3GPP TSG RAN #102

Edinburgh, UK, December 11-15, 2023

RP-233326

Discussion on Rel-19 Channel Modeling for ISAC

Agenda Item:	9.1.1.7
Source:	Intel Corporation
Document for:	Discussion

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Channel modeling for Integrated Sensing & Communication (ISAC)

Background

ISAC SI

From RP-232745

- References: RWS-230488, RP-231540, RP-232617
- RAN to select a small number of ISAC use cases from TR22.837, and to identify appropriate corresponding information needed for the point below, i.e. scenarios, frequency ranges and sensing modes.
  - Also consider the ongoing SA1 TS22.137
- Potential objectives:
  1. A RAN1-led study objective to define channel modelling details for sensing using 38.901 (if applicable to the selected use cases) as a starting point, and taking into account relevant measurements, including:
     - a. modelling of sensing targets and background environment, including, for example (if needed by the selected use cases), radar cross-section (RCS), mobility and clutter/scattering patterns;
     - b. spatial consistency.

     ~~This objective to start after completion of the first (RAN-led) objective if not already done in SID.~~
  - Anything else?

ISAC	**SI only, starting from 2Q'24, ~1 TU for 15 months. Focusing on channel model; check in Sept'24 for possibly additional study beyond channel model**

Channel modeling for Integrated Sensing & Communication (ISAC)

Identification of prioritized use-cases and scenarios

Potential use-cases and Deployment Scenarios from TR 22.837 and TS 22.137

Use-case categories

- Smart transportation incl. UAV
- IIoT
- Smart cities
- Smart homes/office spaces
- Environmental sensing
- Sensing-assisted comms

Some example **deployment scenarios**:

- Outdoor scenarios: Dense urban, highway for smart transportation
- Indoor factories
- Indoor office

Application areas	Illustrative examples
Smart transportation	• Assistance to autonomous driving • On-road parking space detection • Real-time vehicle classification and tracking • Vehicle speed measurements • UAV tracking and coordination
IIoT	• Detection, localization, tracking of equipment and humans • Surveillance and proximity detection • Equipment control • Object recognition and authentication
Smart cities	• Public space monitoring and surveillance • Smart street lighting • Crowd monitoring and management
Smart homes/ office spaces	• Radio fencing and human presence detection • Indoor localization and tracking • Fall detection • Sensing for biomedical use-cases, e.g., respiration monitoring
Environmental sensing	• Pollution and emissions monitoring • Weather monitoring and prediction • Large-scale animal migration monitoring
Sensing-assisted comms	• Beam management • Radio conditions monitoring for assisting RRM • Sensing-assisted CSI

Identification of prioritized use-cases (1/2)

- As summarized in the previous slide, TR 22.837 and TS 22.137 identify a large number of use-cases and corresponding diverse requirements for ISAC.
- Considering the limited time budget (1 TU per meeting for 15 months) expected for the SI, it would be imperative to identify a limited set of use-cases for ISAC when developing channel models.
- Although it is desirable to develop channel model(s) that is/are sufficiently generic to apply to most use-cases of interest, it would be important to identify certain use-cases as prioritized ones in relation to channel model development for ISAC.
  - *Such consideration is necessary to enable development of suitable models for Radio Cross Section (RCS) and background/clutter patterns.*

Identification of prioritized use-cases (2/2)

For initial studies on ISAC, focus on smart transportation including UAV tracking

- Key use-cases that should be prioritized for NR-based ISAC since they would benefit the most from NR-based sensing capabilities, either due to lack of alternative technologies or to enable improved performance using NR-based sensing (via diversity on top of alternative technologies like radar, camera), while allowing for simpler models for RCS and environment/clutter modelling (latter can be realized using existing SCM in TR 38.901 to model reflecting clusters)
  - UAV tracking (flight trajectory tracking, UAV collision avoidance, UAV intrusion detection)
  - Assistance to autonomous driving (Sensing Assisted Automotive Maneuvering and Navigation)

- Following use-cases may be considered in a future release since they are likely to involve complex modelling of RCS and environment/clutter patterns while many of these use-cases can be already addressed much more appropriately using alternative technologies, e.g., cameras, radar, WiFi-based sensing.
  - Environment monitoring
  - Smart homes/ office spaces incl. intruder detection and health monitoring
  - Motion monitoring incl. gesture recognition
  - Sensing-aided communications

Deployment scenarios for ISAC

- While outdoor deployments may be prioritized, the channel models for sensing should also be applicable to indoor deployments as well as outdoor-to-indoor (O2I) links.
  - Environment/clutter modelling may be limited to multi-path modelling realized in current description of SCM in TR 38.901.
- Both FR1 and FR2 (FR2-1 and FR2-2) bands should be considered for channel modelling for ISAC use-cases.

RF Sensing Types

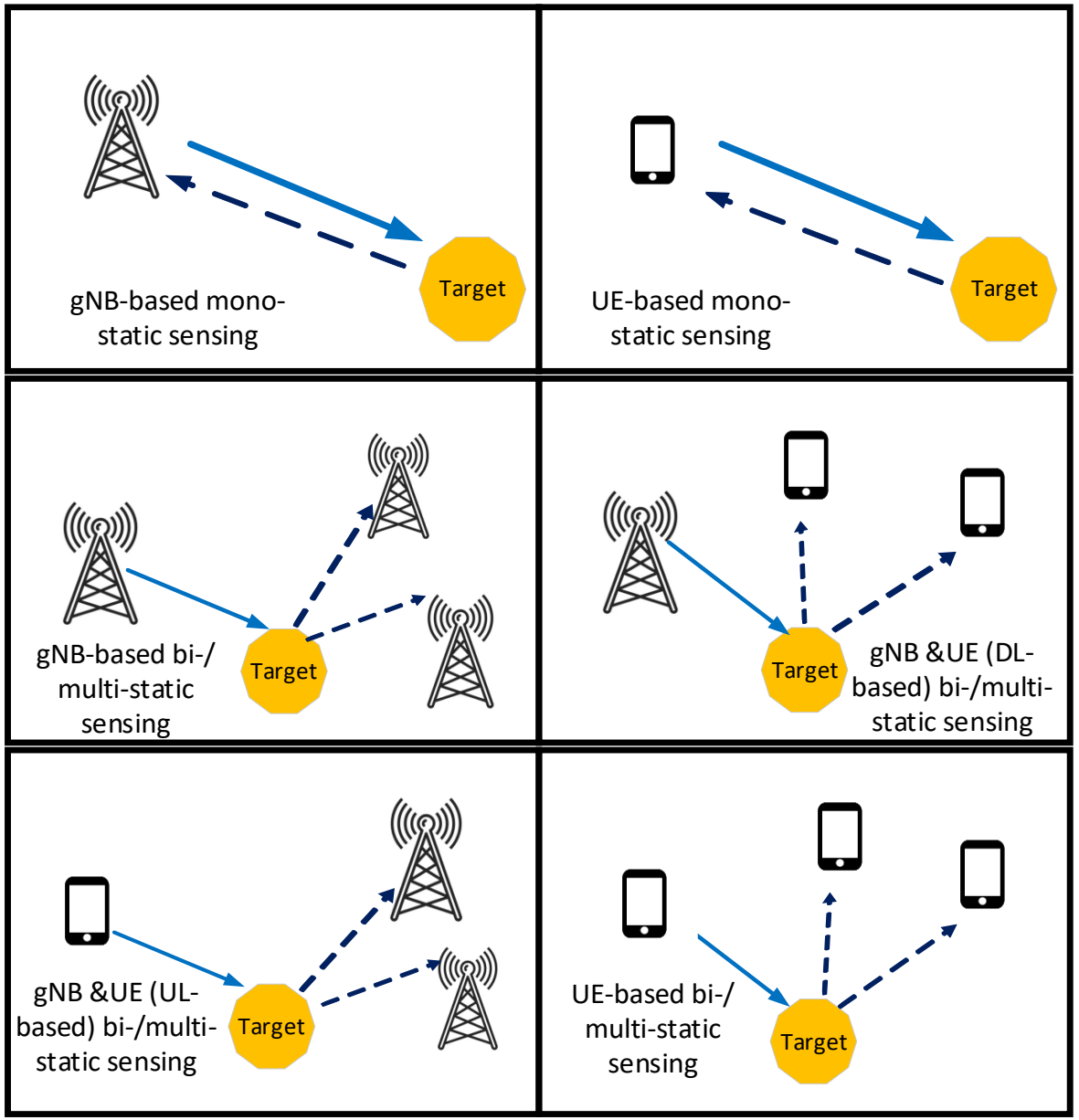
Different sensing types are relevant depending on use cases and should be considered when developing channel models

- Mono-static
- Bi-static
- Multi-static

Different combinations of gNBs and UEs as Tx/Rx nodes for mono-/bi-/multi-static sensing utilizing Uu and SL.

For mono-static sensing, duplex constraints should be considered

- As a baseline, assume constraints on sensing range due to half duplex
  - E.g., Consider an effective "close-in distance" within which targets may not be detected due to half duplex constraint at mono-static sensing nodes (gNB or UE).
- Full duplex based on Tx/Rx isolation can be deferred to a future release.



Channel modeling for Integrated Sensing & Communication (ISAC)

Potential Scope & Objectives

Channel modelling for ISAC

Currently, channel models that allow for modelling of non-Tx/Rx objects in a deterministic manner do not exist within scope of 3GPP channel models.

Necessary modifications to NR channel modelling for sensing:

- Modelling of reflection off targets with spatial consistency
- Modelling of movement of targets ensuring spatial consistency
- Modelling of non-ideal reflectivity of sensing targets via modelling of Radar Cross Section (RCS)

Modelling of non-Tx/Rx objects (deterministic) and environment (possibly randomized) while maintaining spatial consistency.

Potential Scope & Objectives

- Develop channel models for evaluation of NR-based sensing for support of Integrated Sensing and Communication (ISAC) [RAN1-led]
  - Identify necessary channel models for evaluation of RF sensing using TR 38.901 as a starting point, and taking into account relevant measurements for the following prioritized use-cases of object detection and tracking:
    - UAV tracking (flight trajectory tracking, UAV collision avoidance, UAV intrusion detection)
    - Assistance to autonomous driving (Sensing Assisted Automotive Maneuvering and Navigation)
  - The following should be ensured by the developed channel model(s):
    - Modelling of reflection off targets with spatial consistency
    - Modelling of movement of targets ensuring spatial consistency
    - Modelling of non-ideal reflectivity of sensing targets via modelling of Radar Cross Section (RCS)
    - Modelling of environment/clutter patterns using multipath modelling based on SCM in TR 38.901 as a starting point
    - Applicable frequency ranges: FR1, FR2-1, FR2-2
    - Applicable sensing modes: Mono-static, bi-static, multi-static
    - Applicable link types: Uu and Sidelink
    - Applicable deployment scenarios: outdoor, indoor, mix of outdoor and indoor

Appendix I

Channel modeling options for NR Sensing

Potential approaches to channel modelling for RF Sensing Evaluations (1/2)

- Option 1: Hybrid approach involving ray tracing + statistical modelling approach for spatial channel models
  - Adopted by IEEE 802.11bf.
  - Computationally complex, limited to specific choices of environments (that can be supported by measurements), and specific assumptions on dimensions of target objects and their locations relative to the selected environment.

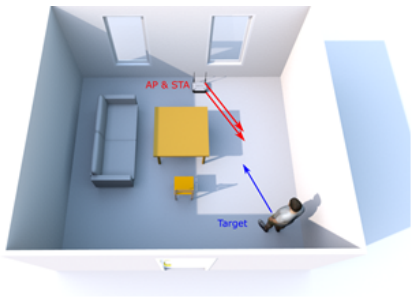


Figure 4. Deployment of living room

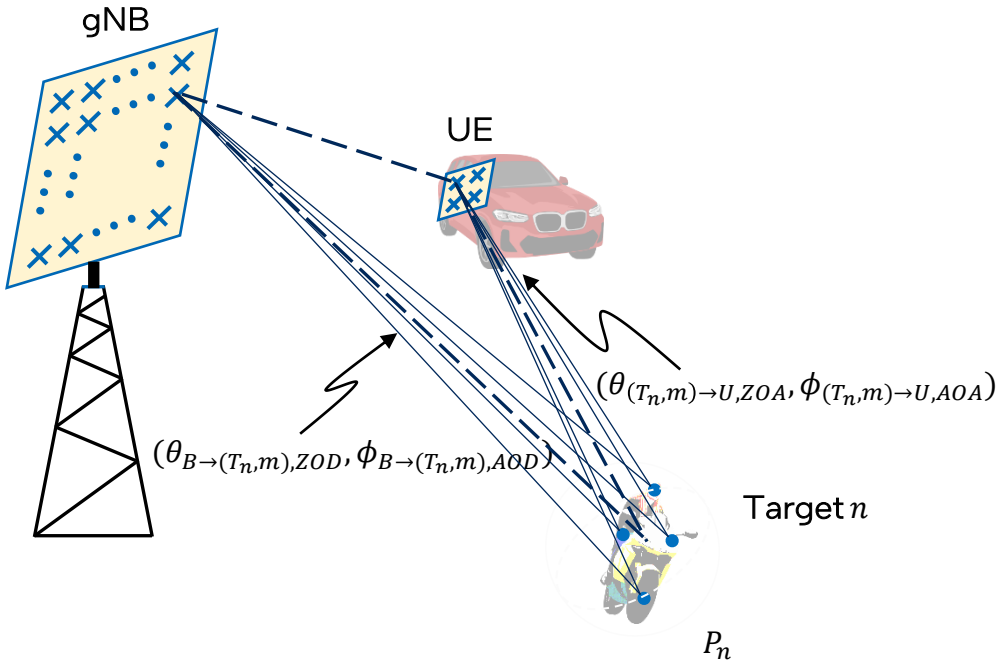
Table 1. Specific parameters of the indoor scenarios

Object	Size		Material
Chair	2.8m x 1.05m x 1m	(L x W x H)	wood
Chair with feet	1.05m x 1.05m x 1m	(L x W x H)	wood
Table1	1.5m x 0.7m x 0.8m	(L x W x H)	wood
Table2	1m x 0.5m x 0.8m	(L x W x H)	wood
Target	0.3m x 1.5m	(R x H)	wood
Door	1m x 2.5m	(W x H)	wood
Windows	1.5m x 1.5m	(W x H)	Glass
Wall			concrete
Floor			concrete
Ceiling			concrete

From: IEEE P802.11: "TGbf Evaluation Methodology and Simulation Scenarios", doc.: 802.11-21/0876r3

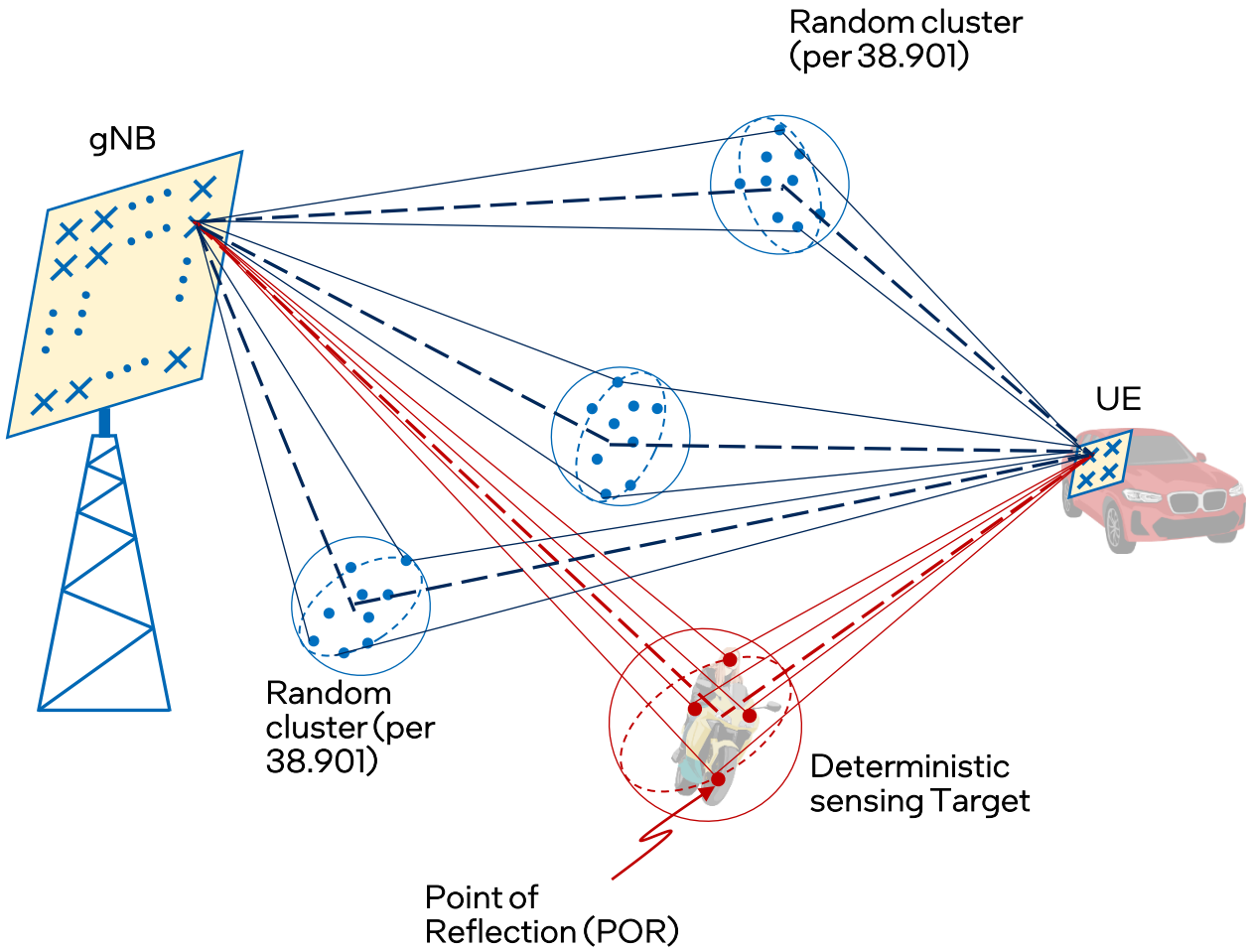
Potential approaches to channel modelling for RF Sensing Evaluations (2/2)

- Option 2: Adaptation of existing 3GPP spatial channel model in TR 38.901
  - A deterministic cluster to model a target
  - Random cluster-based channel model used to model time-varying environment.
  - In case of more than one sensing target, the channel components of different targets are generated independently.
  - In case of more than one BS and/or UE, ensure spatial consistency in generation of channel components of the same sensing object for different BS-UE links.
  - In case of moving sensing target(s), the time evolution of the channel parameters for the target(s) can be modeled based on options in TR 38.901.
  - *Preferred option*

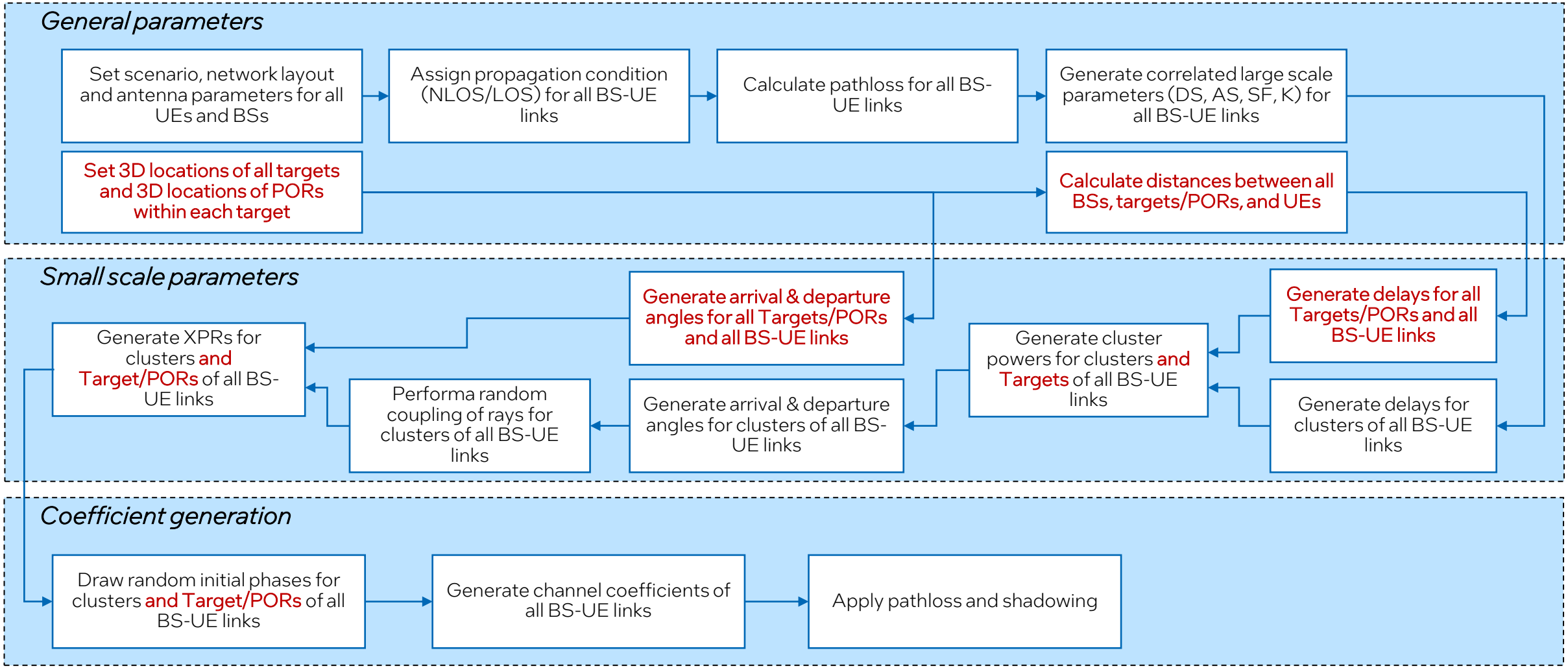


Adaptation of 3GPP SCM in TR 38.901 (1/2)

- A deterministic cluster to model a target - an illustrative example for bi-static case:
  - For a given Tx-Rx link, follow the channel coefficient generation procedure like SCM described in Section 7.5 of 38.901 for NLOS channels, but with one cluster per target at given coordinates with appropriate cluster parameter values
    - Additional reflections for a path from/to Tx/Rx node and target can be considered further



Adaptation of 3GPP SCM in TR 38.901 (2/2)

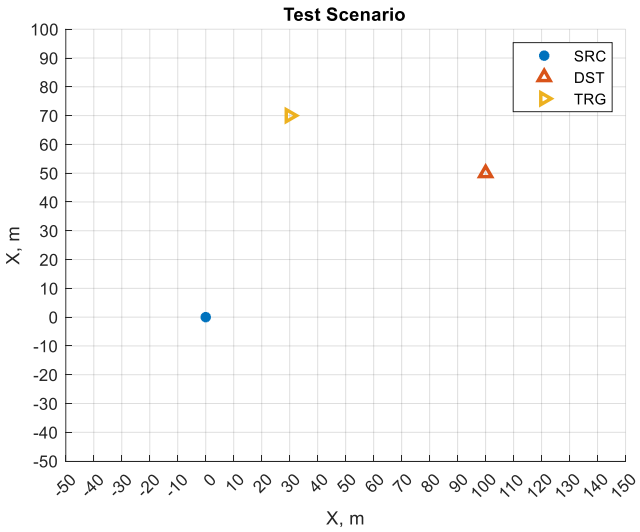


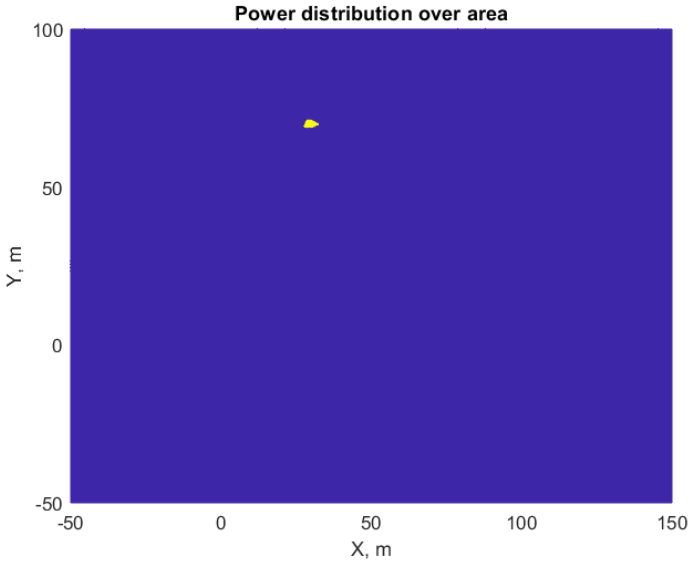
Initial examples of channel power distribution map

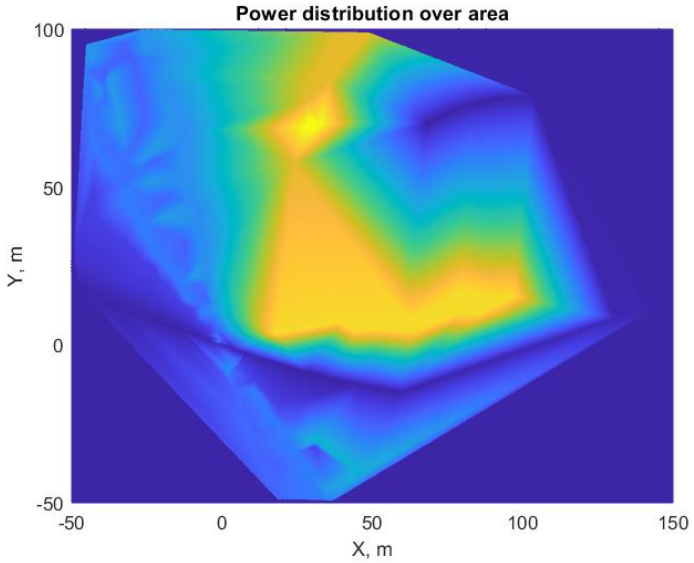
- Test scenario:
  - SRC = [0, 0, 10]
  - DST = [100, 50, 3]
  - TRG = [30, 70, 2]
  - #POR = 20
  - POR generation
    - X = [-2.5, 2.5]
    - Y = [-1.5, 1.5]
    - Z = [-1, 1]
  - UMA NLOS/LOS O2O (Small Scale)
  - UMA Large Scale

- Modelling assumptions:
  - Channel between SRC and DST= NLOS
  - Deterministic sensing Target = 1
  - Number of stochastic clusters = 0
  - Number of strong clusters = 0

- Modelling assumptions:
  - Channel between SRC and DST= NLOS
  - Deterministic sensing Target = 1
  - Number of stochastic clusters = 20
  - Number of strong clusters = 2







Appendix II

RAN-level KPIs for ISAC

Potential KPIs for ISAC (1/2)

KPIs and target performance requirements for sensing from TS 22.137

- Key components @ RAN level: (1) Presence detection; (2) Location, velocity estimation for target

Scenario	Sensing service category	Confidence level [%]	Accuracy of positioning estimate by sensing (for a target confidence level)		Accuracy of velocity estimate by sensing (for a target confidence level)		Sensing resolution		Max sensing service latency [ms]	Refreshing rate [s]	Missed detection [%]	False alarm [%]	Sensing service description in a target sensing service area
			Horizontal [m]	Vertical [m]	Horizontal [m/s]	Vertical [m/s]	Range resolution [m]	Velocity resolution (horizontal/ vertical) [m/s x m/s]					
Object detection and tracking	1	95	10	10	N/A	N/A	10	10	1000	1	5	2	Indoor/outdoor (e.g., detection of human, UAV)
	2	95	5	1	1	1	1	1	1000	1	5	5	Outdoor (e.g., detection of human, UAV) requiring higher performance than category 1
	3	95	1	N/A	1	N/A	1	1 x 1	100 (NOTE 2), or 1000 (NOTE 3)	0.1	2	2	Indoor/outdoor (e.g., detection tracking of human, animal, UAV)
	4	99 for public safety, otherwise, 95	0.5	0.5	1.5 for pedestrian, 15 for vehicle, otherwise, 0.1	1.5 for pedestrian, otherwise, N/A	0.5	5 x 5 for factories 0.5 may be needed	250	0.25	1	5	Indoor/outdoor (e.g., detection tracking of human, animal, UAV, AGV, vehicle) requiring higher performance than category 3
	5	95	short range radar; 0.02, otherwise; 0.1	0.5	0.03	N/A	0.4	0.1 x 0.6	50	0.05	1	1	Indoor/outdoor (e.g., detection tracking of human, animal, UAV, AGV, vehicle) requiring higher performance than category 4
Environment monitoring	6	95	10	0.2	N/A	N/A	N/A	N/A	6000	60	10	3	Nature of environments monitored by sensing.
Motion monitoring	7	95	N/A	N/A	N/A	N/A	N/A	N/A	60000	60	5	5	Human motions and activities obtained by sensing (NOTE 4).
	8	95	0.2	0.2	0.1	0.1	0.375	0.3	5	0.1	5	5	Human hand gestures obtained by sensing

NOTE 1: The additional information on some of the performance requirements can be found in [2].
NOTE 2: The value 100 ms is sourced from [3] and is valid for sensing at crossroads.
NOTE 3: To realize 1m granularity tracking, when the velocity resolution is 1 m/s, the maximum corresponding sensing service latency is 1 s.
NOTE 4: Additional KPI on human motion rate accuracy is defined for contactless sleep/sports monitoring [2].

Potential KPIs for ISAC (2/2)

Potential KPIs/metrics (depending on specific scenario and use-case combinations)

- **Probability of detection** of target object, subject to bounds on **false alarm**
  - FFS: Detection of multiple target objects within a predefined area of interest
- **Accuracy of localization of target object**
  - Range and Field of View (FoV) (equivalent to ranging angle) of detection/localization
- **Accuracy of estimation of velocity/Doppler** of target object
- Study should include considerations on **resolution** of:
  - Range/distance
  - Angle
  - Speed

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