, 100 MHz CBW).
		- Smartphone/Normal UE (including XR)/Type A: The mainstream handheld device; offering improved performance over 5G (e.g., 1T/4R, 2T4R, 200 MHz CBW, 1024QAM).
		- FWA/Advanced UE/Type A+: For Fixed Wireless Access, humanoid robot, etc.; with relaxed form-factor constraints and the highest capabilities (e.g., 4T8R/8T8R, 400 MHz CBW, 4096QAM).
	+ Scalable and forward-compatible framework:
		- Mandatory baseline functionality set: A proposal suggests a mandatory baseline functionality set, in which each functionality shall be well justified to be truly mandatory for all device types. And on top of the mandatory baseline functionality set, different device types could be further defined. Several proposals suggest to have mandatory set as per device type basis. Capability-based parameters: Proposals emphasize that device types should be defined by concrete RF/Baseband parameters, including capabilities such as:
			* Number of Tx/Rx antennas and MIMO layers
			* Min and max Channel Bandwidth
			* Supported modulation orders (DL/UL)
			* Power Class
			* Duplex Mode (FDD, TDD, HD-FDD)
			* RRM mobility
	+ Enhanced signaling and network optimization:
		- UE capability reporting: Introduce a modular and MAC-layer-assisted UE capability reporting framework to enable efficient, category-based network optimization without excessive per-UE signaling overhead.
		- Dynamic capability update: Study the possibility for UEs to update their capabilities (e.g., for foldable devices or different power modes), requiring cooperation between the network and the UE.
	+ RAN4's specific role:
		- Focus on RF-critical attributes: RAN4 should focus on study the RF/RRM/Demod characteristics that differentiate device types, ensuring requirements are achievable, testable and avoid unnecessary specification fragmentation.
* Recommended WF
	+ Study baseline RF capability profiles taken the listed main proposals into consideration. The following aspects could be further studied
		- Investigate detailed RF capability profiles for the most cited device types (e.g., IoT, Wearable, Smartphone, FWA or other possible categorized types). These should include concrete assumptions for number of antennas, max CBW, power class, and supported modulation per frequency range.
		- Study antenna configuration trade-offs of different antenna configurations (e.g., 1T1R vs. 1T2R vs. 2T4R vs. 2T6R vs. 4T8R vs. 8T8R) for the various device types.
		- Study whether unified RF/RRM/Demod requirements or requirements set could be applied to each device types, while exceptions are allowed for some specific devices in certain type. A framework is to be studied for requirements upon device types to address issues identified during the study.
		- Other aspects are not precluded
	+ Collaborate on the framework with other WGs:
		- Provide inputs to RAN with RAN4's analysis on the RF feasibility, testability, and performance impact of the proposed device type parameters and the scalable framework.

# Annex: Companies’ Proposals

#### **Proposal****s from Qualcomm R4-251302**

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| Section 2.1 – Enhancements to DFT-s-OFDM ULProposal:**2.1-1: RAN4 to collaborate closely with RAN1 to determine maximum specification-compliant UL power for various waveform proposals.**Observations:2.1-1: Frequency-domain mapping truncation enables Pi/2 BPSK waveforms to achieve spectral efficiencies similar to QPSK while allowing higher output power.2.1-2: Decoupling frequency-domain allocation size from DFT size enables arbitrary RB allocation sizes without increasing DFT complexity.2.1-3: Power, MPR, and A-MPR are already specified in RAN4 for multi-layer DFT-s-OFDM UL in 5G.2.1-4: Enabling multi-rank UL for DFT-s-OFDM will have minimal impact on RAN4 specifications.Section 2.2 – Advanced Spectral Confinement TechniquesObservation:2.2-1: Advanced spectral confinement techniques can improve spectrum efficiency by enabling additional RBs within the same channel bandwidth. RF trade-offs need further study.Proposal:**2.2-1: RAN4 to study benefits of larger NRB in the same channel bandwidth and investigate RF performance trade-offs of advanced spectral confinement techniques.**Section 2.3 – Channel Bandwidth and FFT Size for 6GProposal:**2.3-1: RAN4 to study increasing channel bandwidth up to 400 MHz within the new FR1 frequency range (up to 8.4 GHz).**Section 2.4 – UE Rx/Tx Chain CountProposals:**2.4-1: Study how to define scalable requirements for different numbers of Rx chains per band.****2.4-2: For 6G, RAN4 to consider MPR specification based on cumulative power across all antenna connectors, independent of Tx chain count.**Section 2.5 – Channel and Sync Rasters**Proposals:****2.5-1: Adopt SCS-based raster as the baseline in all current and future 6G bands.****2.5-2: Study migration of NR bands currently using 100 kHz raster to SCS-based raster.****2.5-3: Optimize sync raster design to improve initial acquisition time and reduce UE power consumption.** |

#### **Proposals from Charter R4-2513026**

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| Proposal 1: Study the feasibility of higher-order modulation schemes such as 1024 QAM in the UL direction in scenarios when good SNR conditions are available such as in FWA.Observation: 3GPP should study UE UL technology such as AI/ML, SiC and GaN. Specially for RAN4, start a study of UE techniques such as DPD and NUC to enable UL 1024-QAM and study of new chip-set and digital processing technologies to support the complexity of UL 1024 QAM. Proposal 2: Study of gNb UL techniques such as Advanced Channel Estimation (ACE), and optimal modulation and coding scheme. Also study how MIMO and Beamforming with improved FEC can handle the complexity of UL 1024 QAM |

#### **Proposals from Apple R4-2513035**

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| ***Proposal 1: It is proposed to discuss and agree on waveform evaluation methodology and assumption in preparation for the low PAPA waveform study.******Proposal 2: It is proposed to consider the following modulation as a starting point for 6G:**** ***UL: up to 256 QAM***
* ***DL: up to 1024QAM***

***Proposal 3: For 6G, maximum CBW of 200MHz can be considered, which both BS and UE should support.******Proposal 4: In case where 400MHz contiguous spectrum is available, the following two solutions can be considered:**** ***Alternative solution 1: 200 + 200 MHz CA***
* ***Alternative solution 2: 6G introduces BS-only 400MHz CBW, i.e., 400MHz is only specified for BS, but not for UE.***

***Proposal 5: It is proposed to consider 3MHz or 5MHz for minimum CBW.*** ***Proposal 6: In terms of CBW granularity, or how many CBWs need to be defined, the current granularity in 5G FR1 can be a starting point for up to 100MHz where the need for each channel bandwidth shall be further assessed based on operators’ deployment plan for 6G. For CBWs between 100MHz and 200MHz, it is recommended to look at operators’ spectrum holding first. Furthermore, the discussion on support of irregular CBW may also impact how many regular CBWs, i.e., in multiples of 5 or 10MHz, may need to be defined in the end.******Proposal 7: To support irregular CBW, it is proposed to*** * ***Set a limit on the size of irregular CBW to be supported, say 10 or 20MHz.***
* ***Use 5G solutions as a starting point***
* ***Study new solutions that may help reduce the number of CBWs to be specified in 6G.***

***Proposal 8: It is proposed to support 8K FFT in 6G.*** ***Proposal 9: It is proposed to have the SCS and CP length for 6G as shown in Table 1.*** ***Proposal 10: It is proposed to study the need of specifying channel raster in 6G. If a need is identified, we can consider specifying 5kHz raster points instead of 100kHz or SCS (15/30kHz) for FR1 to increase channel placement flexibility and to avoid too many sync. raster points.******Proposal 11: It is proposed to study synchronization raster with a goal to reduce UE cell search complexity and enable fast cell search.******Proposal 12: It is proposed to specify and support diverse device types in 6G from day one, at least with the following types:**** ***FWA***
* ***Smartphone***
* ***Wearable device***
* ***IoT***

***By considering the following parameters:**** ***Number of TX/RX***
* ***Min. and max. channel bandwidth***
* ***FFS: Power classes***
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#### **Proposals from Samsung R4-2513043**

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| ***Waveform and modulation*****Observation 1: In RAN1#122, the first agreement of 6GR was achieved to support OFDM-based waveforms such as CP-OFDM (downlink and uplink) and DFT-s-OFDM (uplink) waveform as the basis for 6GR.****Observation 2: For upper limits of modulation order, the high-order modulation is expected as similar level of 1K-QAM for DL and 256-QAM for UL with the conventional formats as agreed in RAN1 for the study.****Observation 3: Together with or without an AI-assisted receiver, study on the level of 1K-QAM for UL or 4K-QAM for DL can be considered in 6GR.****Proposal 1: Based on the initial agreements in RAN1, it would be important for RAN4 to carry out the performance assessments by coordinating closely with RAN1. The study outcome should also consider the impact of implementation feasibility, and performance benefits compared to legacy requirements.*****Numerology, FFT size and CBW*****Observation 4: Emerging 7–8 GHz bands can be treated within the FR1 framework, benefiting from similar propagation and deployment characteristics as the legacy sub-7 GHz spectrum according to the previous studies including a SI for IMT of RAN4.****Proposal 2: Among the three options, our recommendation for FR1 is to extend up to 8.4 GHz (option A or option B) at least, considering the channel propagation characteristics and previous studies of IMT SI.****Proposal 3: To simplify implementation and improve spectral efficiency, we propose a single-SCS per range principle as below.*** **FR1-FDD (≤ 8.4 GHz): 15 kHz**
* **FR1-TDD (≤ 8.4 GHz): 30 kHz**
* **8.4 – 15.35 GHz: 60 kHz**
* **15.35 – 24.25 GHz (if defined): 120 kHz**

**Observation 5: 8K FFT size is now being considered as a baseline configuration in RAN1 to enable effective processing of channels up to 200 MHz and beyond, allowing for greater spectral efficiency and increased capacity.****Proposal 4: Table X is proposed as a unified numerological framework that simplifies and reduces the complexity of network management and allows devices to operate efficiently across both NR and 6GR.****Table 1: Potential SCS, FFT size, and CBW per frequency range**

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| **FR** | **Range** | **SCS (kHz)** | **Required FFT size** | **Max CBW (MHz)** | **Min CBW (MHz)** |
| FR1 | 400 MHz – 6.425 GHz | 15 (FDD)30 (TDD) | 8192 | 100 (FDD) 200 (TDD) | 5 (FDD)10 (TDD) |
| 6.425 – 7.125 GHz | 30 | 8192, [16384] | 200, [400] | 20 |
| FR1-extended | 7.125 – 8.4 GHz | 30 | 8192, [16384] | 200, [400] | 20 |
| [new FR]  | 8.4 – 15.35 GHz | 60  | 8192 | 400 | 20 |
| [new FR] | 15.35 – 24.25 GHz | 120 (if defined) | 4096,8192 | 400,800 | 50 |
| FR2-1 | 24.25 – 52.6 GHz | 120 | 4096, 8192 | 400, 800 | 50 |

***Spectrum utilization and irregular CBW*****Proposal 5: 6G can adopt and evolve 5G NR design philosophy as much as possible, which is to retain the principle of a unified spectral emission mask, defined by a maximum RBs and minimum guardbands****Proposal 6: As a forward-looking evolution, 6GR should explore the concept of irregular channel bandwidths based on 5G framework, and asymmetric band or bandwidths for the extreme spectral efficiency.** ***Synchronization signal and raster*****Observation 6: The pursuit of SSB placement flexibility of 5G introduced superfluous raster points, increasing UE processing overhead and extending initial cell search duration in wideband scenarios.****Observation 7: Furthermore, the default 20ms SSB periodicity of 5G constrained network operators’ ability to optimize energy efficiency dynamically.****Proposal 7: It is recommended for RAN4 to have a fundamental principle for 6G sync raster design considering energy efficiency/saving as well as design complexity and flexibility as follows.*** **Limited step sizes (e.g., 120kHz for FR1, 480kHz for FR2) to reduce grid density while maintaining CBW coverage**
* **Adaptive SSB periodicities (e.g., 40ms for coverage areas, 80ms for high-capacity hotspots) to maximizes energy efficiency gains**

***#Rx and #Tx*****Observation 8: Increasing the number of UE antennas does not guarantee the performance improvement according to the previous discussion in RAN4.****Proposal 8: Consider the 1T/4R architecture from NR for FR1 at the UE, and study the feasibility of sNB/UE architectures such are 6Rx only for FR3.*****Device types*****Proposal 9: Introduce a modular and MAC-layer-assisted UE capability and assistance information reporting framework in 6GR, enabling category-based network optimization while minimizing per-UE management overhead.****Proposal 10: It would be important to classify device types according to concrete product groups expected in commercial deployments for 6GR as summarized below.*** **Device types**
	+ **Type I: e.g., IoT**
	+ **Type II: e.g., Wearable with limited form factor (e.g., smartwatch)**
	+ **Type III: e.g., Smartphone**
	+ **Type IV: e.g., FWA**
* **Add-on use cases: NTN, [FFS for others]**
* **Key parameters for each device types (NTN can be applicable in addition to device types)**

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| **Parameter list** | **Type IV****(FWA)** | **Type III (Smartphone)** | **Type II (Wearable)** | **Type I****(IoT)** | **NTN****(if applicable)** |
| **TX****antenna** | 1-4Tx (depending on FRs)(Note: 2TX can be baseline) | 1Tx baseline (for all FRs), up to 2Tx (optional) | 1Tx | 1Tx | 1Tx to 4Tx (depending on PC). |
| **RX****antenna** | 4, 6 or 8RX (optional) | Below 1 GHz: 2RX, up to 4RX (optional)Around 3.5 GHz: 4RX,Around 7 GHz: 4RX, up to 6 RX (optional)Around 24 GHz: 2RX, up to 4 RX (optional) | 1Rx | 1Rx and up to 2RX (optional) | Depending on device type |
| **DL MIMO****layer** | Up to 4, 6 or 8Layer | Up to 2 or 4layer (depending on FR) | 1 layer | 1 or 2 layers (optional) | 1 layer |
| **RF BW (max)** | 400 MHz | 200 or [400] MHz | 20 MHz | 20 MHz | Depending on device type |
| **Default****output power** | 26 dBm [or 29 dBm] | FDD 23 dBm,TDD 26 dBm | FDD 23 dBm,TDD 26 dBm | FDD 23 dBm, TDD 26 dBm | [Depending on outcome of 5G work] |
| **DL max modulation order** | 1024QAM or [4096QAM] | 1024QAM or [4096QAM] | 64 QAM | 256 QAM | Depending on device type |
| **UL max modulation order** | 256QAM or[1024QAM] | 256QAM or [1024QAM] | 64 QAM | 64 QAM | Depending on device type |

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#### **Proposals from InterDigital R4-2513061**

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| ***Waveform:******Proposal 1: Potential study of new 6G NR waveforms involving RAN4 shall include at least the following KPIs: better PAPR, CM, and Emission Mask, OBE, full compatibility with the current 5G CA and DC band combinations.******Modulation******Proposal 2: RAN4 shall be early involved in any potential study of non-uniform constellations for 6GR.******Frame Structure and Numerology******Proposal 3: 6GR symbol durations, slot definition, subframe and frame are the same as NR.******Proposal 4: 6GR supports at least the SCS values that are supported in NR.******Proposal 5: Support configuration of single SCS per band for a UE.******Proposal 6: 6GR supports symbol level scheduling.******Sync Raster and SSB structure******Proposal 7****:* ***Study sync raster enhancement to reduce cell search complexity and search time.******Proposal 8****:* ***6G radio shall support a common SSB in frequency domain for multiple device types.******Proposal 9****:* ***RAN4 shall be involved in any potential******study of the initial access performance that includes e.g. a combination of sparse SSB transmission with 160-ms or larger periodicity and adaptive on-demand SSB transmissions.*** ***Channel Bandwidth******Proposal 10: The minimum bandwidth for initial access is 3 MHz.*** ***Proposal 11: The maximum channel bandwidth for 6GR is 200 MHz in FR1 and FR3.******Proposal 12: 6GR supports robust, fast, bandwidth adaptation scheme focusing on power efficiency.*** |

#### **Proposals from MediaTek R4-2513075**

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| *<Device type>*Proposal 1: If needed to evaluate 6G system performance and coexistence, RAN4 can consider HHUE (e.g. smartphone) and CPE (e.g. FWA) capabilities and 6G BS antenna configurations.Proposal 2: Introduce a forward compatible device type framework to accommodate the market need for potential new device types in the future.Proposal 3: Consider the inputs in Table 1 and Table 2 for the 6GR coexistence evaluation and system performance analysis with different antenna elements in 6G BS and default power class of 6G UE.*<CBW, FFT, numerology, #Rx, #Tx>***Proposal 4: In 6G, a maximum 8192 FFT size for single carrier is supported.****Proposal 5: Tables for band-specific SCS and CBW can be defined in 6GR spec. However, the detail number of RB and supported CBW are FFS.**Observation 1: In NR, multiple SCS were introduced in one band, and different SCS is allowed for SSB and data. However, these are not used in typical deployments.**Proposal 6: In 6G, consider a single numerology for both SSB and data per band.****Proposal 7: Suggested maximum CBW and SCS for 6G in different frequency ranges are shown in Table 3.****Proposal 8: Follow the NR approach: 5 MHz nominal, with 3 MHz permitted in certain bands.****Proposal 9: Wait for RAN1 conclusions before discussing the requirement impact of potential new modulation in 6G.***<Spectrum utilization>*Observation 2: In NR, the basic rule is that carrier spectrum utilization is assumed to be higher than 90%.Proposal 10: Study the feasibility to enhance spectrum utilization in 6G.*<Synchronization signal and raster>*Observation 3: NR sync raster is over designed and only about 10% of sync raster entries are utilized in real-field environment.**Proposal 11: Study how to overcome the high-density design of sync raster in 6G to achieve more efficient delay and power consumption for initial access.**Observation 4: Increasing SSB periodicity to be larger than 20ms would potentially increase the delay associated with sync raster in 6G, e.g.**Proposal 12: 6G sync raster design needs to ensure its initial access delay is not worse than 5G.**Observation 5: A minimum CBW of 5MHz for sub 3GHz frequency range is assumed as a baseline for sync raster design in NR.**Proposal 13: Study a coarse sync raster(s) based on a larger channel bandwidth(s) as a baseline assumption for 6G.**Observation 6: In NR, a fine step size <1> is assumed as a baseline for GSCN sync raster entries.**Proposal 14: Study coarse sync raster(s) based on larger step size(s) as baseline assumption for 6G.**Observation 7: SSB bandwidth is one of the main contributors for having a highly dense sync raster in NR.**Proposal 15: Study the feasibility of associating sync rater design in 6G with PSS bandwidth instead of SSB bandwidth.****Proposal 16: When discussing the minimum channel bandwidth and sync raster, RAN4 needs to consider both TN and NTN.***<Duplexing>*Proposal 17: Target both FD-FDD and HD-FDD operation at UE side for paired bands.Observation 8: For unpaired spectrum, TDD will be required. However, TDD flexible symbols caused lots of complexity without any clear need or benefit in practical deployment.Proposal 18: Do not consider dynamic TDD or flexible symbols for 6GR.Observation 9: SBFD improves the system performance in unpaired spectrum in terms of latency and UL coverage/throughput, and performance can be maximised in new bands with SBFD aware equipment.**Proposal 19: Study TDD enhanced with SBFD as a fundamental 6G design component for unpaired bands.**Observation 10: UE-SBFD further improves the capacity for latency-bound services and coverage by eliminating the trade-off between DL and UL transmissions.**Proposal 20: Study UE-side SBFD on top of network-side SBFD for 6G.****Proposal 21: RAN4 to identify whether any issue has potential cross-WG impact and arrange the required action, if any.** |

#### **Proposals from China Telecom R4-2513078**

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| **Proposal 1:** Consider up to 400MHz channel bandwidth for 6G FR1 spectrum.**Proposal 2:** Consider both 30kHz and 60kHz sub-carrier spacing for 6G FR1 spectrum. |

#### **Proposals from Skyworks R4-2513114**

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| Proposal on CBW, FFT and numerology for 6G:* + Support of both 4K FTT and 8K FTT with only one SCS per band and band-groups.
	+ Support of different SCS in UL and DL (for NTN? others?)
	+ Band groups could be determined either in terms of:
		- Frequency sub-ranges:
* 15kHz SCS below 2.4GHz => 50MHz@4K FTT, 100MHz@8K FFT: The maximum in that range is 100MHz in band n40)
* 30kHz in 2.4GHz to 5GHz => 100MHz@4K FTT, 200MHz@8K FFT: would support n41 with one CBW in the US and China and most of band n77/78/79 operator’s spectrum
* 60kHz in 5GHz to 10GHz => 200MHz@4K FTT, 400MHz@8K FFT: similar to Wi-Fi® BW support, enable 400MHz in n104 and new spectrum.
* 60 and 120kHz in 10GHz to 52GHz depending on NTN/TN => up to 400MHz@4K FTT, 800MHz@8K FFT: less complex intra-band CA in FR2-1. Some FR2-1 band may even
	+ - Band types:
* 15k SCS and 4K FFT => 50MHz CBW => FDD bands below 1.6GHz
* 15k SCS and 8K FFT => 100MHz CBW => all FDD bands <3GHz
* 30k SCS and 4K FFT => 100MHz CBW => all TDD bands <2.4GHz
* 30k SCS and 8K FFT => 200MHz CBW => all TDD bands <5GHz, FR2-N UL?
* 60k SCS and 8K FFT => 400MHz CBW => all TDD bands <10GHz, FR2-N bands, FR2-1 UL?
* 120k SCS and 8K FFT => 800MHz CBW => all FR2-1 bands
* To address flexible CBW applications and bandwidth parts, transmission BW could use two granularities:
* At RB level: 1RB to ~556RB (with 4K FFT maximum NRB is 276) for 0.4 to 52GHz bands
* At SC level 1/2/4/6/8/10/12 sub-carriers for <2.5GHz?
* NRB per BW could be all equation-based with a guaranteed emissions by design thanks to increased guard-bands for intermediary BWs.
* Thus, only a limited set of CBW could be verified and at the same time, it could cover every MHz at 15kHz SCS, every 5MHz at 30kHz SCS, every 10MHz at 60kHz SCS, etc?

Proposal on waveform: For MPR and SU evaluations* Revisit SEM and ACLR evaluation criteria for the different frequency ranges
* Apply different windowing/BB filtering tradeoffs versus MCS to maximize SU.

Proposal on modulation:* Baseline (smartphone) support for UL 256 QAM and DL 1024 QAM
* Optional support for UL 1024 QAM and DL 4096 QAM assuming better EVM performance at the BS compared to the UE.

Proposal on UE multi-Tx/Rx and MIMO support:* Support from 1 to 4Tx depending on UE types and frequency ranges. Scalability to 8Tx
* Support from 1 to 8Rx depending on UE types and frequency ranges. Scalability to 16Rx
	+ For example: For smartphone sizes, 1Tx/2Rx <1.6GHz, 2Tx/4Rx >1.6GHz
* Support from 2x1 to 8x8 antenna arrays with one or two arrays per UE depending on UE types and frequency ranges
* Look into equation based scalable requirement vs #antennas based on antenna correlation, antenna coupling and beamforming impairments
* Support of UL MIMO with DFT-s-OFDM waveforms
* Support of up to 8x8 DL MIMO and 4x4 UL MIMO
* Support improved beamforming (smaller granularity digital beamforming) for nRx/nTx cases.

Proposal on UE types: RAN4 develops a limited set of UE types based on* UE size (largest of the three dimensions, 1cm to a few 10cm)
* Number of antennas or array size, internal versus external
* Mobility and speed
* Number of band and band combination support
* Possibly considering frequency ranges as a scaling factor.
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#### **Proposals from Ericsson R4-251302**

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| *Numerology***Proposal 2.1: in collaboration with RAN1, study channel arrangements and minimum requirements based on a reduced number of sub-carrier configurations as compared to NR, aiming at a single numerology for data and synchronisation per operating band except for PRACH and possibly SSB while ‘ensuring appropriate set of functionalities’ (objectives of the 6G study) and considering MRSS.** **Observation 2.1: a single sub-carrier spacing configuration per operating band or frequency range would simplify specification of the channel arrangement, channel/carrier spacing, spectrum utilization and guard bands for 6GR and specification of MRSS.***Spectrum utilization***Proposal 3.1: the study of the spectrum utilization and the internal guard bands for channel bandwidths should also consider the possibility of locating a smaller bandwidth (carrier or BWP) within a wider channel bandwidth without restrictions due to internal guard bands.***Channel bandwidth***Proposal 3.2: specification of bandwidths for new spectrum aggregation or multi-carrier arrangements and transmissions from e.g. CCs or bandwidth parts within these should be such that unwanted emissions can be specified in accordance with applicable ITU-R recommendations, e.g. the ITU-R Rec. SM.1539 and the ITU-R Rec. SM.1541.**This effectively means that channel bandwidths with appropriate guard bands must be specified for CCs or bandwidth parts within the aggregated bandwidth. **Observation 3.1: for NR, UE-specific channel bandwidths containing the active BWP within a wider BS bandwidth were specified to ensure that unwanted emissions limits outside the wider carrier are always met.****Proposal 3.3: for the study of channel arrangements and bandwidths in collaboration with RAN1, RAN4 considers bandwidths ranging from 3 MHz for low-complexity devices up to 200 MHz already from the start of the 6G study, support of 400 MHz subject to feasibility.***Carrier spacing, contiguous and non-contiguous blocks of carriers*For 6GR, intra-band carrier aggregation is likely to be replaced by new concepts such as multi-carrier transmissions. Definitions of carrier spacing, contiguous and non-contiguous blocks are needed, nevertheless.**Observation 3,2: for new concepts/configurations of carrier aggregation within a band, or across overlapping bands if applicable, e.g. for multi-carrier transmissions, ‘nominal carrier spacing’ must still be specified for a definition of contiguous aggregation as needed for UE capability indication. Similarly for non-contiguous carriers e.g. in fragmented spectrum.***Synchronisation raster***Proposal 5.1: in collaboration with RAN1, study a synchronisation raster that allows an increased SSB periodicity for energy efficiency yet without NW and UE performance degradation as compared to that with a 20 ms periodicity. A dual synchronisation raster, one with a sparse and another with a dense SSB granularity, can be considered if required for energy efficiency and energy saving.**Support of the 3 MHz channel bandwidth should also be considered to this end.*Channel raster* **Proposal 5.2: given a synchronisation raster, consider a channel raster that allows 6GR compatibility with adjacent legacy channels on the 100 kHz raster and with due account of MRSS.** It is worth observing that**Observation 5.1: the existing NR synchronisation raster does not allow location of an NR carrier at every possible 10 kHz raster entry of the enhanced channel raster.***Spectrum sharing***Proposal 5.3: for spectrum sharing (MRSS), the channel raster for 6GR is designed such that a 6GR channel can be subcarrier aligned with an NR channel.**This does not necessarily mean that the 6GR raster must be aligned with the 100 kHz raster.*Device types***Proposal 6.1: relating to device types, study performance aspects for low-complexity devices e.g. Massive IoT and devices like XR/TCC and FWA from the start.****Proposal 6.2: in collaboration with RAN1, 6GR RAN4 studies requirements for device types characterised by a possibility to signal associated capabilities are specified similarly to e.g. eRedCap or aerials UEs for NR.**The “form factor” should not be used unless a device type:**Proposal 6.3: RAN4 minimum requirements do not consider “form factors” without associated UE capabilities (then cannot be distinguished by the NW).**  |

#### **Proposals from Sony R4-2513122**

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| Observation 1: Each device type may represent a set of common assumptions about UE hardware implementation and can be specified as a set of UE parameters/capabilities/features e.g., UE CBW, number of antennae, TX power, etc., with different values Proposal 1: Devices that share similar hardware capabilities or performance requirements shall be categorized into the same device types. Proposal 2: Considering 1) Massive IoT device, 2) Broadband device with limited formfactor e.g., smartphone, 3) Ultra Broadband devices (e.g., FWA/CPE, XR) as starting point to define, further discuss if more device types need to be defined in 6GR. **Table I. 6GR device type and associated device capability**

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|  | **Massive IoT device, e.g., tracker, wearable devices, meters**  | **Broadband device with formfactor limitations, e.g., smartphone, glass type XR devices** | **Ultra broadband device e.g., FWA/CPE, Vehicle, HMD type XR devices.** |
| **Design considerations** | * Aim for device capability above 4G IoT and below 5G NR,
* with reduced device complexity than legacy devices (e.g., 5G (e)Redcap)
 | * Improved data rate but limited complexity additional to legacy devices (e.g., 5G eMMB)
* consider the formfactor limitation when determining the device parameters/capabilities
 | * focus on fulfilling the extraordinary performance bounds
* no major constraints due to device formfactor but with realistic implementation assumption
 |
| **Frequency range** | Focus on frequency bands < 3 or 4 GHz | FR1, FR2-1, “FR3” | FR1, FR2-1, “FR3” |
| **Minimum UE CBW** | 3MHz | Supporting 3MHz in FR1 | Supporting 3MHz in FR1 |
| **Maximum UE CBW (single CC)**  | UL: 3MHz/ DL: TBD | * 100 MHz in FR1 (same as 5G NR)
* 200 MHz in FR3
* 400 MHz in FR2-1(same as 5G NR)
 | * 200 MHz in FR1
* 400 MHz in FR3
* 400 MHz in FR2-1
 |
| **Duplex mode** | Focus on HD-FDD, FD-FDD/TDD can be supported | FDD/TDD | FDD/TDD |
| **Number of antennas** | 1T/1R | FR1&FR2-1 antenna assumption to be the same as in 5G NR,2T/4R in FR3. | 2T/8R in FR1 and FR3FR2-1 antenna assumption to be the same as in 5G NR. |
| **Default power class** | 23 dBm  | 23 dBm in FR126 dBm in FR3Considering enhancement on PC3 in FR2-1 | 26 dBm in FR131 dBm in FR3PC4 in FR2-1 |
| **Mobility** | Idle mode mobility as baseline | Connected mode mobility | Connected mode mobility |
| **Maximum Modulation order**  | 64QAM UL/64QAM DL | 256 QAM UL/1024 QAM DL in all frequency ranges | 512 QAM UL/1024 QAM DL in all frequency ranges |

Proposal 3: For all device types in 6GR, they should be able to support a minimum UE CBW of 3MHz in FR1. Proposal 4: For massive IoT devices, consider 3 MHz as the maximum UE CBW in UL. Further discuss the DL CBW, considering device complexity and its potential impact on other device types. Proposal 5: Different UL and DL UE CBW can also be considered in the 6GR design.Proposal 6: It is proposed that the maximum UE CBW with a single CC for broadband devices be 100 MHz in FR1, 200 MHz in FR3, and 400 MHz in FR2-1. For ultra-broadband devices, it can be 200 MHz in FR1, 400 MHz in FR3, while keeping 400 MHz in FR2-1.Proposal 7: Adopting the same waveform as 5G NR for 6GR design as the basis. Proposal 8: Further study whether DFT-s-OFDM can be supported in DL as well to improve the network coverage. Proposal 9: Further study whether a new waveform would be needed for sensing in 6GR. Proposal 10: It is proposed that 6G massive IoT can support up to 64 QAM. For broadband and ultra broadband devices, 256 QAM UL/1024 QAM DL and 512 QAM UL/1024 QAM can be considered in 6GR, respectively. Proposal 11: It is proposed to assume a 2k or 4k FFT for massive IoT devices, while an 8k or even larger FFT size is considered for higher-capability device types, pending the feasibility study. Proposal 12: It is proposed that 6GR adopt single numerology per frequency band. Proposal 13: It is proposed that 6GR should adopt 15 kHz SCS for frequency bands below 3 GHz and 30 kHz for frequency bands above 3 GHz in FR1, and further study the proper numerology for other frequency ranges. Proposal 14: For massive IoT devices, it is proposed to adopt 1T/1R as a baseline. Proposal 15: For broadband devices with form factor limitations, like smartphones, it is proposed to retain the same number of antennas as in 5G NR as the starting point for FR1. For FR3, it is proposed to adopt 2T/4R as the starting point. In FR2-1, a device with two antenna panels, each with 4\*1 antenna elements, can be used as a baseline to define the spherical coverage without compromising the minimum requirements of single-panel implementations.Proposal 16: For ultra broadband devices, it is proposed to adopt 2T/8R in FR1 and FR3, while FR2-1, three antenna panels with at least 4\*1 antenna elements can be used as a baseline assumption to define the minimum requirements of the device type. Proposal 17: It is proposed 6G consider the 10 kHz channel raster from the beginning to ensure the spectrum usage of 6G can be more efficient. Meanwhile, further study if different channel raster between 5G NR/LTE and 6GR would cause any issue in terms of MRSS and/or in-band coexistenceProposal 18: It is proposed that RAN4 should study how to ensure the coexistence between 6GR and 4G IoTs. |

#### **Proposals from CMCC R4-2513132**

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| 1. RAN4 is suggested to be involved for the justification of PAPR reduction design study with following aspects:
* PAPR reduction gain (e.g., ACLR, MPR).
* Impact on signal quality (e.g., degradation of EVM).
* Impacts on implementation (e.g., RF implementation complexity for Tx and Rx unit).
1. RAN4 is suggested to be involved early to study the EVM like metric for feasibility validation of new constellation shaping modulation schemes.
2. RAN4 further discuss the possibility of band basis minimum CBW rather than frequency range basis. The basic design principle is to define larger minimum CBW for most legacy operation bands and only consider smaller minimum CBW for the bands that operators spectrum is fragment with smaller spectrum bandwidth.
3. RAN4 to further discuss the possibility of different minimum CBW for different device on the same operating bands.
4. If 30KHz SCS is used, a 400MHz CBW can be achieved for around 7GHz by following approaches:
	1. -BS requirement: Support with a 16K FFT (FFT size = 16384).
	2. -UE requirement: the following options can be considered for further studies
		1. Option 1 (1x16K\_FFTx1CC): UE operates one 16K FFT (FFT size = 16384) in baseband to support 400MHz in one carrier
		2. Option 2 (2x8K\_FFTx1CC): UE operates two 8K FFT (FFT size = 8192) in baseband to support 400MHz in one carrier
		3. Option 3 (1x8K\_FFTx2CC): UE operates 8K FFT (FFT size = 8192) in baseband for each carrier to support 400MHz in two carriers, i.e., 2CC carrier aggregation.
5. For new spectrum around 7GHz, consider 30kHz SCS utilizing the existing NCP configuration from 5G-NR as baseline and study the support of 60 kHz SCS.
6. RAN4 can use the assumption of unified SCS for all channel/signals for sync raster discussion and further update if RAN1 support additional SCS for SSB.
7. RAN4 can discuss spectrum utilization, guard band, sync raster requirements based on current RAN1 numerology discussion and further update as band basis and from operators request if additional numerology is proposed.
8. RAN4 further study the possibility of defining sparser sync raster based on larger CBW which align with operators wider spectrum profile with the benefits of shorter search time and lower power consumption.
9. In 6G, maximum transmission bandwidth configuration should be specified with following principle that less CBW, less minimum guard band.
10. RAN4 consider irregular CBW in the first version with following options:
	1. Option 1: in the first version define RF requirements for all CBW that has defined for NR or proposed by operators and consider other CBW in future release
	2. Option 2: based on the two promising method as concluded from NR study phase
	3. Option 3: specify the minimum RF requirements for min and max CBW as baseline and add scaling factor on top of the baseline for other CBWs.
		1. exception is allowed for certain RF requirements when it’s hard to simplify requirements by scaling factor for different CBW.
	4. Option 4: consider the possibility of defining all/part of RF requirements based on actual configured/activated bandwidth i.e. BWP-like basis rather than CBW basis.
		1. One example, RAN4 define RF requirements per RB basis rather than CBW basis. There is translation from baseline RB configuration to other configurations.
11. RAN4 is suggested to start the PA modelings analysis in study phase based on actual commercial testing data, following models can be further optimized based on commercial testing data
	1. AM-PM
	2. Polynomial
	3. Others are not precluded

 Proposal 13: RAN4 is suggested to be evolved for UE types discussion based on following options.* Option 1: Different UE types is coupled with different UE capability sets
	+ Option 1a: Define minimum capability sets. Different UE types is coupled with different UE capability sets on top of the minimum capability sets
* Option 3: LTE category like UE types, different types are classified based on different throughput
* Option 4: combine LTE category like UE types and FR2 power class related method. I.e. different UE types are classified based on the combination of throughput and RF front end categories.
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#### **Proposals from Nokia R4-2513144**

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| Proposal 1: Support CP-OFDM waveform for downlinkProposal 2: Support CP-OFDM and DFT-s-OFDM for uplinkProposal 3: Provide RAN1 with a PA modelling approach to be used in further waveform related studies in RAN1Proposal 4: Support QPSK-to-1024QAM modulation for downlinkProposal 5: Support QPSK-to-256QAM with CP-OFDM and pi/2 BPSK-to-256QAM with DFT-s-OFDM for uplinkProposal 6: 8k FFT is a baseline for 6GR.**Observation 1:** 16k FFT needed to support 400 MHz CBW with 30 kHz for the appropriate bands.Proposal 7: Consider SCS values shown in Table 2.3-1 as bold for RAN4 evaluations for Sub-6GHz, Around 7GHz and FR2-1.**Observation 2:** Further studies in RAN1 for the frequency range around 15 GHz (**8.4 - 24.25 GHz)** will be needed on the applicable SCS including a potential further split of this frequency range to align the operation with the Around 7GHz band for the lower part and FR 2-1 for the upper part of this frequency range.Proposal 8: For Sub 6GHz (410 MHz-6.425 GHz), support up to 200 MHz Channel bandwidth for TDD and up to 100 MHz Channel bandwidth for FDD, respectively.Proposal 9: For Around 7 & 15 GHz (6.425 to 24.25 GHz), support up to 400 MHz Channel bandwidth.Proposal 10: For FR2-1 (24.25 - 52.6 GHz), support up to 800 MHz Channel bandwidth.Proposal 11: Consider values shown in Table 2.4.2-1 as minimum CBW for different 6GR scenariosProposal 12: Consider four receivers as baseline for 6GR, at least for all the bands re-farmed from 5G.Proposal 13: Consider eight receivers for new 6GR bands for eMBB UE. For FWA devices, consider 16 receivers as baseline for new 6GR bands.Proposal 14: Consider UE devices supporting TX chains up to 4Proposal 15: 6GR to further reduce the time-domain footprint of always-on signals and channel related to initial access compared to 5G NR, aiming at increased energy savings.Proposal 16: The 6G channel raster shall be compatible with NR channel raster for the NR refarming bands. Specifically, the 10 kHz enhanced channel raster shall be the baseline for the bands below 2.4 GHz and SCS based raster shall be the baseline for the bands above them.Proposal 17: The sync raster design is further discussed according to the progress of SS/PBCH design and the minimum channel bandwidth requirement. For bands requiring ~3 MHz CBW, specific raster design may still be needed for 6GR as in NR.Proposal 18: The nominal channel spacing for 6G shall be simplified without considering simultaneous mixed numerologies.Proposal 19: NR spectrum utilization can be considered as the starting point for 6G for the majority of existing NR channel bandwidths.Proposal 20: The minimum guard band for a given SCS and channel bandwidth shall never be larger than the minimum guard band of all the larger channel bandwidths for the same SCS.Proposal 21: RAN4 to discuss how to make channel bandwidth definition more flexible and future proof in 6GR compared to NR**Observation 3:** Scalable design for device types in 6GR requires joint efforts among RAN1, RAN4 and RAN2.**Observation 4:** There can be different factors considered for classifying devices, which include fundamental PHY and RF characteristics e.g.: CBW, RF chains, number of antennas, minimum MIMO layers, power consumption, UE processing time, baseband requirements, RF/RRM/DMD requirements, characteristics such as latency, data rate, and energy efficiency.Proposal 22: RAN4 to study the necessary RF characteristics and attributes for different devices i.e. minimum spectrum allocation, smallest maximum supported RF and Baseband bandwidth, number of RF chains, antennas, HD vs. FD applicability, and power class.Proposal 23: RAN4 to study the necessary RF/RRM characteristics to better understand the needs for 6G smartphones (eMBB), Fixed Wireless Access (FWA) devices and minimum capability devices like massive IoT devices. |

#### **Proposals from Spreadtrum R4-2513147**

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| ***Proposal 1: DFT-s-OFDM waveform can be supported for 6GR for downlink (e.g., massive IoT usage scenarios).*** ***From RAN4 UE perspective, for this waveform, we can study the RFSFENS, demodulation performance and other requirements.******Proposal 2: For 6GR Day1, the highest modulation order can be 256QAM for UL, the highest modulation order can be 1024QAM for DL.******Proposal 3: For 6GR Day1, the channel bandwidth as proposed that:**** ***200MHz as the maximum channel bandwidth for FR3 and U6G;***
* ***For sub-1GHz to sub-6GHz, we can reuse the definition of NR. Whether sub-6GHz can be extended to 200MHz can be further studied.***

***Proposal 4: For FDD, SCS can be 15 kHz and the maximum FFT can be 4096; for TDD, SCS can be 30 kHz and the maximum FFT can be 8192. For FR2-1, we can use 120 kHz SCS and the maximum FFT can be 4096.******Proposal 5: Reuse the NR for Tx/Rx MIMO as the baseline for 6GR.**** ***2T4R can be handheld UE. 4Tx/8Rx can be FWA UE.***
* ***1Tx/2Rx can be for XR and (e)Redcap UE.***
* ***1Tx/1Rx can be for IoT devices.***

***Proposal 6: More sparse sync raster design can be considered in 6GR. Whether the principle in NR for sync raster should be followed in 6GR needs to be discussed.******Proposal 7: For the re-farming bands, 6GR channel raster can be 10 kHz when these bands in NR can support 10 kHz. For other bands, channel raster can be SCS in 6GR.******Proposal 8: For supporting improved spectrum utilization and operations over one or more carriers/bands, these mechanisms can be considered.**** ***CA mechanism.***
* ***MCSC (Multi-Carrier Single Cell) mechanism.***

***Proposal 9: For MCSC, from RAN4 perspective, UE architecture, interference and other requirements need to be considered.******Proposal 10: To support flexible utilization of spectrum resources for DL and UL over different carriers/bands, these aspects need to consider.**** ***Whether to redefine the definition of bands***
* ***Whether the UE architecture is changed (e.g., filter)***
* ***Interference between DL and UL spectrum resources***

***Proposal 11: A solution to address the irregular channel bandwidth with high efficiency (e.g., flexible BW) in 6G can be studied.******Proposal 12: we proposed the design principle for device types as follows.**** + - ***A limited set of device types to avoid market fragmentation in 6G day1***
		- ***Device type should be categorized based on main communication usage scenarios (e.g eMBB, Massive IoT) together with some device hardware limitations (e.g. form factor)***
		- ***Scalable and forward-compatible design***
			1. ***- A common basic mandatory function set is defined for all device types;***
			2. ***- on top of it, a different additional mandatory capability set is defined for each device type;***
			3. ***- Further, each device type may additionally indicate optional capability/feature sets for different new usage scenarios or new services.***

***Proposal 13: The Table 2 could be considered as the starting point to achieve scalable and forward-compatible design.*****Table 2: 6GR UE/Device type example**

|  |  |  |  |
| --- | --- | --- | --- |
| **6G communication usage scenarios** | **Example device type** | **Scalable and forward-compatible design** **to avoid market fragmentation** | **Example devices/use cases** |
| A common basic mandatory function set for all device types | A different additional mandatory capability set for each device type | Optional capability/feature sets for different new usage scenarios or new services. |  |
| eMBB | TypeA | * Waveform
* Frame structure
* Channel coding
* Initial access design
* DL and UL control channel design
* Scheduling/HARQ operation
* BS/UE energy saving features

etc. | * 200M
* 2T/4R
* Modulation: 256 QAM DL/UL
* Power class: 3
 | Optional set A1* #MIMO layers
* Processing time
* Spectrum aggregation capabilities

Power clas | Set A2…4T/8R | … | Smart phone,CPE/FW,VUE,VSAT,Robots… |
| Type B | * 100M/200M
* 1T2R
* Modulation: 256 QAM DL/UL
* Power class: 3
 | Optional set B1* #MIMO layers
* Processing time
* Spectrum aggregation capabilities
* Power class

Access control, etc. | Set B2… | … | 2RX XR,High-end watch |
| Massive IoT | Type C | * 20M
* 1T1R
* Modulation:64 QAM DL/UL

Power class: 3 or 5 | Optional set C1* Processing time
* Power class
* Access control

Scaling factor, etc. | Set C2… | … | Wearables,Industrial sensors,Low-end watch,Video surveillance… |

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#### **Proposals from CATT R4-2513240**

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| Proposal 1: RAN4 to consider “one belt – one numerology” instead of “one band – one numerology” to avoid support for multiple SCS within a certain number of frequency blocks.Proposal 2: RAN4 to study and consider a new sync raster design in 6G to minimize the number of sync raster entries defined for each operating band.Proposal 3: RAN4 to study and consider a new concept of band in 6G to enable UL/DL decoupling operation.Proposal 4: RAN4 to consider a higher spectrum utilization in 6G but not to mandate a specific waveform in 6G standards which means waveform realization is considered an implementation issue.Proposal 5: RAN4 to study how to enable efficient and scalable support of irregular bandwidths, avoiding specification proliferation while maximizing spectrum utilization in diverse regional allocations.Proposal 6: RAN4 to study and consider the definitions of various device types, which may differ from those used in other working groups, with focus on attributes that directly impact RF requirements. |

#### **Proposals from vivo R4-2513250**

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| **Waveform****Observation 1: Waveform with high PAPR would decrease PA efficiency and further reduce maximum output power, which is a key requirement in RAN4.****Proposal 1: The basic waveform is decided by RAN1, but the PAPR and PA efficiency related aspect can be discussed and decided in RAN4.****Observation 2: Transparent spectrum shaping schemes to reduce PAPR such as FDSS have been discussed extensively in 5G R15 and R18 stage.****Observation 3: CFR-SE demonstrates superior performance in terms of PAPR compared to FDSS, FDSS-SE, CFR and TR.****Proposal 2: Study transparent and non-transparent techniques to further reduce PAPR, including CFR-SE. RAN 4 could start the evaluation of affected RF requirements, such as EVM, ACLR, MPR and applicable requirements in the extended RBs if needed. Other related spec impact needs further identification.****Observation 4: Net gain is adopted as an efficient metric of evaluating the comprehensive performance of a low-PAPR waveform in R18.****Proposal 3: Net gain (defined as MPR gain minus SNR loss at a BLER of 0.1) could be considered as the starting point of the metric to evaluate the comprehensive performance of low-PAPR waveform scheme in 6G.** **Proposal 4: Recommend to align a widely accepted PA model for MPR simulation.** **Modulation****Observation 5: In RAN1, some discussions regarding higher modulation order are currently under discussion, including 1024 QAM for UL and 4096QAM for DL.** **Proposal 5: If the study of higher modulation orders beyond 5G is confirmed by RAN1, the feasibility validation from RAN4 perspective is necessary, including UE/BS Tx EVM.** **CBW, FFT, numerology****Proposal 6: For 6GR FR1, it is proposed that minimum channel bandwidths 5MHz and maximum channel bandwidth 200MHz can be supported.****Proposal 7: For operators those has only 3MHz spectrum resources, RAN1 may need to specify a mechanism to support the operation of 3MHz spectrum usage.****Proposal 8: For a specific frequency range/band, it is proposed to support only one numerology.****Proposal 9:** **For Sub-6GHz, maximum FFT size 4096 is suggested for maximum 100MHz with 30kHz SCS;****For FR1 U6G and FR3, maximum FFT size 8192 is suggested for the expected maximum 200MHz with 30kHz.** **Channel raster, synchronization signal and raster, spectrum utilization****Proposal 10: It is suggested to only adopt SCS based channel raster for 6GR, additional frequency raster shift can be considered to align with 5G channel raster.****Proposal 11: To discuss whether the fundamental sync raster design principle can still be applied to 6GR:****Sync Raster interval =Min BWCHANNEL-BWSSB+ ΔFCH,Raster****Proposal 12: For existing channel bandwidths 0-100 MHz, reusing current 5G spectrum utilization for 6GR can be a starting point. For newly introduced channel bandwidth, e.g. 200MHz, spectrum utilization evaluation is needed, considering the RF requirements (SEM/EVM/ACLR) for U6G and FR3.****Irregular channel bandwidth****Proposal 13: RAN4 need discuss the granularity for the CBW in 6G*** **RAN4 should limit the number of mandatory CBW in the spec**
* **For CBW≤100MHz, CBW specified in NR can be the starting point**
* **For CBW > 100MHz, 50 or 100MHz as granularity can be considered**
	+ **Other CBW can be supported by single cell multi carrier or intra-band contiguous CA**

**Observation 6: The performance gain of irregular CBW at UE side is lack of justification.****Observation 7: If the irregular CBW is only supported in DL, the RF requirements can be easier defined based on closed nominal CBW.** **Proposal 14: Study the solution to utilize the irregular channel bandwidth which is transparent to UE design in 6G.*** **Overlapping UE CBW and Larger CBW in TR38.844 can be the starting point.**
* **Check whether single cell multi-carrier operation can help on utilizing irregular channel bandwidth**
* **FFS whether only enable irregular CBW in DL**

**Device types****Observation 8: The lesson from LTE and NR is that to classify UE type to a certain extent (or high-level category) is helpful for classifying the UE performance and feature but too fragmented device type is over-designed.****Proposal 15: Study on introducing limited number of device types (or Cats) and corresponding baseline BB/RF capability in RAN4. The following 4 types can be considered as starting point.*** **Type A+: FWA, CPE**
* **Type A: Smart phone, immersive eMBB device**
* **Type B: Reduced capability eMBB device, wearable/XR**
* **Type C: IoT**

**Proposal 16: The maximum channel bandwidth for each device type can be different, and the following value can be considered as starting point for further discussion:*** **Type A+: FWA, CPE🡪 200MHz，400MHz optional**
* **Type A: Smart phone, immersive eMBB device🡪 200MHz，400MHz optional**
* **Type B: Reduced capability eMBB device, wearable/XR🡪 100MHz**
* **Type C: IoT🡪 20 MHz**

**Proposal 17: For device type A (smartphone), the following table can be considered as starting point of RF capability:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency Range | < 1GHz  | 1 GHz ~ 6425 MHz | 6425~7125MHz | [FR3] |
| Default Power class | PC2  | PC2 | PC2 | PC2 |
| Minimum Channel bandwidth | 5MHz | 5MHz | 20MHz | 20MHz |
| Maximum Channel bandwidth | 100MHz | 100MHz |  200MHz | 200MHz |
| Numerology | 15kHz for FDD;30kHz for TDD; | 15kHz for FDD;30kHz for TDD; | 30/60 kHz can be studied; | 30/60/120 kHz can be studied |
| Maximum FFT size | 4K FFT | 4K FFT | 8K FFT | 8K FFT |
| #Rx, #Tx | 1Tx/2Rx | 1Tx/4Rx， optional 2Tx | 2Tx/4Rx, optional 6Rx  | 2Tx/4Rx，optional 6Rx  |

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#### **Proposals from LG Electronics R4-2513256**

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| Proposal 1: Start 6G RF study based on 5G waveform of RAN1 agreementCP-OFDM and DFT-s-OFDM for ULCP-OFDM for DLProposal 2: Study RAN4 RF impact for other waveformincluding impact on PAPR, Spectrum utilization, and other feature (e.g, sensing)Proposal 3: Consider CBW of up to 200 MHz in frequencies > 3GHz bands, and 400MHz for FR3 (7.125 GHz ~ 24.25 GHz)Proposal 4: Study RF impact of wide CBWs such as 200MHz and 400MHzProposal 5:–Consider 4096-FFT size as a baseline in frequencies < 3GHz–Study feasibility of 8192-FFT for wide CBW (200MHz, 400MHz) in frequencies > 3GHz & FR3Proposal 6: Study impact of numerology on RF including–Single SCS per carrier, per band, or per frequency range as a baseline–Multiple SCS for special use cases, such as, NTN and ISACProposal 7–Study baseline UE architecture•1Tx/2Rx in frequencies < 3GHz, with PC3 as default power class•2Tx/4Rx in frequencies > 3GHz, with PC2 as default power class•FFS on IoT/ RedCap type of devices–Reuse #Tx/#Rx of 5G-NR in frequency at Sub 6GHz and around 7GHz–Study link budget and coverage gain of 8Tx/16Rx architecture on top of #Tx/#Rx used in 5G-NR to confirm its ability to achieve 5G coverage in frequency around 15GHz (FR3)Proposal 8–Consider synchronization raster used in 5G as starting point–In frequencies around 15GHz, consider synchronization raster granularity larger than 1.44MHz to reduce searching time–Study whether to reuse 5G synchronization raster under MRSS scenarioProposal 9: Study higher spectrum utilization than 5GProposal 10: Consider simplified and streamlined framework for 6G device types– To avoid RF specification fragmentation per device type |

#### **Proposals from ZTE, Sanechips R4-2513269**

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| Waveform**Observation 1. For 6GR, CP-OFDM and DFT-s-OFDM waveforms are the basis for UL and DFT-s-OFDM waveform is the basis for DL, Other OFDM based waveforms are not precluded and under discussing in RAN1.** **Observation 2. For 6GR, waveform design aims to improve spectrum efficiency, power efficiency and coverage. It should consider both DL and UL, and support multiple scenarios and needs such as ISAC as well.****Proposal 1: From RAN4 perspective, 6GR waveform design should consider the following metrics:*** EVM
* SEM/ACLR/Spurious emission
* Complexity

**Proposal 2: Postpone the waveform discussion in RAN4 to 2026 Q1 when initial RAN1 progress is made.**Channel bandwidth, FFT size and numerology**Observation 3. 60kHz SCS is precluded for between 24.25GHz - 52.6GHz, and 15kHz SCS is precluded for around 7GHz.****Observation 4: Based on the simulation results, 30kHz SCS has a better performance than 60kHz SCS with about 1 dB gain.** **Proposal 3: For the maximum channel bandwidth, FFT and SCS, it is proposed to adopt the following table:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Frequency range** | **SCS (kHz)** | **FFT size** | **Max. CBW (MHz)** |
| Sub-6GHz (FDD) | 15/([30]) | 8k (8192) | 100 |
| Sub-6GHz (TDD) | 30 | 8k (8192) | 200 |
| around 7GHz | 30 | 16k (16384) | 400 |
| 24.25GHz - 52.6GHz | 120 | 8k (8192) | 800 |

Device type**Proposal 4 For 6GR, at least the following three types of devices are recommended as the target.*** **Scalable UE: Designed for the reduced capability scenarios, offering lower complexity and cost.**
* **Normal UE: Providing improved performance compared to 5G eMBB**
* **Advanced UE: Designed for the demand of high data rate, low latency scenario, with relaxed restriction of form factor and higher capability than normal UE.**

**Proposal 5: A normal 6G UE (handheld UE) should have higher capabilities than 5G handheld UEs**Tx and Rx number**Proposal 6: For 6GR Normal UE (handheld UE) in 6GR, we propose:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Sub 1GHz | 1~3GHz | 3~6GHz | Around 7GHz |
| 6GR Normal UE (Handheld UE) | 1Tx/2Rx | 2Tx/4Rx | 2Tx/ 6Rx | 4Tx/8Rx |

 **- As exception, it is proposed to support 8Rx for vehicle UE and a lower number of Rx for XR UE in 6GR.****Proposal 7: For 6GR advanced UE, it is proposed to use 8Tx/8Rx as baseline capability.****Proposal 8: For 6GR scalable UE, it is proposed to use 1Tx/1Rx as baseline capability.**Sync raster and channel raster**Proposal 9: In 6GR, both 10kHz channel raster (sub-3GHz bands) and SCS based channel raster shall be supported.****Proposal 10: Consider the following principles to design 6GR sync raster:*** **The balance between the step size of sync raster, longer SSB periodicity and deployment flexibility to achieve better performance than 5G NR**
* **Non-overlapping with 5G sync raster**
* **Reserving sufficient frequency separation between 5G and 6GR sync raster**

**Proposal 11: For detailed 6GR sync raster design, it needs to wait for RAN1 conclusion about SSB design.**Spectrum utilization**Observation 5: In 5G NR, for the same channel bandwidth, higher SCS means lower spectrum utilization, lower SCS means higher spectrum utilization.****Proposal 12: The spectrum utilization for 6GR shall not be smaller than the 5G NR.****Proposal 13: For the same channel bandwidth, the spectrum utilization of lower SCS shall be higher than the spectrum utilization of higher SCS.****Proposal 14: The guard band for small channel bandwidth should be less than that of large channel bandwidth.****Proposal 15: The spectrum utilization should be discussed with other aspects like waveform, Tx/Rx RF requirements, PA models and so on.**Irregular channel bandwidth**Proposal 16: In 6GR, if the demand for irregular CBW is limited, it is proposed to standardize the irregular channel width as other regular bandwidth in the specification.****Proposal 17: In 6GR, if the number of irregular CBW is very large, it is not feasible to standardize all of them, and it’s better to develop a universal solution that can address all irregular channel bandwidths.**Modulation**Observation 6. For 6GR, the existing 5G NR modulations are supported as basis, other modulations are not precluded and are under discussion in RAN1.** **Proposal 18: It is proposed to use the 5G EVM requirement as starting point and further discuss how to define more appropriate EVM requirement for the RAN1 agreed basis modulation order to cater for the realistic deployment instead of considering SU-MIMO with up to 2/4 MIMO layers in the corresponding BS RF and UE RF agenda.** |

#### **Proposals from Xiaomi R4-2513272**

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| Overall scope **Proposal 1: RAN4 initial study on system parameters focus on following direction:*** Unify candidate numerologies (data and SSB) as sub-frequency range basis
* Decide minimum CHBW and maximum CHBW compatible with diverse device types
* Simplify sync raster and channel raster design compatible with variable CHBW and device types
* Evaluate solutions to support irregular bandwidths with minimized complexity from both gNB and UE side
* Harmonize design for diverse device types with basic RF/BB capabilities

Waveform /Modulation order **Observation 2-1: RAN1 agreed to reuse NR waveforms and modulation orders as baseline, with necessary enhancement which pending on further discuss in RAN1.** **Proposal 2-1: Postpone waveform/modulation order discussion until sufficient progress reached in RAN1 e.g., start from Q2’ 26.**Numerology/FFT/CHBW/Spectrum utilization **Proposal 3-1: Limit to single numerology as per sub-frequency range/per band basis at least for DL/UL control channel and data channel except PRACH** **Proposal 3-2: Same numerology is applied for SSB (initial cell access) and DL channel in same band** **Proposal 3-3: On 5G migration spectrum/bands, harmonize the numerology between 5G and 6G by taking existing NR commercialization deployment choice into account.****Proposal 3-4: Following numerology choice is proposed on different sub-frequency ranges**

|  |  |  |
| --- | --- | --- |
| **Frequency range** | **SCS for data/control channel except PRACH** | **SCS for PBCH** |
| **Below 3GHz (FDD bands)** | 15kHz | 15kHz |
| **Below 3GHz (TDD bands)** | 30kHz | 30kHz |
| **3GHz ~ 7.125GHz**  | 30kHz | 30kHz |
| **7.125GHz ~8.4GHz**  | 30kHz | 30kHz |
| **24.25 GHz -52GHz** | 120kHz | 120kHz |

**Proposal 3-5: Considering both 3MHz and 5MHz as minimum CHBW pending on operating bands** **Proposal 3-6: Take 8K FFT as baseline assumption****Proposal 3-7: Specify the minimum CHBW and maximum CHBW based on numerologies**

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| --- | --- | --- |
| **SCS** | **Min CHBW** | **Max CHBW** |
| **15kHz**  | 5MHz3MHz (below 1GHz bands) | 100MHz |
| **30kHz** | 10MHz | 200MHz |
| **120kHz** | 50MHz | 800MHz |

**Proposal 3-8: RAN4 further evaluate spectrum utilization with trade-off between improved SU, RF performance and UE/gNB complexity with detailed parameter assumption*** RF non-linearity assumption: PA model, I/Q imbalance, PN
* TX RF core performance assumption: OBE (emission and ACLR), Tx EVM
* Waveform and modulation orders
* Spectrum sharing technologies

Channel raster/sync raster **Proposal 4-1: Support 5kHz channel raster in day 1 for below 3GHz****Proposal 4-2: Remove per band channel raster concept with following value per sub-frequency range basis**

|  |  |
| --- | --- |
| **Frequency range**  | **Channel raster**  |
| **<3GHz** | 5kHz |
| **3GHz ~ 24.25kHz**  | 30kHz |
| **24.25GHz ~ 52GHz**  | 120kHz  |

**Proposal 4-3: Postpone sync raster discussion until sufficient progress reached in RAN1 on 6GR initial cell search design e.g., no early Q2’ 2026****Proposal 4-4: Further evaluate to simplify sync raster to facilitate UE initial cell search (complexity/initial search time/power consumption vs flexibility for SSB placement) with potential area*** Flexible step size per sub-frequency range/per band
* Per band group-based default SSB periodicity
* SS raster design for MRSS

Irregular bandwidth**Proposal 5-1: RAN4 shall careful exam channel bandwidth sets to balance UE design/test complexity and flexibility to fully usage operators’ spectrum*** RAN4 requirements and system parameter design are developed based on Channel bandwidths
* Granularity of CHBW sets need to be carefully considered

**Proposal 5-2: Study potential solution to support irregular spectrum with following direction:*** Overlapping CA /Overlapping CHBW from network perspective
* Channel raster/sync raster and channel allocation mapping rule design to be compatible with flexible BW

Device type and RF/BB capabilities **Proposal 6-1: RAN4 needs to discuss how to handle and discriminate different device types/form factors (not necessary treated as device types/capabilities) from RAN4 requirements perspective****Proposal 6-2: RAN4 shall focus on mandatory RF/BB capabilities assumption for 6GR devices*** Which can be further categorized based device type/form factor

**Proposal 6-3: A basic set of mandatory RF/BB capability shall include following candidate factors with optional capabilities on top of that** * Number of Tx/Rx
* Maximum CHBW
* Modulation oder
* Duplex mode
* Power class
* RRM mobility

**Proposal 6-4: At least IoT device Type and MBB device type shall be considered in RAN4** * FFS whether need to further split sub-device type under each category e.g. low-end MBB, high-end MBB
* FFS whether need to consider dedicated device type for FWA

**Proposal 6-5: For handheld UE, basic UE RF/BB capabilities can be further decided by per sub-frequency rang basis****Proposal 6-7: UE capability update can be further studied e.g. operating state for foldable device, operating mode of eMBB device (power saving mode, high performance mode)*** Cooperation between NW and UE required for UE capability update e.g., conditional BS mandatory feature set
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#### **Proposals from NTT DOCOMO R4-2513290**

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| Observation 1: In 6GR, regardless of frequency band, CP-OFDM is defined as the only waveform for DL, while both CP-OFDM and DFT-s-OFDM are defined for UL. Other waveform candidates are also not excluded from consideration.Observation 2: If only CP-OFDM and DFT-s-OFDM are defined by RAN1, NR RF requirements can likely be reused for 6G in RAN4. However, if waveform enhancements such as FDSS are introduced, RAN4 should assess potential impacts on EVM, ACLR/SEM, MPR, and reference sensitivity/ACS.Observation 3: RAN4 needs to define RF and demodulation requirements as based on RAN1 agreements. For some NR requirements, there are issues where the applicable scope for 6GR may need to be reconsidered depending on device type or power class.Proposal 1: When defining a new waveform, RAN4 should specify any additional RF and demodulation requirements as necessary.Observation 4: For 6G, to achieve a simpler design compared to NR, introducing only one SCS per band is under consideration.Proposal 2: RAN4 should develop specifications considering implementation feasibility, including the impact of fading and minimum guard band width, depending on the SCS patterns introduced.Observation 5: For 6G, synchronization raster needs to be defined as sparsely as possible to minimize UE power consumption during cell search.Proposal 3: RAN4 should coordinate with RAN1 to ensure that synchronization raster definitions for 6G are kept minimal and consider options such as not defining synchronization raster for FR2 or defining them with a much sparser configuration compared to NR.Observation 6: For 6G, which is more advanced than 5G, more features may be feasible on certain devices only, so it is more important to define requirements optimized for various device types.Proposal 4: RAN4 should consider a 6G framework that combines both commonality and differentiation will be expected for different device devices. |

#### **Proposals from Huawei, HiSilicon R4-2513304**

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| ***Channel bandwidth**** *Min/Max channel bandwidth per band*

***Observation 1-1****: Channel bandwidth and related parameters are being discussed across RAN4, RAN1 and the RAN plenary.****Proposal 1-1: RAN4 conduct studies on channel bandwidth and related parameters (e.g., numerology) from an implementation perspective, tracking progress within RAN1 and RAN. All decisions should be closely coordinated with relevant working groups and the RAN plenary to ensure consistency and feasibility.**** *Improved procedure to introduce new CBW in future releases*

***Observation 1-2****: The introduction of new channel bandwidths in NR lacks clear guidelines regarding mandatory support and release applicability.****Proposal 1-2: Study in 6GR the establishment of an improved framework and procedure for the consistent and efficient introduction of new channel bandwidths in future releases.**** *Relative channel bandwidth*

***Proposal 1-3: Study in 6GR whether the maximum relative channel bandwidth criteria remain valid or require updates in light of advancements in RF component technologies.******Spectrum utilization**** *Higher SU than 5G*

***Observation 2-1****: SU for NR smaller channel bandwidths (e.g.≤20 MHz) remains comparatively low, generally below 95% for most such bandwidths.****Observation 2-2****: 6GR has a clear objective to achieve improved SU relative to NR.****Proposal 2-1: Study in 6GR to further enhance SU in line with 6G targets, particularly for channel bandwidths with SU<95%.******Proposal 2-2: RAN4 to discuss evaluation assumptions and applicable requirements for the initial SU study.**** *SU issue identified in 5G*

***Proposal 2-3: Study in 6GR appropriate SU and associated guard bands to prevent non-monotonic guard band issues that may cause access difficulties in real networks.******Channel raster and sync raster**** *Channel raster*

***Observation 3-1****: For bands introduced in NR, especially with higher frequency range, SCS-based channel raster is defined to enable more flexible configuration for wider bandwidth.****Proposal 3-1****:* ***Study whether 6GR should retain the 100 kHz / 10 kHz channel raster or adopt an SCS-only channel raster for bands evolved from NR in low and mid-frequency ranges.**** *Sync raster*
* ***Observation 3-2****:**Certain aspects of the synchronization raster depend on further studies within RAN1.*
* ***Observation 3-3****: Inconsistent SSB SCS designs can delay the deployment of certain bands, as observed in 5G.*
* ***Proposal 3-2: 6GR should aim for consistent SSB design across supported bands, particularly for adjacent or similarly banded frequencies, to facilitate harmonized deployment and avoid fragmentation.***

***Channel spacing******Observation 4-1****: Differentiation of intra-band non-contiguous and contiguous CA based on the nominal channel spacing, which may fail to accommodate certain real-world spectrum allocation used by operators.****Proposal 4-1****:* ***Study in 6GR to develop a proper definition of channel spacing for intra-band CA to support flexible operator deployment scenarios.******Flexible channel bandwidth******Observation 5-1:*** *Irregular spectrum blocks may exist in some specific bands, e.g. GSM, CDMA refarming bands.****Observation 5-2:*** *From the UE implementation and test coverage perspective, only a finite set of channel bandwidth would be possible.****Observation 5-3:*** *On BS side it would be acceptable to support the irregular channel bandwidth for the specific band.****Proposal 5-1: it is proposed to study scalable CBW framework from 6G day 1.******UE implementation assumptions (xTyR)******Proposal 6-1: Consider higher number of #Tx/#Rx as a potential method to meet the ITU IMT-2030 TPR and new services supported by 6GR.******Proposal 6-2: Higher #Tx/#Rx than 5G NR could be studied since the day-1 of 6GR.******Proposal 6-3: For 7GHz spectrum, considering higher maximum achievable #Tx/#Rx than 5GNR 3.5GHz spectrum.******UE device types******Proposal 7-1: RAN4 is suggested to study whether to include following parameters for defining device types: formfactor, cost, UE antenna implementation, power consumption, regulation.******Proposal 7-2: At least Formfactor and antenna implementation (omni-directional antenna or antenna array) need to be included as parameter for defining device types.*** |

#### **Proposals from OPPO R4-2513315**

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| **Waveform**Observation 1: Other OFDM based waveforms are not precluded from RAN1 study.Proposal 1: CP-OFDM and DTF-s-OFDM can be used as baseline to start the RAN4 6G study, other waveforms can be considered later pending on RAN1 conclusions.Observation 2: The DFT-s-OFDM for DL can provide NES gain and coverage gain in different channels.Observation 3: The two DL waveforms (DFT-s-OFDM and CP-OFDM) will increase UE implementation complexity.Proposal 2: To study the DL DFT-s-OFDM waveform impact on RAN4 RF requirements.Observation 4: Before introducing higher order modulation, MPR study, Link level study, tthroughput and coverage study are needed in RAN4.Proposal 3: For high modulation, to further study the MPR, required SNR and throughput and coverage in RAN4.Observation 5: Geometric shaping has non-uniform constellation.Observation 6: For higher order modulation, 1dB gain can be reached by the non-uniform constellation.Proposal 4: Further study Geometric Shaping impact on spectrum utilization and UE RF requirement if introduced in RAN1.Observation 7: Probabilistic shaping uses uniform constellation but with different probability of each point.Observation 8: 1dB gain can be reached by the PS with QAM constellation.Proposal 5: Further study Probabilistic Shaping impact on spectrum utilization and UE RF requirement if introduced in RAN1.Proposal 6: To introduce 8192 maximum FFT size in 6GR.**Numerology**Observation 9: In SID, it has indicated to avoid multiple numerologies for the same band / sub-rangeObservation 10: Most of the FR1 bands can be re-farmed to 6GR, for better co-existence with 5G, the same SCS for FR1 is good for MRSS as for 6GR FR1Proposal 7: For 6GR FR1, TDD bands apply 30kHz SCS and FDD bands apply 15kHz SCS.Observation 11: The new frequency range allocated for 6GR are around 7GHz and around 15GHz.Observation 12: The frequency range for around 7GHz and around 15GHz are not typical FR2 bands, and can be considered to be harmonized to FR1.Proposal 8: For 6GR, 30kHz SCS for around 7GHz range and 60kHz SCS for around 15GHz range is proposed.**Minimum Channel bandwidth**Observation 13: 5MHz for 15kHz SCS and 10MHz for 30kHz has been agreed as minCBW for FR1 in early 5G NR.Observation 14: 3MHz has been introduced in total 12 bands as minCBW at the end of Rel-19.Proposal 9: When define min CBW, initial access, spectrum status and spectrum utilization need to be considered.Proposal 10: 5MHz for TDD and 3MHz for FDD bands as the 6GR system minCBW and each band can determine larger minCBW based on spectrum status and operator request.Proposal 11: It is proposed to agree on 3/5 MHz for FDD bands and 5/10/20 MHz for FR1 TDD bands, 10/40MHz for around 7GHz bands, 50MHz for around 15GHz and FR2-1 as minCBW.**Maximum Channel bandwidth**Observation 15: Spectrum availability, regulatory constraints, and technical feasibility are used to determine the max CBW.Observation 16: 50MHz and 100MHz has been proposed as maxCBW in FR1 considering 15kHz SCS and 30/60kHz SCS in 5G.Observation 17: Currently the 5G FDD bands with the largest available spectrum is band n65 with UL and DL both 90MHz.Observation 18: 27 of 36 FDD bands has smaller than 50MHz available spectrum.Observation 19: Use 50MHz for FDD bands as maxCBW can enjoy less UE implementation complexity and power consumption.Proposal 12: For 6GR FR1 FDD bands, the maxCBW is proposed to be 50 MHz. Further study if 100MHz can be used for maxCBW.Observation 20: Considering the exact spectrum allocation, UE implementation and PA bandwidth, the maxCBW in 5G NR FR1 is 100MHz. Proposal 13: For 6GR FR1 TDD bands, the maxCBW is proposed to be 200MHz.Observation 21: Together consider the SCS and UE implementation complexity, 200MHz is more suitable for around 7GHz range. Proposal 14: For 6GR around 7GHz bands, the maxCBW is proposed to be 200MHz corresponds further SCS study.Observation 22: The spectrum available in 15GHz is only 500MHzObservation 23: For 6GR around 15GHz bands, the maxCBW is proposed to be 400 corresponds further SCS study.**CBW step size**Observation 24: The step size is 5MHz from 5 to 50MHz and 10MHz from 50 to 100MHz as smaller step size in the small CBW and larger step size in the larger CBW.Observation 25: In 5G, irregular bandwidth has been introduced with only one specific CBW at one time which cannot match the large number of fragmented spectrums hold by operators. Proposal 15: Propose 5MHz step size for 5 to 50MHz; 10MHz step size for 50 to 100MHz and 20MHz step size for 100 to 200MHz.**Flexible Channel bandwidth**Observation 26: Smaller granularity than 5/10MHz is needed such as 7MHz which might need 1MHz granularity, Observation 27: Many operators’ spectrum doesn’t have suitable 3GPP CBW which makes the spectrum cannot be fully utilized.Observation 28: If choose the nearest small regular CBW, then the additional spectrum is wasted.Observation 29: If choose the nearest large regular CBW, then the filter design does not match the bandwidth which will suffer interference.Observation 30: If BS support irregular CBW while UE support regular CBW, the component carrier RB level alignment, channel raster SCS level alignment and large enough overlapping part to put SSB and Correset0 are hard to guarantee.Observation 31: For small irregular CBW, it is difficult to put two SSB non-overlapping with the BS CA method.Observation 32: Current solution doesn’t work well with irregular CBW.Proposal 16: To introduce flexible CBW in 6G to solve the 5G irregular CBW.Observation 33: The introduction of flexible channel bandwidth need to further study the UE RF requirement applicability, guard band definition and reduce test burden. Observation 34: All requirements can either scale with bandwidth or be irrelevant with the bandwidth.Proposal 17: For the requirements not related to CBW, same requirement apply when introduce flexible channel bandwidth.Proposal 18: For requirements are scalable with bandwidth, the requirements can be scaled with flexible channel bandwidth same as NR principle.Observation 35: Examples has been shown for different methods with different RBs for flexible CBW.Observation 36: The nearest SU method as smaller SU is chosen to guarantee the guard band but the scaling method helps to guarantee the SU Proposal 19: To further study the two methods as nearest SU method and scaling SU method and their impacts to SU.Observation 37: Current 5G carrierBandwidth for both initial access and RRC connected mode can support the flexible RB configuration for irregular CBW.Proposal 20: Further study the signalling design of 6GR to guarantee the flexible CBW work properly.Proposal 21: To reduce test burden, specific regular channel bandwidth will be defined and the test only apply to regular channel bandwidth.**UL/DL asymmetric CBW**Observation 38: In 5G, besides of symmetric CBW, the asymmetric CBW in downlink and uplink are specified separately, and UE needs to indicate whether it can support asymmetric CBW through signalling.Proposal 22: Proposal 8: All bands can apply symmetric/asymmetric CBW in downlink and uplink in 6G day one.**Number of RX and TX**Observation 39: For hand-held UE, maximum capability is 2TX and 6RX till the end of NR evolution.Observation 40: For reduced capability UE, 1T1R for FR1 FDD and 1T2R for FR1 TDD have been agreed.Proposal 23: The number of TX/RX below is proposed based on different device types:* Table 2.6-1 Proposed Number of TX and RX for different device type

|  |  |
| --- | --- |
|  | Device type |
| 6G IoT(Lowest-tier) | eMBB (Handheld UE) | FWA (e.g., CPE) |
| FR1 FDD | FR1 TDD | FR3 |
| number of Tx/Rx  | Baseline: 1T1ROptional: 2R  | Baseline: 1T2R Optional: 2T/3T; 4R | Baseline: 1T4R Optional: 2T/3T; 6R | Baseline: 2T4ROptional: 3T; 6R | Baseline: 4T8ROptional: 6T;12R |

**Sync raster**Observation 41: SCS level alignment of sync raster and channel raster has been agreed in 5G NR and kssb is introduced to find the RB edge.Observation 42: For 5MHz minCBW, the SS granularity is 1.2MHz for smaller than 3GHz and 1.44MHz for larger than 3GHz.Observation 43: For 3MHz minCBW, the SS granularity is 0.6MHz.Proposal 24: Define unified sync raster design for different bands, minCBW, SCS and channel raster in 6G.Observation 44: MinCBW, Channel raster, BWSSB are the main factors that impact the sync raster design. Mi CBW will limit the sync raster steps. Make sure all possible channel has SSB.Observation 45: By obeying the Rule 1 as for each carrier of minCBW, there should be a whole SSB included, we can have coarser sync raster points.Proposal 25: Consider allowing some channels that do not have SSB like pure data channel.Proposal 26: 6GR sync raster design to have coarser sync raster points and try to avoid Kssb.Observation 46: Using 1RB as reference channel raster can avoid Kssb since the grid are RB level aligned.Observation 47: The reference channel raster is coarser than the channel raster.Observation 48: With the granularity of different minCBW are integer numbers of times of 3MHz granularity, the all-other sync raster points of larger minCBW are subset of sync raster points of 3MHz.Observation 49: This ensure with different minCBW, no new sync raster points are introduced.Observation 50: With 1RB reference channel raster, for different minCBW cases, large sync raster points reduction can be reached.Proposal 27: It is proposed to use 1RB as reference channel raster for specific initial access carrier. Proposal 28: The per band basis minCBW apply and the sync raster granularity can be defined accordingly.

|  |  |  |  |
| --- | --- | --- | --- |
| Minimum BW | SCS for SS | NRB,Carrier  | ΔFSS,Raster |
| 3 | 15 | 15 | 0.72 |
| 5 | 15 | 25 | 2.16 |
| 10 | 30 | 24 | 4.32 |
| 15 | 30 | 38 | 9.36 |
| 20 | 30 | 51 | 14.4 |

Observation 51: The data carrier can use channel raster to enjoy the full SU as well as the flexibility of deployment.Proposal 29: The data carrier after IA can use channel raster to establish the specific carrier.**Channel raster**Observation 52: 5G has introduced 10MHz enhanced channel raster to get rid of 100kHz raster from LTE.Observation 53: 5kHz is the GCD of 10kHz and 15kHz and used as global frequency raster in NR-ARFCN.Proposal 30: For re-farming FR1 bands with 100khz channel raster, using 5khz common channel raster, and avoid diverse channel raster in these bands. For other FR1 bands and new bands, SCS based channel raster is adopted**Spectrum Utilization**Observation 54: Theoretically, still some potential RBs can be further used to enhance the SU.Observation 55: The waveform, modulation, SEM, EVM, ACLR, demodulation and new PA models are factors need to be considered in the SU evaluation.Proposal 31: Start with the agreed baseline waveform, modulation, SEM, EVM, ACLR, demodulation and new PA models, to evaluate how much RB can be improved in the SI. Observation 56: NR has agreed the relaxation of ACLR/SEM/EVM to improve the MPRProposal 32: Study the relaxation of ACLR/SEM/EVM requirements to improve the SU in 6G.**Device Type**Observation 57: The 5G device types are not mutually exclusive. Different device types have been introduced as some of them are depend on the usage scenario such as vehicular, UAV, XR and NTN while some of them are depend on capability such as smartphone, FWA and redcap.Observation 58: Differentiate device types from UE RF capability perspective and they are number of TX/RX, maxCBW, duplex mode, Max MIMO layers and CA support.Proposal 33: Define a “lean” Mandatory baseline functionality set, in which each functionality shall be well justified to be truly mandatory for all device types. Proposal 34: Purely device type-specific attributes (e.g., mobility/moving speed, UE power class, etc.) are not necessarily included in Mandatory baseline functionality set.Proposal 35: Use the lowest-tier 6G IoT functionality set as a template/starting point for definition of the Mandatory baseline functionality set for 6GR.Proposal 36: Functionalities specially optimized for low-tier 6G IoT (e.g., extreme coverage enhancement) does not have to be included in the Mandatory baseline functionality set.Proposal 37: Taking the categorization similar as in Table 2.9.3-1 as a starting point for the Mandatory baseline functionality set and device types.Table 2.9.3-1: Mandatory baseline functionality set

|  |  |  |
| --- | --- | --- |
| Mandatory Capability | Mandatory baseline functionality set | Examples of device types |
| 6G IoT(Lowest-tier) | eMBB (Handheld UE) | FWA (e.g., CPE) |
| Max. UE bandwidth | [5~20MHz] | [5~20MHz] | [200MHz] | [400MHz] |
| Peak data rate | [DL: 5Mbps/UL: 5Mbps] | [DL: 5Mbps/UL: 5Mbps] | [DL: 5Gbps/UL: 2Gbps] | [DL: 5Gbps/UL: 2Gbps] |
| Max. MIMO layers | 1T1R | [1T1R] | [3T6R] | [4T8R] |
| UE power class | N.A. | [26dBm] | [29dBm] | [32dBm] |
| Duplex mode | FDD/TDD | FDD/TDD/HD-FDD | FDD/TDD/SBFD | FDD/TDD/SBFD |
| Max. DL modulation order | 64QAM | 64QAM | [1024QAM] | [4096QAM] |
| UE energy efficiency | Basic power saving | Enhanced power saving | Basic power saving | Basic power saving |
| Coverage | Basic coverage enhancement | Extreme coverage enhancement | Basic coverage enhancement | Basic coverage enhancement |
| Mobility/speed | [3km/h] | [120]km/h | 120km/h | 3km/h |
| … |  |  |  |  |

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#### **Proposals from CSCN R4-2513330**

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| ***Proposal 1: For 6GR bands, consider reducing the SCS options set.******Proposal 2: For 6GR NTN bands, consider only two SCSs for each new bands.******Proposal 3: For sub-6GHz (FR1) and FR2(under 10G), 30kHz SCS should be supported for FDD mode in additional to 15kHz.******Proposal 4: In 6GR NTN, TDD mode could be adopted to improve spectrum utilization efficiency.*** ***Proposal 5: In 6GR NTN, it is worth to study new DL-UL pattern which is suitable for NTN deployment scenario.*** ***Proposal 6: In 6GR, HD-FDD mode should be supported for NTN device type.******Proposal 7: Under the premise that the maximum FFT size of 6GR is 8K at least for some special scenarios,**** ***For 30kHz SCS, a maximum bandwidth of 200MHz should be supported.***
* ***For 120kHz SCS, a maximum bandwidth of 800MHz should be supported.***

***Proposal 8: Recommend up to two receivers and two transmitters for 6GR NTN terminals.******Proposal 9: 6GR NTN reuse 5G-NTN spectrum resources.******Proposal 10: 6GR NTN may share the spectrum resource of TN network on top of further study on TN-NTN co-existence.*** ***Proposal 11: 6GR NTN should support diverse NTN device types including handheld UE, IoT device and VSAT with different RF/BB capabilities.***  |

#### **Proposals from Google R4-2513351**

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| Proposal 1: It is proposed that RAN4 can adopt 3MHz as the baseline for 6GR minimum UE channel bandwidth and the maximum transmission bandwidth configuration can be further discussed based on the outcome of minimum guard band.Proposal 2: It is proposed to first include at least IoT/Wearable/Smartphone/FWA as the initial set of 6G device types and other detailed device type configuration sets can be further discussed. |