3GPP TSG RAN WG1 Meeting #122 b **R1-2507337**
Prague, Czechia, October 13th – 17th, 2025

Agenda Item: 10.5.1

Source: EURECOM

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.
  - o For other waveform and reference signals, companies are to share relevant information
  - o 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.
  - o 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

<table>
<tr><th colspan="2">Parameters</th><th>Value</th></tr>
<tr><td colspan="2">Applicable communication scenarios</td><td>UMi, UMa, RMa, SMa
UMi-AV, UMa-AV, RMa-AV</td></tr>
<tr><td>Sensing transmitters and receivers properties</td><td>Rx/Tx Locations</td><td>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.</td></tr>
<tr><td rowspan="6">Sensing target</td><td>LOS/NLOS</td><td>LOS and NLOS</td></tr>
<tr><td>Outdoor/indoor</td><td>Outdoor</td></tr>
<tr><td>3D mobility</td><td>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.</td></tr>
<tr><td>3D distribution</td><td>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.</td></tr>
<tr><td>Orientation</td><td>Random in horizontal domain</td></tr>
<tr><td>Physical characteristics (e.g., size)</td><td>Size:
• Option 1: 1.6m x 1.5m x 0.7m
• Option 2: 0.3m x 0.4m x 0.2m</td></tr>
</table>

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): $L_{TX-SPST-RX} = PL_{dB}(d_1) + PL_{dB}(d_2) + 10lg\left(\frac{c^2}{4\pi f^2}\right) - 10lg\left(\sigma_{RCS,A}\right) + SF_{dB,1} + SF_{dB,2}$

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 ($P_{n',m',n,m}^{k,p}$), Tx/Rx antenna pattern, 3 polarization matrixes, i.e., $\sqrt{P_{n',m',n,m}^{k,p}} \begin{bmatrix} F_{rx,u,\theta}\left(\theta_{rx,n',m',ZOA}^{k,p}, \phi_{rx,n',m',AOA}^{k,p}\right) \\ F_{rx,u,\phi}\left(\theta_{rx,n',m',ZOA}^{k,p}, \phi_{rx,n',m',AOA}^{k,p}\right) \end{bmatrix}^T CPM_{rx,n',m'}^{k,p} CPM_{n',m',n,m}^{k,p} CPM_{tx,n,m}^{k,p}$ $\cdot \begin{bmatrix} F_{tx,s,\theta}\left(\theta_{tx,n,m,ZOD}^{k,p}, \phi_{tx,n,m,AOD}^{k,p}\right) \\ F_{tx,s,\phi}\left(\theta_{tx,n,m,ZOD}^{k,p}, \phi_{tx,n,m,AOD}^{k,p}\right) \end{bmatrix}$
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.

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

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.

2. Discussion

2.1 Sensing metrics

The following requirements are used to evaluate UAV detection performance

Metric	Requirements
Missed Detection Probability	5%
False Alarm Rate	5%
Horizontal Positioning Accuracy	10 m @ 90%
Vertical Positioning Accuracy	10 m @ 90%
Radial Velocity Accuracy	1 m/s

Table 1: Sensing requirements

Proposal 1: The sensing requirements in UAV scenarios are defined in Table 1.

2.2 Evaluation steps

In order to set up and measure the metrics in the simulation to evaluate UAV detection performance, we follow the following steps:

1. Simulation parameter configuration

2. Sensing scenario generation

3. Drop N targets, N $\in$ {0, 5}
4. Channel generation
5. Sensing node selection
6. Sensing signal generation: sensing signal is generated based on the parameters configured in Step 1 such as sequence type, comb sizes, time and frequency resources.
7. Sensing signal transmission
8. Receive signal at the receiver
9. Channel estimation
10. Target detection: a threshold is chosen for target detection based on the requirement of false alarm rate and detection rate
11. Sensing metric calculation (if a target is detected): positioning, velocity by using 2D-FFT algorithm as the sensing algorithm. 2D-FFT algorithm is used as a baseline for the sensing algorithms
12. Sensing results: range, angle, velocity

The BSs do not cooperate together in sensing one target. Each BS senses the target and derives the target's range and velocity independently. The performance metrics are calculated independently for each BS and sensing target pair.

Proposal 2: The evaluation simulation is set up following the below steps:

1. **Simulation parameter configuration**
2. **Sensing scenario generation**
3. **Drop N targets, N $\in$ {0, 5}**
4. **Channel generation**
5. **Sensing node selection**
6. **Sensing signal generation: sensing signal is generated based on the parameters configured in Step 1 such as sequence type, comb sizes, time and frequency resources.**
7. **Sensing signal transmission**
8. **Receive signal at the receiver**
9. **Channel estimation**

10. **Target detection: a threshold is chosen for target detection based on the requirement of false alarm rate and detection rate**
11. **Sensing metric calculation (if a target is detected): positioning, velocity by using 2D-FFT algorithm as the sensing algorithm. 2D-FFT algorithm is used as a baseline for the sensing algorithms**
12. **Sensing results: range, angle, velocity**

Proposal 3: 2D-FFT algorithm is used as a baseline for the sensing algorithms.

Proposal 4: Multi-BS-cooperation sensing is not supported.

Proposal 5: The performance metrics are calculated independently for each BS and sensing target pair.

Proposal 6: Range, angle and velocity is reported in the measurement report.

2.3 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, 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, PDCCH and PDSCH. The BS processes the received signal to derive range, velocity of the target and angle of arrival of the signal.

Proposal 7: OFDM is used as the baseline waveform of sensing signal.

Proposal 8: The sensing performance of CSI-RS, DL-PRS, SSB, DMRS of PDCCH or PDSCH is evaluated based on the agreed metrics.

2.4 Beam configuration

The BS transmits the sensing signal in the beams. The BS uses beam sweeping to cover an area in the sky in order to detect the UAV. Different beams are multiplexed in time division where the beams are transmitted alternatively from the first beam to the last beam then start again from the first beam in time domain.

Proposal 9: Beams are multiplexed in TDM for beam sweeping.

2.5 Self-interference

In monostatic sensing, the BS transmits and receives signal in the same frequency band. For this reason, a self-interference between the Tx and Rx in the BS happens. The BS Tx-Rx isolation needs to be determined. Consequently, the Tx power must be smaller than sum of the BS Tx-Rx isolation and the Rx tolerable power to ensure the sensing performance under the impact of the self-interference.

Proposal 10: the Tx power is smaller than sum of the BS Tx-Rx isolation and the Rx tolerable power to ensure the sensing performance under the impact of the self-interference.

3. Conclusion

Proposal 1: The sensing requirements in UAV scenarios are defined in Table 1.

Proposal 2: The evaluation simulation is set up following the below steps:

1. **Simulation parameter configuration**
2. **Sensing scenario generation**
3. **Drop N targets, N $\in$ {0, 5}**
4. **Channel generation**
5. **Sensing node selection**
6. **Sensing signal generation: sensing signal is generated based on the parameters configured in Step 1 such as sequence type, comb sizes, time and frequency resources.**
7. **Sensing signal transmission**
8. **Receive signal at the receiver**
9. **Channel estimation**
10. **Target detection: a threshold is chosen for target detection based on the requirement of false alarm rate and detection rate**
11. **Sensing metric calculation (if a target is detected): positioning, velocity by using 2D-FFT algorithm as the sensing algorithm. 2D-FFT algorithm is used as a baseline for the sensing algorithms**
12. **Sensing results: range, angle, velocity**

Proposal 3: 2D-FFT algorithm is used as a baseline for the sensing algorithms.

Proposal 4: Multi-BS-cooperation sensing is not supported.

Proposal 5: The performance metrics are calculated independently for each BS and sensing target pair.

Proposal 6: Range, angle and velocity is reported in the measurement report.

Proposal 7: OFDM is used as the baseline waveform of sensing signal.

Proposal 8: The sensing performance of CSI-RS, DL-PRS, SSB, DMRS of PDCCH or PDSCH is evaluated based on the agreed metrics.

Proposal 9: Beams are multiplexed in TDM for beam sweeping.

Proposal 10: the Tx power is smaller than sum of the BS Tx-Rx isolation and the Rx tolerable power to ensure the sensing performance under the impact of the self-interference.