**3GPP TSG-RAN WG4 Meeting#116bis R4-251xxxxxx**

**Prague, CZ, 13th – 17th Oct, 2025**

**Agenda item:**  8.1

**Source:** Moderator (ZTE)

**Title:** Topic summary for [[116bis][109] 6G sensing](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Inbox/Drafts/%5B116bis%5D%5B109%5D%206G%20sensing)

**Document for:** Information

# Introduction

*Briefly introduce background, the scope of this email discussion (e.g. list of treated agenda items) and provide some guidelines for email discussion if necessary.*

It is appreciated that the delegates for this topic put their contact information in the table below.

Agenda: 8.11

# Topic #1: Identification and reduction of BS OTA test scope

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| **[R4-2513051](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513051.zip)** | Samsung | Discussion on sensing for 6GR1. ISAC standardization discussion should avoid pursuing extreme sensing performance but instead focus on providing reasonable sensing performance for high-commercial-potential scenarios with limited system framework and physical interface modifications.
2. The sensing and communication performance can only achieve optimality from the Pareto optimality perspective. In other words, the sensing performance and the communication performance satisfy tradeoff relationship.
3. The tradeoff relationship of sensing and communication service could be investigated.
4. 6GR ISAC study keeps focusing on the communication performance of an ISAC system to maintain sensing service cost of the ISAC system at the affordable level.
5. RAN4 could identify the use cases of ISAC in advance, then investigate the ISAC system performance and develop specific performance requirements based on the selected use case.
6. RAN4 adopts UAV sensing target in outdoor scenario and AGV sensing target in indoor scenario as representative use cases for evaluations and simulation.
7. The fundamental issues for 5G-A ISAC study and 6GR ISAC study remain the same, and the conclusions derived in 5G-A UAV use case may still applicable for the use cases in 6GR.
8. The starting point of RAN4 ISAC discussion builds upon the fundamental conclusions derived by RAN1 5G-A ISAC study in the UAV use case, and further carries out detailed 6GR ISAC research and discussions.
9. RAN4 considers TRP monostatic sensing mode, TRP-to-TRP bistatic sensing mode, TRP-to-UE sensing mode, and UE-to-TRP sensing mode in ISAC technology study at first.
10. Both FR1 and FR2 should be considered for RAN4 6GR ISAC study.
11. For TDM, dedicated time resources (with full exploitation of the entire allocated bandwidth) are beneficial for range estimation, and the switching time between communication and sensing needs to be considered.
12. For FDM, the multiplex method can be classified to two scenarios: 1) multiplexing in a sub-band level, which divides the whole channel bandwidth into two mutually exclusive frequency ranges and 2) multiplexing in a subcarrier-level while occupying the same entire channel bandwidth. The clarification is able to be made based on RAN1’s further investigations.
13. For TRP monostatic sensing, RAN4 should prioritize TDM and FDM method, while deprioritizing SDM due to its processing complexity and restrictions on precoding selection.
14. The interference suffered by ISAC system can be classified into two types: 1) self-interference, which can be defined as the received undesired signal from the transmit antennas of the same sector in the same site 2) neighbouring cell interference, including 2.1) co-site inter-sector co-channel interference and 2.2) inter-site TRP-TRP co-channel interference, which can be defined as the received undesired signal from the transmit antennas of neighbouring sector in the same site and the received undesired signal from the transmit antennas of neighbouring sites, respectively.
15. When an ISAC system is working in TDM mode, there is no self-interference between sensing and communication service. However, the self-interference between the sensing transmitter and the sensing receiver may exist under some circumstances.
16. When an ISAC system is working in FDM mode, the self-interference exists between 1) the sensing receiver and communication transmitter, 2) the communication receiver and the sensing transmitter, as well as 3) the sensing transmitter and the sensing receiver.
17. For the simplification perspective, RAN4 could adopt receive SNR of sensing signals as the intermediate performance indicator for sensing performance evaluation.
18. RAN4 could investigate the modelling of the detection target RCS, and define typical RCS values for common detection targets.
19. RAN4 could investigate detection target distribution and discuss the feasible target distribution parameters.
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| **[R4-2513135](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513135.zip)** | CMCC | Discussion on sensing for 6GR study**Proposal 1: for RAN4 study, it is proposed to consider use cases of detection and/or tracking of passive objects, at least including UAVs, human, vehicles and AGVs.****Proposal 2: It is proposed to take Table 1 as stating point for metric discussion for sensing.****Proposal 3: It is proposed to take Table 2 as stating point to discuss KPI on sensing.****Proposal 4: it’s RAN4’s scope for self-interference cancellation/spatial isolation analysis and the adjacent carrier co-existence simulation for following scenarios*** **Between 5G legacy network and 6G sensing network**
* **Between 6G normal network and 6G sensing network based on detailed interference avoidance scheme.**

**Proposal 5: RAN4 to further discuss the possibility of introduce more OTA requirements for 1-H. On the other side, OTA requirements numbers are limited to reduce testing workload.****Proposal 6: it is proposed to study the impact on UE measurement for the sensing modes involving UE.**  |
| **[R4-2513178](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513178.zip)** | CATT | Discussion on Sensing/ISAC for 6G study**3.1 Scenario, Use case and KPI for 6G Sensing/ISAC****Observation 1: the use cases of detection and/or tracking of passive objects, at least including UAVs, human, vehicles and AGVs, are supported by 6GR and 6G RAN architecture referring to the latest TR 38.914.****Observation 2-1: For positioning, the positioning accuracy is considered as the KPI, which include Horizontal positioning accuracy in the horizontal plane (i.e., x/y axis, or latitude/longitude) and [Vertical positioning accuracy in the vertical direction (i.e., z-axis, or altitude)].****Observation 2-2: For Sensing, Detection Probability, False Alarm Probability, Horizontal/Vertical Localization Accuracy and Velocity Accuracy are considered as the KPI.****Proposal 1: As RAN1/RAN2 haven’t started to discuss sensing/ISAC for 6GR, the modes including Monostatic, Bistatic, Multistatic should be considered from 6G study’s perspective.****3.2 Targeted Frequency****Observation 3: For the agreed use cases of 6GR sensing , i.e. UAVs, human, vehicles and AGV, all of them can meet the RCS requirements of Optical Region for the centre frequency equal to or larger than 2GHz.****Observation 4: for the same size of antenna, the less wave length is, the less Radar azimuth/elevation angular resolution is.****Proposal 2: When the targeted centre frequency is discussed, the following factors should be considered together, e.g. the size (a) of physical object to be detected, Radar azimuth/elevation angular resolution (**$θ\_{3dB} or φ\_{3dB}$**), the Radar Function / the targeted receiving Power of echo signal and the Doppler frequency/Maximum velocity of object.****3.3 Bandwidth of Sensing signal****Observation 5: No matter what kind of Radar system we choose, the bandwidth of sensing signal will determine the range resolution of sensing signal.****3.4 sensing signal: Continuous Wave (CW) / Pulse Wave (PW)****Proposal 3: the characteristics above for Pulse Wave (PW) Radar and Continuous Wave (CW) Radar can be considered as the part of RAN4 6G ISAC study.**

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|  | **Pulse Wave (PW) Radar** | **Continuous Wave (CW) Radar** |
| **Time Domain characteristic** | C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590141225592.pngOr C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_1759015675802.png |  C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590155946145.png |
| **Frequency Domain****characteristic** |  C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590147362028.png | C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590157586880.png |
| **Time-Bandwidth Product (TBP)** | $$τ×B=1$$ | $$τ×B>1$$ |
| **Operating State of the transmitter PA** | Saturation State for larger output power | Saturation State or linear State due to large TBP |
| **Duplex Mode** | The operation of transmission and receiving is in the Time Division Duplex (TDD). | The operation of transmission and receiving is in the Full Duplex at the same time and frequency (bandwidth). |
| **Self-interference** | As TDD is used for transmission and receiving, there is no self-interference issue. | There is a strong receiving self-interference coupled from transmitter. Generally, the methods of moving target detection technology should be used to eliminate the self-interference, e.g. self-heterodyne, Pulse-Doppler Method. |
| **Range Blind Zone** | cτ/2 | If Full Duplex Operation between transmission and receiving is used, there is no Range Blind Zone for CW Radar. |
| **Pulse Compression** | Not supported | Supported. For example, matched filter is used to complete the Pulse Compression for LMF signal, but the side lobe of strong Object may interfere the detection of the small Object. |

**Proposal 4: RAN4 should actively and closely work with RAN1 on design of sensing signal from system performance impacts and coexistence perspective.** |
| **[R4-2513254](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513254.zip)** | vivo | Discussion on 6G Sensing**Background****Observation 1:** It is the first-time sensing being discussed in RAN4.**Observation 2:** Although 6G ISAC is the current agenda, the 5G ISAC study as in other working groups studied still need to be considered by RAN4.**Observation 3:** SA has already defined many use cases for 5G ISAC and related service-level performance requirements.**Observation 4:** RAN1 has defined channel modelling for ISAC in Rel-19 in 38.901.**Observation 5:** RAN1 has an active 5G Rel-20 SI on ISAC which focus on UAV cases, that might potentially provide some guidance to RAN4.**Observation 6:** RAN4 is part of the group involved in 6G RAN SI.**Proposal 1:** RAN4 start to identify topics which are not RAN1/2 dependent and start with what can be identified.**Observation 7:** Only general and preliminary analysis can be done given the vast and unconfirmed scenarios and use cases in 6G ISAC.**Observation 8:** The current scenarios of 6G ISAC is far more broad than 5G case.**RF Impact****Observation 9:** The impact of sensing for BS/UE RF requirements is highly dependent on particular use cases and physical layer specifications.**Proposal 2:** The RF impact analysis can generally postponed until more focused use cases and physical layer progress be made.**Proposal 3:** As a 6G SI, both BS and UE would have to be taken into consideration. The demod/CSI requirements need not be considered in SI stage.**Proposal 4:** The need for co-existence can be discussed later when more input from RAN and RAN1 can be obtained.**New Metric and Testability****Observation 10:** It may be necessary to define new test metrics and the metric discussion is also RAN/RAN1 related.**Proposal 5:** The testing methodology for ISAC could use established practices from the sensor industry as a starting point reference.**Proposal 6:** Postpone the feasibility and performance metric discussion for ISAC until RAN1/RAN has more detailed design.**RRM****Proposal 7:** Postpone RRM discussion on ISAC till until more detail design from RAN1 is available. |
| **[R4-2513261](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513261.zip)** | LG Electronics Inc. | Initial Views on 6G RAN4 SensingProposal: RAN4 to start discussion after the progress of RAN1 discussion (e.g., from 2Q 2026) – such as frequency, waveform, frame structure, etc. |
| **[R4-2513279](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513279.zip)** | Xiaomi | Overview for RAN4 6GR ISAC scope**Observation 1-1: In 6GR, target use cases, sensing modes (e.g., mono-static, bi-static) and deployment scenarios are subject to RAN/SA and RAN1’s discussion and decision.** ***Observation 1-2: With sufficient progress from other WGs, it’s hard to have efficient discussion in RAN4 for ISAC*** ***Proposal 1-1: RAN4 can start ISAC discussion from the typical sensing modes (e.g. TRP-TRP mono static sensing and TRP-UE bi-static sensing).***Coexistence study:**Observation 2-1: For FDM ISAC, adjacent channel interference to the FDD receiver should be considered.****Observation 2-2: For TDM ISAC, the ACLR and ACS can be reused.*****Proposal 2-1: RAN4 should waits the agreements from RAN1 to decide whether the coexistence study is necessary.*****Observation 2-3: The aggressor base stations work in ISAC-UAVs scenario will generate higher interference to other base stations.*****Proposal 2-2: RAN4 should discuss the necessity of the coexistence study for the scenario of ISAC-UAVs to other base stations.***RF impact**Observation 3-1: The detailed RF impact is pending other WGs’ design.** **Proposal 3-2: In initial stage, RAN4 shall focus on the study on reference architecture and RF feasibility of interference handling on receiver side from gNB side (*TRP-TRP mono static sensing)***RRM study:***Proposal 4-1: Which types of RRM requirements shall be studied in 6G SI can wait for the other WGs’ progress.******Proposal 4-2: RAN4 can consider the several common measurements requirements below for sensing purpose:**** ***Power strength, timing delay, Doppler, angle in sensing RX***
* ***Power strength, timing delay, Doppler, angle per path in the sensing RX***

**Observation 4-1: the reference signal for the sensing located the different frequency layer as the communication needs the gap-based measurement.****Observation 4-2: measurement type for sensing is upon RAN1’s design of sensing reference signal.*****Proposal 4-3: RAN4 can discuss the baseline assumption on measurement type needed after RAN1 has stable conclusion on the physical layer reference signal design.*****Observation 4-3: From RAN4 perspective, if UE needs to receive the more than one sensing signals from the different cells/carriers as the serving cell, the gap window like the measurement gap in NR will be specified in RAN4 spec.****Observation 4-4: In order to support the more precise and contiguous Doppler shift estimation over a measurement sample, the measurement duration of one occasion shall be not less than 40ms.** ***Proposal 4-4: From RAN4 perspective, the measurement gap pattern for sensing especially for the Doppler shift estimation can be reconsidered.***Test **Proposal 4-5: RAN4 need to study test method for ISAC considering movement of sensing targets, new sensing requirement metric and ISAC channel model.**  |
| **[R4-2513329](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513329.zip)** | ZTE Corporation, Sanechips | Discussion on 6G ISAC study**Proposal 1**: Propose to discuss the timeline between option 1 and option 2 for 6G ISAC RAN4 study considering the overall workload in SI phase. IMG_256Figure 2.2-2. two alternatives of study timeline for 6G RAN4 ISAC**Proposal 2:** For 6G ISAC, the applicable use cases should at least include* Detection and tracking of UAV, Pedestrian, Vehicle, AGV, and Ship
* Infrastructure collapse monitoring
* Micro-deformation detection

**Proposal 3**: Collect the regulatory requirements for sensing if available from different regions. **Observation 1**: In order to meet the RAN Sensing KPI for IMT-2030, the measurement bandwidth for sensing signal should be at least larger than 100MHz;**Observation 2**: In order to meet more than 100MHz sensing signal bandwidth, FR1 high TDD bands and FR2-1 bands are more suitable for ISAC deployment; **Proposal 4**: For 6G ISAC study, consider FR1 TDD with available spectrum wider than 100MHz at least, FR2-1 bands and FFS for FR3 bands; **Proposal 5**: For the UAV use case of 6G ISAC study, consider the mono-static deployment as 1st priority and bi-static deployment as 2nd priority;**Proposal 6**: For the UAV use case of 6G ISAC study, discuss the achievable timing accuracy performance among different BSs for bi-static deployment.**Proposal 7**: For the 6G ISAC study, consider TDM based sensing operation and full duplex based sensing operation.**Proposal 8**: For the 6G ISAC BS with option 1 TDM operation, consider the RF feasibility evaluation from the receiver’s in-channel linearity and also out of carrier blocking performance.**Proposal 9**: For the 6G ISAC BS with option 2 FDM operation, consider the RF feasibility including fully overlapping transmission/reception between DL and UL. **Proposal 10**: For the 6G ISAC BS, the coexistence studies between ISAC system(s) and the legacy system need to be conducted to figure out the appropriate RF requirements. **Proposal 11**: For the different use case of ISAC deployment, propose to consider differentiating the deployment to make the evaluation more realistic and closer to the deployment. **Proposal 12**: For the 6G ISAC coexistence study in RAN4, propose to use the same configuration as captured in Annex E of TR 38.858 as starting point and make further updates based on discussion if necessary. **Proposal 13**: For the UAV use case of 6G ISAC study at least, propose to consider the distance, angle estimation and velocity estimation as the basic metric for the study in RAN4.**Proposal 14**: For the UAV use case of 6G ISAC study at least, propose to consider the distance accuracy impacts, angle estimation accuracy impacts and velocity estimation accuracy impacts to quantify the performance impacts from both co-channel and adjacent channel.**Proposal 15**: For the 6G ISAC coexistence study in RAN4, for 6GR performance metric, propose to use the legacy throughput loss as basic metric. **Proposal 16**: For the 6G ISAC RRM requirement, propose to postpone the discussion until there are sufficient progress made in RAN1/RAN2/RAN3.**Proposal 17**: For the 6G ISAC conformance testing, propose to discuss the OTA test setup for conformance testing of moving sensing target. |
| **[R4-2513333](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513333.zip)** | Nokia | RAN4 aspects for Sensing in 6G networks 1. RAN4 to consider the six sensing modes (i.e., TRP monostatic, UE monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-TRP bistatic, and UE-UE bistatic) at the start of the 6G study. Further updates on the considered sensing modes can be made based on input from RAN1.
2. RAN4 should study the framework for measurement and reporting for 6G sensing based on the framework defined for sensing / ISAC in NR.
3. RAN4 should study measurement and reporting for 6G sensing for gap-assisted and gapless measurements, both for periodic and aperiodic measurement procedures, in RRC idle, RRC inactive and RRC connected mode.
4. Timing requirements for 6G sensing are tightly coupled with latency and interruption constraints, which vary significantly across use cases and must be managed to avoid collisions with other operations.

The diversity of sensing scenarios in 6G demands flexible and adaptive timing requirements, with RAN4 needing to tailor specifications to each use case and sensing mode.Depending on use cases and sensing mode, the timing requirements in RAN4 are dependent on RAN1’s outcome including the signal structures, waveform, channel models, measurement configurations, and procedures for sensing transmission, reception, resource allocation, and/or synchronization mechanisms.1. RAN4 should study the RAN4 impact on timing and delay requirements once RAN1 makes sufficient agreements.
2. RAN4 to investigate minimum timing requirements for 6G sensing and also whether UE can support more stringent timing requirements.

The concerns from RAN1 related to UE using DL waveform, Tx and Rx separation for full-duplex mode, and higher than 31 dBm maximum output power will impact RF. Reusing radar technologies can help to solve the issues related to detecting/localizing/tracking ground targets, improve sensing accuracy, increase the accuracy of positioning estimate, and increase the accuracy of velocity estimate. 1. When adopting the benefits of other technologies, such as radar technologies, into 3GPP domain to solve sensing issues mentioned in RAN and RAN1, consider adjusting them to be LTE/NR compatible to reduce the workload and reduce the impact to RF.
2. RAN4 should study the RAN4 impact on RF requirements once RAN1 makes sufficient agreements.
3. RAN4 should distinguish between i) RF coexistence of sensing with other RATs in adjacent spectrum and ii) service coexistence of sensing with communication or positioning procedures in 6G RAT in the same spectrum.
4. RAN4 to focus on sensing scenarios without communication or concurrent positioning procedures with first priority.
5. RAN4 to investigate UE energy saving aspects when sensing is activated for the different sensing modes.

A testing framework is essential for validating 6G sensing performance, and its development in RAN4 depends on foundational definitions from RAN1.Scenario-specific DUT and TE configurations are critical for accurate sensing evaluation, and existing test setups, e.g., positioning testing, can offer a foundation for future 6G sensing tests.RAN4’s progress on sensing testing is contingent on RAN1’s definition of signal, channel, and measurement types/procedures, requiring close inter-WG collaboration.1. RAN4 can start the study with the testability aspects that are independent from RAN1 scope.
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| **[R4-2513336](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513336.zip)** | Ericsson Canada Inc. | On radio based sensing in 6G radio communications networks* ***Observation 1 (RRM)****: The reflected signals in ISAC may have lower SINRs than usually considered for other RRM measurements.*
* ***Observation 2 (RRM)****: Some ISAC measurement and accuracy requirements may need to be specified by RAN4, since new sensing-specific measurements may be introduced.*
* ***Observation 3 (RRM)****:* Not all ISAC deployment scenarios will have the same RAN4 specification impact.
* ***Observation 4 (RRM)****: Legacy (6G) simulation setups and test cases can be more difficult to reuse as such for ISAC, e.g., because:*
	+ *a sensing target can be neither a transmitter nor a receiver of a radio signal(s) for sensing,*
	+ *more entities are to be modelled in ISAC simulations and test cases (e.g., at least one transmitter, one receiver, and one passive object can be envisioned).*
* ***Observation 5 (RRM)****: Since the legacy simulation setups cannot be just directly reused as such and a lot of simulator development work may potentially be needed, it is important to identify the scenarios and the simulations needed earlier on.*
* ***Observation 6 (RRM)****: RAN4 ISAC studies and requirements must be based on the assumptions which are relevant for general radio communications network deployment scenarios and an acceptable trade-off level between resources needed for radio communications services and resources needed to support sensing.*
* ***Observation 7 (Co-existence & RF)****: RAN4 needs to establish a co-existence framework to study and define upon the need appropriate emission and reception requirements for ISAC operation.*
* ***Observation 8 (Co-existence & RF)****: The co-existence framework should specify what counts as “performance loss” for 6G sensing and how to define it.*

***Proposal 1:*** *RAN4 should await detailed discussions on 6G ISAC until the fundamental concepts are first clarified and agreed in RAN and RAN1.* |
| **[R4-2513352](https://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_116bis/Docs/R4-2513352.zip)** | Apple | Initial views on RF coexistence scenarios for 6G sensingObservation 1: 6G ISAC system deployment parameters, such as cell layout, user density, and propagation conditions, can at least be a superset of the corresponding parameters for NR ISAC.Observation 2: For 6G ISAC coexistence analysis, RAN4 can consider NR cellular network and 6G cellular network as two potential victim systems. The aggressors can be an ISAC base station or an ISAC UE performing sensing.Observation 2: More agreements related to the 6G ISAC system design are needed to determine the assumptions on frequency band(s), signal waveform and signal bandwidth.Proposal 1: RAN4 should continue to monitor the progress of NR ISAC and 6G ISAC system design to derive the necessary assumptions for RF coexistence analysis. |

## Open issues summary

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

### Sub-topic 1-1 General

*Sub-topic description:*

*Open issues and candidate options before e-meeting:*

**Issue 1-1: Timeline for ISAC study**

* Proposal 1: Propose to discuss the timeline between option 1 and option 2 for 6G ISAC RAN4 study considering the overall workload in SI phase. [ZTE]



Figure 2.2-2. two alternatives of study timeline for 6G RAN4 ISAC

* Proposal 2: RAN4 should await detailed discussions on 6G ISAC until the fundamental concepts are first clarified and agreed in RAN and RAN1. [Ericsson]
* Proposal 3: RAN4 should waits the agreements from RAN1 to decide whether the coexistence study is necessary. [Xiaomi]
* Proposal 4: RAN4 to start discussion after the progress of RAN1 discussion (e.g., from 2Q 2026) [LG]
	+ – such as frequency, waveform, frame structure, etc.
* Proposal 5: RAN4 start to identify topics which are not RAN1/2 dependent and start with what can be identified. [Vivo]
* Proposal 6: RAN4 should actively and closely work with RAN1 on design of sensing signal from system performance impacts and coexistence perspective [CATT]
* Proposal 7: The starting point of RAN4 ISAC discussion builds upon the fundamental conclusions derived by RAN1 5G-A ISAC study in the UAV use case, and further carries out detailed 6GR ISAC research and discussions. [Samsung]
* Recommended WF:
	+ Given the limited time and huge workload for ISAC study in 6G, RAN4 start to identify topics which are not RAN1/2 dependent;
	+ Closely work with RAN1/2.

**Issue 1-2: Use case**

* Proposal 1: for RAN4 study, it is proposed to consider use cases of detection and/or tracking of passive objects, at least including UAVs, human, vehicles and AGVs. [CATT]
* Proposal 2: RAN4 adopts UAV sensing target in outdoor scenario and AGV sensing target in indoor scenario as representative use cases for evaluations and simulation. [Samsung]
* Proposal 3: For 6G ISAC, the applicable use cases should at least include [ZTE]
	+ Detection and tracking of UAV, Pedestrian, Vehicle, AGV, and Ship
	+ Infrastructure collapse monitoring
	+ Micro-deformation detection
* Recommended WF:
	+ Further discuss the above proposal.

**Issue 1-3: Operating frequency**

* Proposal 1: Both FR1 and FR2 should be considered for RAN4 6GR ISAC study. [Samsung]
* Proposal 2: For 6G ISAC study, consider FR1 TDD with available spectrum wider than 100MHz at least, FR2-1 bands and FFS for FR3 bands; [ZTE]
* Recommended WF:
	+ For 6G ISAC, at least FR1 and FR2-1 is not precluded in RAN4.

**Issue 1-4: Sensing mode**

* Proposal 1: RAN4 to consider the six sensing modes (i.e., TRP monostatic, UE monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-TRP bistatic, and UE-UE bistatic) at the start of the 6G study. Further updates on the considered sensing modes can be made based on input from RAN1. [Nokia]
* Proposal 2: RAN4 can start ISAC discussion from the typical sensing modes (e.g. TRP-TRP mono static sensing and TRP-UE bi-static sensing). [Xiaomi]
* Proposal 3: As RAN1/RAN2 haven’t started to discuss sensing/ISAC for 6GR, the modes including Monostatic, Bistatic, Multistatic should be considered from 6G study’s perspective. [CATT]
* Proposal 4: RAN4 considers TRP monostatic sensing mode, TRP-to-TRP bistatic sensing mode, TRP-to-UE sensing mode, and UE-to-TRP sensing mode in ISAC technology study at first. [Samsung]
* Proposal 5: For TRP monostatic sensing, RAN4 should prioritize TDM and FDM method, while deprioritizing SDM due to its processing complexity and restrictions on precoding selection. [Samsung]
* Proposal 6: For the UAV use case of 6G ISAC study, consider the mono-static deployment as 1st priority and bi-static deployment as 2nd priority; [ZTE]
* Recommended WF:
	+ The following sensing modes are not precluded from RAN4 perspective
		- TRP monostatic, UE monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-TRP bistatic, and UE-UE bistatic
	+ Further discuss whether to prioritize some sensing modes;
	+ Further discuss the proposal 5;

**Issue 1-5: Evaluation metric and ISAC sensing signal**

* Proposal 1: When the targeted centre frequency is discussed, the following factors should be considered together, e.g. the size (a) of physical object to be detected, Radar azimuth/elevation angular resolution ($θ\_{3dB} or φ\_{3dB}$), the Radar Function / the targeted receiving Power of echo signal and the Doppler frequency/Maximum velocity of object. [CATT]
* Proposal 2: the characteristics above for Pulse Wave (PW) Radar and Continuous Wave (CW) Radar can be considered as the part of RAN4 6G ISAC study. [CATT]

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|  | **Pulse Wave (PW) Radar** | **Continuous Wave (CW) Radar** |
| **Time Domain characteristic** | C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590141225592.pngOr C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_1759015675802.png |  C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590155946145.png |
| **Frequency Domain****characteristic** |  C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590147362028.png | C:\Users\zhangpeng16\AppData\Local\Temp\企业微信截图_17590157586880.png |
| **Time-Bandwidth Product (TBP)** | $$τ×B=1$$ | $$τ×B>1$$ |
| **Operating State of the transmitter PA** | Saturation State for larger output power | Saturation State or linear State due to large TBP |
| **Duplex Mode** | The operation of transmission and receiving is in the Time Division Duplex (TDD). | The operation of transmission and receiving is in the Full Duplex at the same time and frequency (bandwidth). |
| **Self-interference** | As TDD is used for transmission and receiving, there is no self-interference issue. | There is a strong receiving self-interference coupled from transmitter. Generally, the methods of moving target detection technology should be used to eliminate the self-interference, e.g. self-heterodyne, Pulse-Doppler Method. |
| **Range Blind Zone** | cτ/2 | If Full Duplex Operation between transmission and receiving is used, there is no Range Blind Zone for CW Radar. |
| **Pulse Compression** | Not supported | Supported. For example, matched filter is used to complete the Pulse Compression for LMF signal, but the side lobe of strong Object may interfere the detection of the small Object. |

* Proposal 3: It is proposed to take Table 1 as stating point for metric discussion for sensing. [CMCC]
* Proposal 4: It is proposed to take Table 2 as stating point to discuss KPI on sensing. [CMCC]

Table 1 Metrics for sensing

|  |  |
| --- | --- |
| **Metric** | **Definition** |
| **Miss detection probability** | Miss detection probability is the probability that a true target is not associated with a detected target.From the aspect of evaluation, it is defined as$$P\_{md}={\sum\_{n=0}^{N−1}\frac{D\_{n}}{M\_{n}}}/{N}$$Where, * $D\_{n}$ is the number of missed targets in the drop n, i.e., the true target not associated with any detected object
* $M\_{n}$ is the number of true targets in the drop n.
* $N$ is total number of drops with at least one target per drop
 |
| **False alarm probability** | **Definition Type 1** (no target dropped in simulation area)**:** False alarm probability is defined as the probability that an object is detected when there is no target present in simulation area is considered a false alarm.From the aspect of evaluation, it is defined as$$P\_{f1}=\frac{\sum\_{n=0}^{N−1}Q\_{n}}{N}$$Where,* $Q\_{n}$ equal to 1 if at least one object is detected when there is no target dropped in the simulation area in the drop n, otherwise $Q\_{n}$ equal to 0.
* $N$ is the total number of drops without targets in the simulation area.

**Definition Type 2** (targets dropped in simulation area): False alarm probability is defined as the probability that an object is detected but not associated with any true targets in the simulation area is considered as a false alarm. From the aspect of evaluation, it is defined as$$P\_{f2}={\sum\_{\begin{array}{c}0\leq n<N\\M\_{n}^{'}\ne 0\end{array}}^{}\frac{D\_{n}^{'}}{M\_{n}^{'}}}/{K}$$Where,* $D\_{n}^{'}$ is the number of detected objects but not associated with any true targets in the drop n.
* $M\_{n}^{'}$ is the total number of detected objects in the drop n.
* $K$ is number of drops (N)
 |
| **Horizontal/Vertical Positioning Accuracy** | Horizontal/vertical positioning accuracy is defined as the 95th percentile point of the cumulative distribution function (CDF) of the horizontal/vertical position estimation error.From the aspect of evaluation, the horizontal/vertical position estimation error is the norm of the difference between the estimated horizontal/vertical position and the corresponding true position of a sensing target. |
| **Velocity Accuracy** | Velocity accuracy is defined as the 95th percentile point of the cumulative distribution function (CDF) of the velocity estimation error.From the aspect of evaluation, the velocity estimation error is the norm of the difference between the estimated velocity and the corresponding true velocity of a sensing target. |
| **Sensing Capacity**Note 1 | Sensing capacity is defined as the maximum number of the targets per sector when sensing results of all targets in observation zone fulfil QoS requirements with 95% probability. The QoS requirements are defined by other KPIs (except sensing capacity itself) on sensing. |
| **Max sensing service latency** | Max sensing service latency is the time elapsed between the event triggering the determination of the sensing result and the availability of the sensing result at the sensing system interface. |
| **Refreshing rate** | Refreshing rate is the rate at which the sensing result is generated by the sensing system. It is the inverse of the time elapsed between two successive sensing results. |
| Note 1: An intuitive evaluation methodology for sensing capacity can be found in **Annex A**. |

Table 2 KPIs on sensing

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Use case** | **Positioning Accuracy** | **Velocity Accuracy****[m/s]** | **Max sensing service latency****[ms]** | **Refreshing rate****[Hz]** | **Sensing Capacity****[per sector]** | **Missed detection****[%]** | **False alarm****[%]** |
| **Horizontal****[m]** | **Vertical****[m]** |
| UAV detection | 10 | 10 | 1 | 1000 | 1-10 | 100 | 1 | 1 |
| UAV tracking | 1 | 1 | 1 | 100-1000 | 1-10 | 100 | 0.1-1 | 1 |
| Automotive detection and tracking | 1 | N/A | 1 | 1000-5000 | 10 | 100 | 1 | 3 |
| Human detection | 1 | N/A | N/A | 1000 -5000 | 10 | 100 | 5 | 2 |
| Note 1: Metrics for tracking can be different with detection. And metrics for tracking should be evaluated independently. |

* Proposal 5:For the simplification perspective, RAN4 could adopt receive SNR of sensing signals as the intermediate performance indicator for sensing performance evaluation. [Samsung]
* Proposal 6: RAN4 could investigate the modelling of the detection target RCS, and define typical RCS values for common detection targets. [Samsung]
* Proposal 7: RAN4 could investigate detection target distribution and discuss the feasible target distribution parameters. [Samsung]
* Proposal 8: For the UAV use case of 6G ISAC study at least, propose to consider the distance accuracy impacts, angle estimation accuracy impacts and velocity estimation accuracy impacts to quantify the performance impacts from both co-channel and adjacent channel. [ZTE]
* Recommended WF:
	+ RAN4 don’t need to discus the sensing signal which is up to RAN1’s design.
	+ RAN4 need to further discuss how to model the sensing metric for the system level evaluation in RAN4;.

**Issue 1-6: Coexistence and RF feasibility**

* Proposal 1: RAN4 should continue to monitor the progress of NR ISAC and 6G ISAC system design to derive the necessary assumptions for RF coexistence analysis. [Apple]
* Proposal 2: When adopting the benefits of other technologies, such as radar technologies, into 3GPP domain to solve sensing issues mentioned in RAN and RAN1, consider adjusting them to be LTE/NR compatible to reduce the workload and reduce the impact to RF. [Nokia]
* Proposal 3: RAN4 should study the RAN4 impact on RF requirements once RAN1 makes sufficient agreements. [Nokia]
* Proposal 4: RAN4 should distinguish between i) RF coexistence of sensing with other RATs in adjacent spectrum and ii) service coexistence of sensing with communication or positioning procedures in 6G RAT in the same spectrum. [Nokia]
* Proposal 5: RAN4 should discuss the necessity of the coexistence study for the scenario of ISAC-UAVs to other base stations. [Xiaomi]
* Proposal 6: In initial stage, RAN4 shall focus on the study on reference architecture and RF feasibility of interference handling on receiver side from gNB side (TRP-TRP mono static sensing) [Xiaomi]
* Proposal 7: The RF impact analysis can generally postponed until more focused use cases and physical layer progress be made.[Vivo]
* Proposal 8: As a 6G SI, both BS and UE would have to be taken into consideration. The demod/CSI requirements need not be considered in SI stage. [Vivo]
* Proposal 9: The need for co-existence can be discussed later when more input from RAN and RAN1 can be obtained. [Vivo]
* Proposal 10: Postpone the feasibility and performance metric discussion for ISAC until RAN1/RAN has more detailed design. [Vivo]
* Proposal 11:RAN4 to focus on sensing scenarios without communication or concurrent positioning procedures with first priority. [Nokia]
* Proposal 12: it’s RAN4’s scope for self-interference cancellation/spatial isolation analysis and the adjacent carrier co-existence simulation for following scenarios [CMCC]
	+ Between 5G legacy network and 6G sensing network
	+ Between 6G normal network and 6G sensing network based on detailed interference avoidance scheme.
* Proposal 13: For the UAV use case of 6G ISAC study at least, propose to consider the distance, angle estimation and velocity estimation as the basic metric for the study in RAN4. [ZTE]
* Proposal 14: For the UAV use case of 6G ISAC study at least, propose to consider the distance accuracy impacts, angle estimation accuracy impacts and velocity estimation accuracy impacts to quantify the performance impacts from both co-channel and adjacent channel. [ZTE]
* Proposal 15: For the 6G ISAC coexistence study in RAN4, for 6GR performance metric, propose to use the legacy throughput loss as basic metric. [ZTE]
* Proposal 16: For the 6G ISAC BS, the coexistence studies between ISAC system(s) and the legacy system need to be conducted to figure out the appropriate RF requirements. [ZTE]
* Proposal 17: For the different use case of ISAC deployment, propose to consider differentiating the deployment to make the evaluation more realistic and closer to the deployment. [ZTE]
* Proposal 18: For the 6G ISAC coexistence study in RAN4, propose to use the same configuration as captured in Annex E of TR 38.858 as starting point and make further updates based on discussion if necessary. [ZTE]
* Proposal 19: For the UAV use case of 6G ISAC study, discuss the achievable timing accuracy performance among different BSs for bi-static deployment.[ZTE]
* Proposal 20: For the 6G ISAC study, consider TDM based sensing operation and full duplex based sensing operation. [ZTE]
* Proposal 21: For the 6G ISAC BS with option 1 TDM operation, consider the RF feasibility evaluation from the receiver’s in-channel linearity and also out of carrier blocking performance. [ZTE]
* Proposal 22: For the 6G ISAC BS with option 2 FDM operation, consider the RF feasibility including fully overlapping transmission/reception between DL and UL. [ZTE]
* Recommended WF:
	+ Further discuss whether the following adjacent channel coexistence case should be considered
		- Between 5G legacy network and 6G sensing network
		- Between 6G normal network and 6G sensing network
	+ Further discuss whether to consider the co-channel interference between sensing and communication;
	+ For 6G ISAC study, both BS and UE need to be considered.
	+ Further discuss the RF feasibility which depends on the sensing RF architecture assumption;

**Issue 1-7: RRM**

* Proposal 1: RAN4 should study the framework for measurement and reporting for 6G sensing based on the framework defined for sensing / ISAC in NR. [Nokia]
* Proposal 2: RAN4 should study measurement and reporting for 6G sensing for gap-assisted and gapless measurements, both for periodic and aperiodic measurement procedures, in RRC idle, RRC inactive and RRC connected mode. [Nokia]
* Proposal 3: RAN4 should study the RAN4 impact on timing and delay requirements once RAN1 makes sufficient agreements. [Nokia]
* Proposal 4: RAN4 to investigate minimum timing requirements for 6G sensing and also whether UE can support more stringent timing requirements.[Nokia]
* Proposal 5: Which types of RRM requirements shall be studied in 6G SI can wait for the other WGs’ progress. [Xiaomi]
* Proposal 6: RAN4 can consider the several common measurements requirements below for sensing purpose: [Xiaomi]
	+ Power strength, timing delay, Doppler, angle in sensing RX
	+ Power strength, timing delay, Doppler, angle per path in the sensing RX
* Proposal 7: RAN4 can discuss the baseline assumption on measurement type needed after RAN1 has stable conclusion on the physical layer reference signal design. [Xiaomi]
* Proposal 8: From RAN4 perspective, the measurement gap pattern for sensing especially for the Doppler shift estimation can be reconsidered. [Xiaomi]
* Proposal 9: Postpone RRM discussion on ISAC till until more detail design from RAN1 is available. [Vivo]
* Proposal 10: it is proposed to study the impact on UE measurement for the sensing modes involving UE. [CMCC]
* Proposal 11: For the 6G ISAC RRM requirement, propose to postpone the discussion until there are sufficient progress made in RAN1/RAN2/RAN3. [ZTE]
* Recommended WF:
	+ Further discus the above proposals:
		- Option 1: postpone the RRM discussion until RAN1 make some consensus on sensing measurement/report framework and sensing signal design;
		- Option 2: RAN4 continue the RAN4 driven issues without RAN1/RAN2 inputs;

**Issue 1-8: Testability**

* Proposal 1: RAN4 can start the study with the testability aspects that are independent from RAN1 scope. [Nokia]
* Proposal 2: RAN4 need to study test method for ISAC considering movement of sensing targets, new sensing requirement metric and ISAC channel model. [Xiaomi]
* Proposal 3: The testing methodology for ISAC could use established practices from the sensor industry as a starting point reference.[Vivo]
* Proposal 4: For the 6G ISAC conformance testing, propose to discuss the OTA test setup for conformance testing of moving sensing target. [ZTE]
* Recommended WF:
	+ For different ISAC use case, propose to discuss the test setup case by case;
	+ Further discuss the sensing metrics and the corresponding OTA setup according to the RAN1’s conclusion.

**Issue 1-9: Other**

* Proposal 1: RAN4 to investigate UE energy saving aspects when sensing is activated for the different sensing modes. [Nokia]
* Proposal 2: Collect the regulatory requirements for sensing if available from different regions. [ZTE]
* Recommended WF:
	+ Collect the regulatory requirements for sensing if available from different regions.
	+ Further discuss the proposal 1.