3GPP TSG RAN WG1 Meeting #124 **R1-2600363**
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Agenda Item: 9.5.1

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Title: Evaluation assumptions and performance evaluation for ISAC

Document for: Discussion and decision

1. Introduction

According to the SI for Release 20 ISAC [1], the objective of this SI is as follows:

> Evaluate the performance of gNB-based mono-static sensing (i.e., single TRP with co-located sensing transmitter and receiver) for UAV use case [RAN1]
>
> - Identify and study metrics, measurements, and relevant measurement quantization for UAV use case
> - As baseline, existing DL NR waveform and DL NR reference signals are to be used for evaluations.
>   - For other waveform and reference signals, companies are to share relevant information
>   - No UE impacts
> - Deployment scenario and assumptions for channel model calibration for UAV sensing targets in the Rel-19 ISAC channel model SI [*FS_Sensing_NR*] are used as starting point for evaluation assumptions.
>   - FR1 frequency range is prioritized.
>
> Study the procedures, signaling between RAN and CN to support ISAC [RAN3]
>
> Study network architecture for gNB-based mono-static sensing for UAV sensing target use cases [RAN3]
>
> - Applicability to gNB bistatic sensing may be considered as part of this network architecture without additional architecture impacts.
> - No inter-gNB coordination will be studied.
> - Coordination with SA2 as necessary.

The following agreements were made in Release 19 for UAV sensing scenarios:

Evaluation parameters for UAV sensing scenarios

Parameters		Value
Applicable communication scenarios		UMi, UMa, RMa, SMa UMi-AV, UMa-AV, RMa-AV
Sensing transmitters and receivers properties	Rx/Tx Locations	Rx/Tx locations are selected among the TRPs and UEs locations in the corresponding communication scenarios. Note1: This may include aerial UEs for UMi-AV, UMa-AV, RMa-AV communication scenarios. In this case, other Rx/Tx properties (e.g. mobility) are also taken from the corresponding communication scenario.
Sensing target	LOS/NLOS	LOS and NLOS
	Outdoor/indoor	Outdoor
	3D mobility	Horizontal velocity: uniform distribution between 0 and 180km/h, if horizontal velocity is not fixed to 0. Vertical velocity: 0km/h, optional {20, 40} km/h NOTE2: 3D mobility can be horizontal only or vertical only or a combination for each sensing target NOTE 3: time-varying velocity may be considered for future evaluations.
	3D distribution	Horizontal plane: Option A: *N* targets uniformly distributed within one cell. Option B: *N* targets uniformly distributed per cell. Option C: *N* targets uniformly distributed within an area not necessarily determined by cell boundaries. $N = \{1, 2, 3, 4, 5\}$ NOTE4: N=0 may be considered for the evaluation of false alarm Vertical plane: Option A: Uniform between 1.5m and 300m. Option B: Fixed height value chosen from {25, 50, 100, 200, 300} m assuming vertical velocity is equal to 0.
	Orientation	Random in horizontal domain
	Physical characteristics (e.g., size)	Size: • Option 1: 1.6m x 1.5m x 0.7m • Option 2: 0.3m x 0.4m x 0.2m

Minimum 3D distances between pairs of Tx/Rx and sensing target	Min distances based on min. TRP/UE distances defined in TR36.777 as a starting point. NOTE5: the sensing target is assumed in the far field of sensing Tx/Rx
Minimum 3D distance between sensing targets	Option 1: At least larger than the physical size of a target Option 2: 10 meters
[Unintended/Environment objects, e.g., types, characteristics, mobility, distribution, etc.]	Can be considered in future evaluations

NOTE: A percentage of TRPs/UEs that have sensing capabilities may be considered for future evaluations.

Simulation assumptions for large scale calibration for UAV sensing targets

Parameters	**Values**
Scenario	UMa-AV
Sensing mode	TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic
Target type	UAV of small size (0.3m x 0.4m x 0.2m)
Sectorization	Single 360-degree sector can be assumed
Carrier Frequency	FR1: 6 GHz FR2: 30 GHz
BS antenna configurations	Single dual-pol isotropic antenna
BS Tx power	FR1: 56dBm FR2: 41dBm
Bandwidth	FR1: 100MHz FR2: 400MHz
BS noise figure	FR1: 5dB

	FR2: 7dB
UT antenna configurations	Single dual-pol isotropic antenna; (M,N,P,Mg,Ng;Mp,Np) = (1,1,2,1,1;1,1)
UT noise figure	FR1: 9dB FR2: 10dB
UT height	1.5m for terrestrial UTs,
UT Tx power	23dBm
UT Distribution	• The overall number of UTs is 30 uniformly distributed in the center cell. • All of the UTs are either terrestrial UTs or aerial UTs, all outdoors. • Vertical distribution of aerial UE: Fixed height value of 200 m. • FR1 is assumed for aerial UE.
Sensing target distribution	1 target uniformly distributed (across multiple drops) within the center cell. Vertical distribution: Fixed height value of 200 m.
Component A of the RCS for each scattering point	-12.81 dBsm
Minimum 3D distances between pairs of Tx/Rx and sensing target	10 m
Wrapping Method	No wrapping method is used if interference is not modelled, otherwise geographical distance based wrapping
Coupling loss for target channel	power scaling factor (pathloss, shadow fading, and RCS component A included): $L_{TX-SPST-RX} = PL_{dB}(d_1) + PL_{dB}(d_2) + 10lg\left(\frac{c^2}{4\pi f^2}\right) - 10lg(\sigma_{RCS,A}) + SF_{dB,1} + SF_{dB,2}$

Sensing Tx/Rx selection	Best N = 4 Tx-Rx pairs to be selected for the target. NOTE1: Based on the Tx-Rx pairs with the smallest power scaling factor of the target channel.
Metrics	Coupling loss for target channel Coupling loss for background channel (in case of monostatic sensing, this is the coupling loss between Tx and one reference point) Note: CDFs can be separately generated for target channel, background channel

Simulation assumptions for full calibration for UAV sensing targets

Parameters	Values
Scenario	UMa-AV
Sensing mode	TRP monostatic, TRP-TRP bistatic, TRP-UE bistatic, UE-UE bistatic
Target type	UAV of small size (0.3m x 0.4m x 0.2m)
Sectorization	Single 360-degree sector can be assumed
Carrier Frequency	FR1: 6 GHz FR2: 30 GHz
BS antenna configurations	Single dual-pol isotropic antenna
BS Tx power	FR1: 56dBm FR2: 41dBm
Bandwidth	FR1: 100MHz FR2: 400MHz
BS noise figure	FR1: 5dB

	FR2: 7dB
UT antenna configurations	Single dual-pol isotropic antenna; (M,N,P,Mg,Ng;Mp,Np) = (1,1,2,1,1;1,1)
UT noise figure	FR1: 9dB FR2: 10dB
UT height	1.5m for terrestrial UTs
UT Tx power	23dBm
UT Distribution	• The overall number of UTs is 30 uniformly distributed in the center cell. • All of the UTs are either terrestrial UTs or aerial UTs, all outdoors. • Vertical distribution of aerial UE: Fixed height value of 200 m. • FR1 is assumed for aerial UE.
Sensing target distribution	1 target uniformly distributed (across multiple drops) within the center cell. Vertical distribution: Fixed height value of 200 m.
RCS for each scattering point	Component A: -12.81 dBsm Component B1: 0 dB Component B2: 3.74 dB for standard deviation The same values are used for monostatic RCS and bistatic RCS
Minimum 3D distances between pairs of Tx/Rx and sensing target	10 m
Wrapping Method	No wrapping method is used if interference is not modelled, otherwise geographical distance based wrapping
Fast fading model	TR 36.777 Annex B.1.3
(u, std) for XPR of target	Mean 13.75 dB, deviation 7.07 dB

The power threshold for path dropping after concatenation for target channel	FFS
The power threshold for removing clusters in step 6 in section 7.5, TR 38.901 for background channel	FFS
Coupling loss for target channel	By definition, need to consider all direct and indirect paths. The following parameters are included in the calculation: • power scaling factor (pathloss, shadow fading, and RCS component A included) • for small scale RCS B1/B2 and power of rays in Tx-target/target-Rx links ($P^{k,p}_{n',m',n,m}$), Tx/Rx antenna pattern, 3 polarization matrixes, i.e., $$\sqrt{P^{k,p}_{n',m',n,m}}\begin{bmatrix}F_{rx,u,\theta}\left(\theta^{k,p}_{rx,n',m',ZOA},\phi^{k,p}_{rx,n',m',AOA}\right)\\F_{rx,u,\phi}\left(\theta^{k,p}_{rx,n',m',ZOA},\phi^{k,p}_{rx,n',m',AOA}\right)\end{bmatrix}^T CPM^{k,p}_{rx,n',m'}CPM^{k,p}_{n',m',n,m}CPM^{k,p}_{tx,n,m}$$ $$\cdot\begin{bmatrix}F_{tx,s,\theta}\left(\theta^{k,p}_{tx,n,m,ZOD},\phi^{k,p}_{tx,n,m,AOD}\right)\\F_{tx,s,\phi}\left(\theta^{k,p}_{tx,n,m,ZOD},\phi^{k,p}_{tx,n,m,AOD}\right)\end{bmatrix}$$
Sensing Tx/Rx selection	Best N = 4 Tx-Rx pairs to be selected for the target. NOTE1: Based on the Tx-Rx pairs with the smallest power scaling factor of the target channel.
Absolute delay	The model of UMa scenario defined in TR 38.901 7-24GHz channel modeling [ref] is reused for UMa-AV for all sensing modes.

Metrics	Coupling loss for target channel Coupling loss for background channel (in case of monostatic sensing, this is the linear sum of coupling losses between Tx/Rx and all reference points) Note: CDFs can be separately generated for target channel, background channel CDF of Delay Spread and Angle Spread (ASD, ZSD, ASA, ZSA) For monostatic sensing mode: delay spread and angle spread of the background channel is calculated separately for each reference point Definition of Delay Spread is similar to the definition of angle spread in Annex A of TR 25.996, Definition of Angle Spread can ref to Annex A of TR 25.996.

The following agreements were made in RAN1 #122 meeting for Release 20 for UAV evaluation:

Agreement

Horizontal/vertical positioning accuracy are agreed as performance metrics for NR ISAC.

- It is defined as the absolute value of the difference between the estimated horizontal/vertical position and the corresponding true position of a sensing target.
  - Note: in RAN1 evaluations, there should be only one estimated horizontal/vertical position corresponding to the true position of a sensing target.

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions
Scenario	UMa-AV, Optional RMa-AV
Carrier frequency	Mandatory: one value either 4 GHz or 4.9GHz. optional for FR1: 6 GHz

	[optional for FR2: 28 GHz]
System bandwidth	100 MHz
Numerology	SCS = 30kHz
BS Layout	Hexagonal grid, 7 macro sites, 3 sectors per site. See Note1 3 sectors with 30, 150, 270 degrees
Inter-BS (2D) distance	Uma-AV: 500m, optional 1000m, RMa-AV: 1732m
BS antenna height	25m for UMa-AV, 35m for RMa-AV
Wrap-round	No wrap-round

Note1: target(s) are dropped only in the center site, and inter-BS interference is not modelled.

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions
Target type	UAV with small size (0.3m x 0.4m x 0.2m)
Target distribution when target(s) are dropped	N = 5 targets per sector in the center site. Optional: N is uniformly distributed from 1 to 10. Horizontal plane: uniformly distributed in a sector Vertical plane: Uniformly distributed between 25m and 300m, optionally distributed between 1.5m and 300m
Mobility	horizontal speed: uniformly distributed between 0 and 180km/h vertical speed: 0km/h

Note: N=0 will be discussed in a later proposal in relation to false alarm.

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions
Minimum BS-target 3D distance	10 m
Minimum target-target (3D) distance	10 m
Target outdoor/indoor proportion	100% outdoor
LOS/NLOS	LOS and NLOS
Orientation	Random in horizontal domain
RCS model	RCS model 1 for UAV with small size

Agreement

For the purpose of performance metric calculation, association of the detected object(s) and the true target(s) should fulfil at least the following conditions:

- One true target is associated with at most one detected object.
- One detected object is associated with at most one true target.
- The same association applies to miss detection, false alarm probability Type 2 (if defined) and positioning/velocity accuracy.
- Companies to report the method used for association of the detected object(s) and the true target(s).

Agreement

Missed detection probability is agreed as performance metric for NR ISAC.

- It is defined as the conditional probability of not detecting the presence of a target when the target is actually present in the simulation area.

$$P_{md} = \sum_{n=0}^{N-1} \frac{D_n}{M_n} / N$$

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.

Agreement

False alarm probability is agreed as performance metric for NR ISAC.

- For cases without true target dropped in simulation area, False alarm probability Type 1 is computed and reported
- For cases with true targets dropped in simulation area, False alarm probability Type 2 is computed and reported
- Note: both False alarm probability Types are mandatory
- KPI values for False alarm probability Type 1 and 2 can be discussed separately.

Definitions:

- False alarm probability Type 1 (no target dropped in simulation area): An object is detected when there is no target present in simulation area is considered a false alarm.

$$P_{f1} = \frac{\sum_{n=0}^{N-1} Q_n}{N}$$

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.

- False alarm probability Type 2 (targets dropped in simulation area): An object is detected but not associated with any true targets in the simulation area is considered as a false alarm.

$$P_{f2} = \sum_{\substack{0 \le n < N \\ M'_n \neq 0}} \frac{D'_n}{M'_n} / K$$

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.
- FFS:
  - Option 1: K is number of drops (N)
  - Option 2: K is number of drops with at least one detected object

Note: the number of targets should be reported by companies when providing False alarm probability Type 2.

Agreement

Velocity accuracy is agreed as performance metric for NR ISAC.

- Velocity accuracy is defined as the absolute value of the difference between the estimated velocity and the corresponding true velocity of a sensing target.
- For single TRP monostatic sensing,
  - The radial velocity accuracy can be estimated
    - The true radial velocity is the projection of true velocity on the direction from TRP to target for TRP monostatic.
  - The true velocity accuracy can be estimated.

The following agreements were made in RAN1 #122b meeting for Release 20 for UAV evaluation:

Agreement

On False alarm probability Type 2 (targets dropped in simulation area), the parameter K is the number of drops with at least one detected object.

Conclusion:

Sensing resolution is not considered as a performance metric for evaluation of NR ISAC.

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions	
BS antenna configuration	For 4GHz, 4.9GHz: • Option 1 as optional - Tx: (12,16, 2,1,1;2,16) - Rx: (12,16,2,1,1;2,16) • Option 2 - Tx: (8,8,2,1,1;4,8) - Rx: (8,8,2,1,1;4,8)	For 6GHz: • Option 1 as optional - Tx: (16,16, 2,1,1;4,16) - Rx: (16,16,2,1,1;4,16) • Option 2: - Tx: (8,8,2,1,1;4,8) - Rx: (8,8,2,1,1;4,8)
	Mandatory: (d_H, d_V) = (0.5, 0.8)λ, +45°/-45° polarization Optional: (d_H, d_V) = (0.5, 0.5)λ, +45°/-45° polarization	

Note: Tx antenna elements and Rx antenna elements are operating simultaneously

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions
BS antenna radiation pattern	Table 9 in Report ITU-R M.2412
BS antenna mechanic tilt (downtilt angle without electrical tilt)	90° in GCS (pointing to horizontal direction)
BS antenna electrical tilt (downtilt angle after mechanic and electrical tilt)	Option 1: no electrical tilt Option 2: 102° in GCS
Polarized antenna model	Model-2 in clause 7.3.2 in TR 38.901

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions
gNB-target link	gNB-aerial UE of UMa/RMa parameters in 36.777 with Alternative 3
Concatenation of TX-target and target-RX links	Up to company choice between two options for concatenation defined in Step 9 in section 7.9.4.1, TR 38.901
The power threshold for path dropping after	-25dB and -40dB are respectively used for the two options for concatenation

concatenation for target channel	

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions
Co-site inter-sector interference	Not modelled
Adjacent channel interference	Not modelled
BS receiver noise figure	5dB

Agreement

When Tx/Rx operates simultaneously (baseline case), the following parameters are used for the evaluation on NR ISAC:

Antenna isolation	• Option 1: 65dB • Option 2: 80dB
Maximum BS Tx power	• Option 1: 37dBm • Option 2: 52dBm The above options are calculated with BS_maxpower = BS Rx saturation power + antenna isolation by assuming the BS Rx saturation power = -28dBm and the antenna isolation = 65dB and 80dB, respectively

- Optionally: companies should report the maximum BS Tx power when it is assumed that Tx and Rx don't operate simultaneously. Companies should report how the maximum BS Tx power is derived.

Agreement

The following evaluation parameters are agreed for the evaluation on NR ISAC.

Parameters	Assumptions

CPI (coherent processing interval)	Companies to report the CPI value assumed
Waveform	CP-OFDM as baseline, other waveform is up to companies report

Agreement

When Tx/Rx operates simultaneously, the following evaluation parameters are agreed for the evaluation on NR ISAC.

Self-interference	The residual leakage interference/noise is modelled e.g. by additional additive white Gaussian noise, -94+X dBm in 100 MHz, X is up to company report. Companies to provide details on their modelling. Note: X = -Infinity corresponds to not modelling self-interference

Agreement

For the evaluation on NR ISAC,

- 3 kinds of resources are defined
  - Type 1: resources that are used for sensing signal transmission
  - Type 2: part of Type 1 resources that are used for communication purpose
    - Note: it is possible the resource type 2 doesn't exist
  - Type 3: resources that are not used for sensing signal transmission, and cannot be used for communication purpose due to sensing operation
- Both options should be reported for sensing resource ratio
  - Option 1: (Type_1 + Type_3) resources over all radio DL and UL resources
  - Option 2: (Type_1 - Type_2 + Type_3) resources over all radio DL and UL resources
  - Note: if Type 2 resource doesn't exist, two options are the same

For the evaluation on NR ISAC,

- Company should report T/F RE mapping of sensing RS, assumed TDD UL/DL configuration if applicable.
  - Company should report which sensing RS resources are considered as Type 2 resource and related reason.

Agreement

Companies are encouraged to report the high-level sensing signal/data processing method used in the evaluation, e.g., 2D FFT, MUSIC, and any other methods.

Agreement

Up to company to model low power cluster in the evaluation of NR ISAC

Agreement

Companies should report details of the Tx beam information (number of Tx beams, wide/narrow Tx beam) being used at TRP.

- The details of the Tx beam information (number of Tx beams, wide/narrow Tx beam) being used at TRP will be captured along with the corresponding evaluation results in the Rel-20 TR

Agreement

The following performance objectives are adopted for evaluation purpose of NR ISAC.

Metric	Value
Missed detection Probability	[5]%
False Alarm Probability Type 1	[5]%
False Alarm Probability Type 2	[5]%
Horizontal Positioning Accuracy	[10] m with confidence level 90%
Vertical Positioning Accuracy	[10] m with confidence level 90%
Velocity Accuracy	[5] m/s with confidence level 90%

The following agreements were made in RAN1 #123 meeting for Release 20 for UAV evaluation:

Agreement

In section 6.2 Performance evaluation results in TR 38.765,

- Multiple configurations of the following parameters are defined to respectively analyze the evaluation results
  - At least Two baseline configurations 1 & 2 are defined for evaluation purpose

	Parameters	Configuration 1 Baseline	Configuration 2 Baseline

1	Scenario	(UMa-AV, 500m)	(UMa-AV, 500m)
2	Sensing Tx/Rx operating simultaneously or not	Sensing Tx/Rx operating simultaneously	Sensing Tx/Rx operating simultaneously
3	Carrier frequency	4 or 4.9GHz	4 or 4.9GHz
4	Max BS Tx power	52 dBm	37 dBm
5	BS antenna configuration	• (M, N, P, Mg, Ng, Mp, Np) - Tx: (8,8,2,1,1;4,8) - Rx: (8,8,2,1,1;4,8) (d_H, d_V) = (0.5, 0.8)λ, +45°/-45° polarization	• (M, N, P, Mg, Ng, Mp, Np) - Tx: (8,8,2,1,1;4,8) - Rx: (8,8,2,1,1;4,8) (d_H, d_V) = (0.5, 0.8)λ, +45°/-45° polarization
6	Number of targets per sector in center site	N=5	N=5
7	Target vertical distribution	25-300m	25-300m

- Additional configurations can be defined for other assumptions of the parameters, based on reported evaluation results in RAN1 #124.

Agreement

- Companies should report whether a same target is modeled in the ISAC channel of single, multiple or all STXs/SRXs
  - Company should report how to determine the single or multiple STXs/SRXs for a target
  - The details of STX/SRX determination will be captured along with the corresponding evaluation results in the TR for NR ISAC
  - If the evaluation results are derived by measurement reports from multiple/all STXs/SRXs, companies should report how measurement reports from multiple/all STXs/SRXs are used

Agreement

From RAN1 perspective, the following measurements that may be reported from RAN are identified in the study of NR ISAC. Note: Down selection of Level(s)/Option(s) for recommendation can be discussed separately.

- Level A: Raw data per Tx antenna port per OFDM symbol per RX antenna port per TRP for a given time stamp
  - Option A1: Amplitude and phase samples in time/delay domain of the estimated channel, i.e., Amplitude and phase values of channel impulse response
  - Option A2: Amplitude and phase per subcarrier in frequency domain of the estimated channel
- Level B: Amplitude and phase profile of delay, and/or Doppler, and/or angle per TRP for a given time stamp by using window(s) of the [consecutive] samples in delay, Doppler and/or angle domain
  - Option B1: Delay-Doppler profile per Tx antenna port per Rx antenna port, which includes the amplitude and phase samples distributed across different delays and Doppler shifts.
  - Option B2: Delay-Angle profile per Tx antenna port per OFDM symbol, which includes the amplitude and phase samples distributed across different delays and spatial angles (e.g., Angle of Arrival).
  - Option B3: Delay-Doppler-Angle profile per Tx antenna port, which includes the amplitude and phase samples distributed across delay, Doppler, and angle domains.
  - Option B4: Delay profile per Tx antenna port per OFDM symbol per Rx antenna port, which includes the amplitude and phase samples distributed across different delays.
  - Note: Level B is applicable for either LCS or GCS
- Level C: per detected path/point measurements per Tx antenna port per TRP which may be reflected/scattered from scattering point(s).
  - Option C1: Delay/range, Doppler/velocity, one or multiple 3D angles, and [power/confidence metric] per detected path for a given time stamp.
    - A path is associated with one couple {delay/range, Doppler/velocity, [power/confidence metric]}, and one or multiple 3D angles.
  - Option C2: Doppler/velocity, position, and [power/confidence metric] per detected path for a given time stamp.
    - A path is associated with one doppler/velocity, [power/confidence metric], one or multiple positions
  - Option C3: Delay/range, Doppler/velocity, 3D angle, and [power/confidence metric] per detected path for a given time stamp.
    - A path is associated with one delay, and one or multiple triple {Doppler/velocity, 3D angle, [power/confidence metric]}
  - Option C4: Delay/range, Doppler/velocity, 3D angle, and [power/confidence metric] per detected point for a given time stamp
    - A point is associated with one range/delay, one Doppler/velocity, one 3D angle
  - Option C5: Position, velocity, and [power/confidence metric] per detected point for a given time stamp
    - A point is associated with one position, one velocity
  - FFS: Velocity can be
    - Opt 1: radial velocity

- Opt 2: 3D velocity
- Note:
  - Position can be defined in either LCS or GCS
  - Angle can be defined in either LCS or GCS
  - Ambiguity issue will be further discussed
  - 3D angle refers to a pair of horizontal and vertical angles

- Level D: Object/target level measurement [per TRP or per gNB]
  - One or more value pair(s) {position, velocity} in GCS for a given time stamp is reported for a detected object/target,
    - Option D1: Only one value pair {position, velocity} in GCS for a given time stamp is reported for a detected object/target. The association of multiple measurements across different time stamps for the same detected object/target is not reported.
    - Option D2: Only one value pair {position, velocity} in GCS for a given time stamp is reported for a detected object/target. The association of multiple measurements across different time stamps for the same detected object/target is reported.
    - Option D3: One or more value pairs {position, velocity} in GCS for a given time stamp are reported for a detected object/target. The association of multiple measurements across different time stamps for the same detected object/target is reported.
    - Option D4: One or more value pairs {position, velocity} in GCS for a given time stamp are reported for a detected object/target. The association of multiple measurements across different time stamps for the same detected object/target is not reported.
  - Note: Ambiguity issue can be further discussed if any
  - Note: velocity is 3D velocity for Option D2/D3
  - FFS: velocity can be radial velocity or 3D velocity for Option D1/D4
- Note: the possible information from RAN to SF for further processing can be further discussed for all levels
- Note: the possible information from SF to RAN can be further discussed for all levels
- Note: confidence metric can be further discussed for options of Level C/D
- Note: definition of time stamp for each of all options of all Levels can be further discussed
- For Level A/B/C, Tx antenna port means reference signal antenna port for sensing purpose

Agreement

RAN1 confirms the performance objectives in the early agreement from RAN1 #122bis by removing the brackets

Agreement

The following performance objectives are adopted for evaluation purpose of NR ISAC.

Metric	Value
Missed detection Probability	~~[~~5~~]~~%
False Alarm Probability Type 1	~~[~~5~~]~~%
False Alarm Probability Type 2	~~[~~5~~]~~%
Horizontal Positioning Accuracy	~~[~~10~~]~~ m with confidence level 90%

Vertical Positioning Accuracy	[10] m with confidence level 90%
Velocity Accuracy	[5] m/s with confidence level 90%

Agreement

Confidence level of the X% represents X percentile point of the cumulative distribution function (CDF) of the estimation errors

Conclusion

Sensing service latency and refreshing rate are not considered as performance metrics for evaluation of NR ISAC.

Agreement

- Up to company to report evaluation results for UAV tracking in NR ISAC study.
  - Proponent company should clarify the details on how target trajectory is modeled

Agreement

- The following general procedure for performance evaluation of NR ISAC is to be captured in TR 38.765.

1) Simulation parameter configuration
2) Sensing scenario generation, including the deployment of sensing Tx/Rx (STXs/SRXs)
3) Dropping N target(s), where N is equal to 0 or larger than 0
4) Channel generation and STX/SRX determination for the targets
5) Sensing signal generation and passing the sensing signal to the generated channel
6) Sensing signal processing at each SRX, optionally, sensing signal processing based on fusion from multiple STXs/SRXs
   - E.g., optionally, sensing signal processing based on tracking
7) Sensing performance metric calculation.

Note: company should report the details on sensing signal processing and ISAC channel generation

Agreement

- The following evaluation assumptions for optional FR2-1 carrier frequency are considered for evaluation of NR ISAC

Parameters	**Values**
Scenario	UMi-AV
Carrier Frequency	30 GHz

System bandwidth	400 MHz
SCS	120 kHz
Inter-BS (2D) distance	200 m
BS antenna configurations	(M,N,P,Mg,Ng;Mp,Np) = (16,16,2,2,1;1,1), (dH,dV) = (0.5, 0.5 or 0.8)λ, +45°/-45° polarization for whole panel; (16,16,2,1,1;1,1) for Tx and (16,16,2,1,1;1,1) for Rx
Beam set at TRxP	Up to company report
Antenna isolation	80 ~ 100 dB
Max BS Tx power	30 dBm
BS noise figure	7 dB

- Up to company to report evaluation results and additional configuration information for FR2-1.

Agreement

- The attached template in R1-2509242 (Proposal 5.3-1-rev2) is used as starting point for evaluation results collection

2. Discussion

2.1 Measurement reports

For the report from RAN level, in level A and B, the overhead of the reports is thousand times higher than that in level C and D.

In level C, a report of Delay/range, Doppler/velocity, 3D angle, and [power/confidence metric] per detected point can lead to an error in tracking the trajectory of two or more objects when their trajectories cross in each other as shown in Figure 1.

A report in level D reduces overhead compared to level A and B. It also avoids the wrong trajectory association in level C. Moreover, a report in level D does not require the assistance information to be transmitted to assist the processing at SF.

For these reasons, we support the measurement report in level D where a report is based on the results of position and velocity per target.

In level D report, the association of multiple measurements across time per target is reported.

Proposal 1: Level D measurement report is supported. The association of multiple measurements across time per target is reported.

Proposal 2: No assistance information is necessary to be transmitted to CN to assist the data processing in level D.

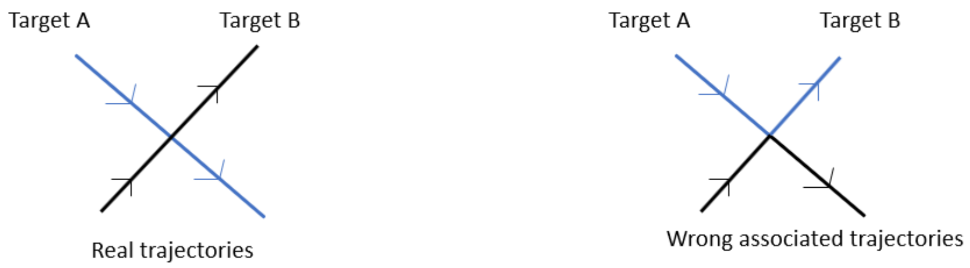

Figure 1: Wrong associated trajectories when the measurements are reported in level C

2.2 Sensing signal

The evaluation focuses on monostatic sensing where the base station transmits the sensing signal to the UAV target and receives the reflected signal. In order to evaluate the sensing performance, OFDM is used as a baseline waveform for sensing signal the conventional DL signal is used as a baseline for sensing signal. The BS transmits CSI-RS, DL- PRS, SSB, TRS, PDCCH (DMRS) or PDSCH (DMRS) to the sensing UAV target. Different comb sizes and CPI are used for the sensing signal. The sensing performance is evaluated for each signal CSI-RS, DL-PRS, SSB, TRS, PDCCH and PDSCH. The BS processes the received signal to derive range, velocity of the target and angle of arrival of the signal. Due to time limit for this study, CSI-RS and DL-PRS have a higher priority for sensing performance evaluation because they are not limited in bandwidth with 240 subcarriers as SSB and are also not mixed with communication signal such as DMRS in PDCCH and PDSCH.

Proposal 3: The sensing performance of CSI-RS, DL-PRS, SSB, TRS, DMRS of PDCCH or PDSCH is evaluated based on the agreed metrics. CSI-RS and DL-PRS have a higher priority for sensing performance evaluation.

The period of SSB is 20 ms. The minimum period of CSI-RS and DL-PRS is 4 slots. The minimum period of TRS is 20ms. These periods make the system unable to achieve a maximum unambiguous velocity to estimate the velocity that can reach 160 km/h as agreed in the UAV scenarios. At f_c = 5 GHz, the period is equal to 340 us to achieve a maximum unambiguous velocity of 160 km/h. With SCS of 15 kHz and 30 kHz, this period is smaller than a slot so CSI-RS and SSB are required to repeat in mini-slot level to achieve the required maximum unambiguous velocity. A comb-4 in time is required for SCS of 15 kHz and a comb-7 in time is required for SCS of 30 kHz

Proposal 4: The signal used for sensing purpose is required to have smaller period (e.g 340 us for fc = 5 GHz) than the current standard to satisfy the maximum unambiguous velocity of 160 km/h for UAV.

Proposal 5: Comb-4 and comb-7 in time are used for the sensing signal.

For frequency resource allocation, comb-pattern of the sensing signal affects the maximum unambiguous range as shown in Table 1. SCSs of 15 and 30 kHz are used for evaluation. In this case, in order to guarantee the maximum unambiguous range to satisfy the requirement of the UAV scenario, comb pattern 2 and 4 are used for evaluation.

	Comb 2	Comb 4	Comb 6	Comb 12
SCS = 15 kHz	4996	2498	1665	832
SCS = 30 kHz	2498	1249	832	416
SCS = 60 kHz	1250	624	416	208
SCS = 120 kHz	624	312	208	104
SCS = 240 kHz	312	156	104	52

Table 1: Maximum unambiguous range for different comb pattern

Proposal 6: Comb-2 and Comb-4 in frequency are used for the sensing signal.

3. Conclusion

Proposal 1: Level D measurement report is supported. The association of multiple measurements across time per target is reported.

Proposal 2: No assistance information is necessary to be transmitted to CN to assist the data processing in level D.

Proposal 3: The sensing performance of CSI-RS, DL-PRS, SSB, TRS, DMRS of PDCCH or PDSCH is evaluated based on the agreed metrics. CSI-RS and DL-PRS have a higher priority for sensing performance evaluation.

Proposal 4: The signal used for sensing purpose is required to have smaller period (e.g 340 us for fc = 5 GHz) than the current standard to satisfy the maximum unambiguous velocity of 160 km/h for UAV.

Proposal 5: Comb-4 and comb-7 in time are used for the sensing signal.Proposal 6: Comb-2 and Comb-4 in frequency are used for the sensing signal.