3GPP TSG RAN #101

Bangalore, India, September 11th – 15th 2023

RP-232559

Discussion on Rel-19 Channel Modeling Studies

Agenda Item: 8A.2.11

Source: Intel Corporation

Document for: Discussion

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Potential Scope for Channel Modeling Study

- 7 – 24 GHz (mid-band) channel model verification
- Channel modeling for Integrated Communication & Sensing (ICAS)
  - Including a study on identification of target scenarios, use-cases, and KPIs at the RAN level.

7 – 24 GHz (mid-band) Channel Model Verification

Channel Modeling for Mid-band (7 – 24 GHz)

- 5G channel model development in RAN1 was primarily based on sub-6 and mmWave band channel data
  - > 80% data submitted to RAN1 was from mmWave/sub-6 bands

- Propose evaluation/calibration/validation of large scale channel modeling parameters applicable for this frequency range in TR 38.901

- Validation may include study on near-field LOS MIMO
  - Spherical wave consideration for predominantly LOS channels (very little to no scattering/reflection)
  - Indoor deployments with large antenna arrays and large spacings (lap-top, TVs)
  - Could potentially be more relevant for mid-band operations

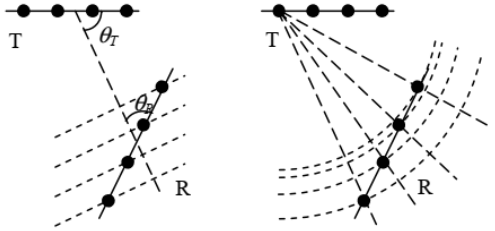


Figure 1: (a) Point-source model. (b) Distributed-source model.

Ref: J. Jiang and M. A. Ingram, "Distributed Source Model for Short-Range MIMO"

- Note: no regulatory study is expected to be needed for channel model verification.

Potential Scope & Objectives

- Evaluate and validate channel models for frequencies between 7 to 24 GHz
  - The evaluation should focus on verifying channel models with large bandwidth and large antenna arrays
  - Evaluation should include effects of near-field LOS MIMO, and if needed updating the near-field LOS MIMO modeling in 38.901 to better fit practical channels in 7 to 24 GHz.
- Suggested Timeline
  - Suggest to start the SI with two quarter delay. This may enable companies to better prepare for the evaluations for the channel model verification.
  - Start SI from beginning of Q3, 2024.
  - Target completion by end of Q2 2025.

Channel modeling for Integrated Communication & Sensing (ICAS)

Channel modeling for Integrated Communication & Sensing (ICAS)

Motivation & Background

RF Sensing in NR systems: Background and Motivation

NR-based RF sensing

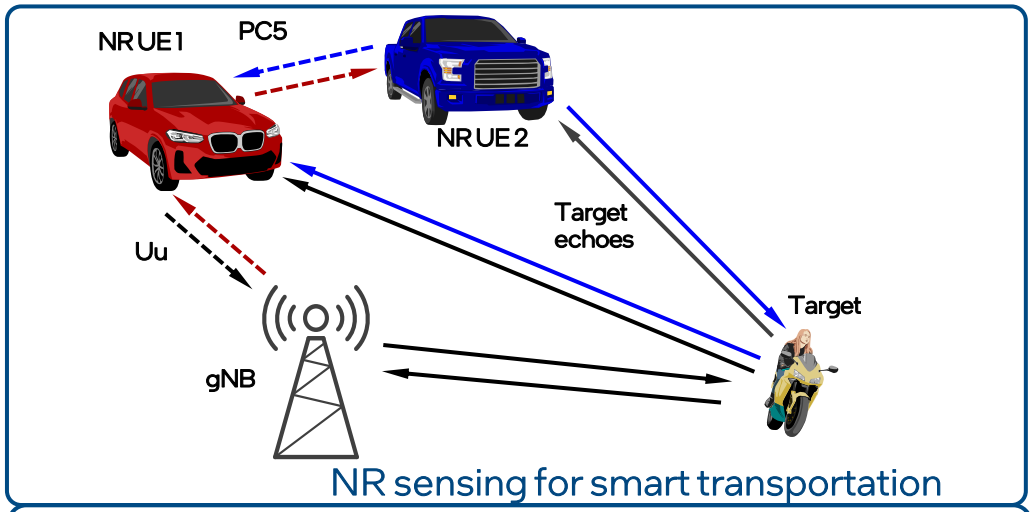
- A new Location-Based Service (LBS) leveraging on NR positioning framework

NR positioning features specified in Rel-16/17/18

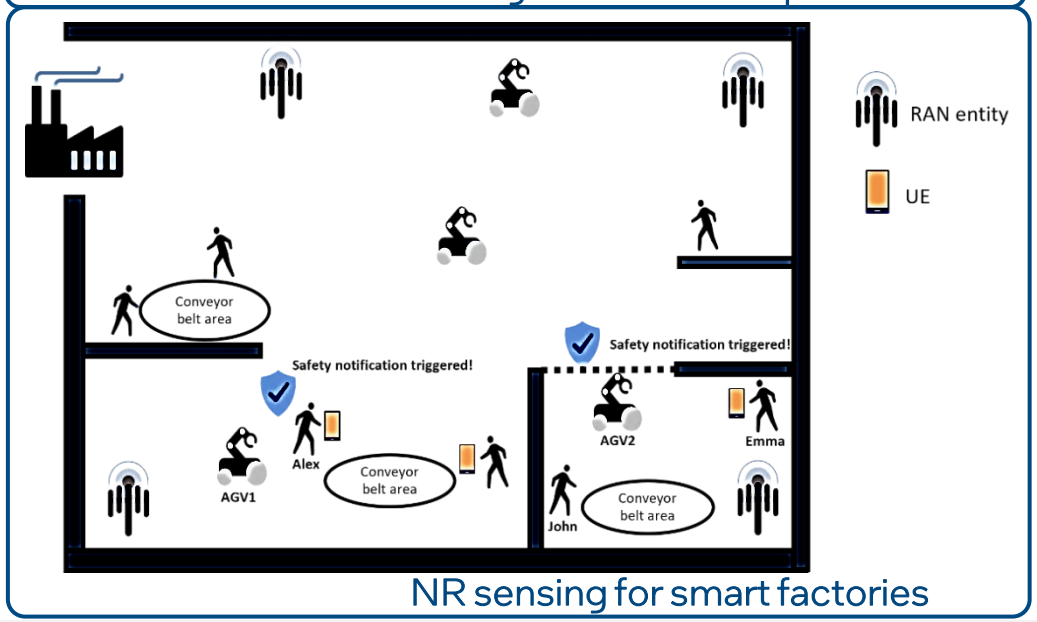
- Already support various methods over Uu and/or PC5 interfaces focusing on devices which transmit/receive NR signals.

Further evolution

- Wireless sensing capability is a natural evolution of the positioning framework, enabling environment sensing, presence detection, etc. in scenarios like smart transportation, IIoT, smart cities, and smart homes.
- New RAN features to include support of:
  - Localization of "device-free" targets (e.g., objects, humans, etc.) based on detection of NR signals reflected off such objects.
  - Velocity estimation of targets.



NR sensing for smart transportation



NR sensing for smart factories

RF sensing vs. communications

Wireless sensing may involve one or more of:

- (i) Detection of presence, (ii) localization, (iii) determination of velocity, and (iv) classification, incl. determination of shape/size, of a target that does not participate as a wireless transmitter or receiver.

Key difference from communications (and positioning)

- Sensing involves entities that are neither a transmitter or a receiver of wireless signals.
- Equivalent to the problem of estimating the wireless channel to and/or from a target object via reception of signals reflected off it.
  - The signals can be realized via appropriately designed reference signals/pilot signals known at the receiving node(s).

Currently, channel models that allow for modelling of such entities in a deterministic manner do not exist within scope of 3GPP channel models.

Why NR-based sensing?

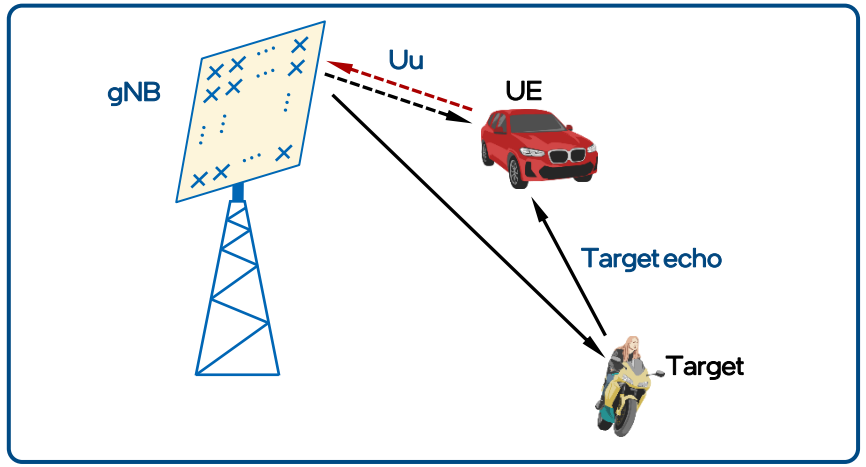
- Support new and existing use-cases by utilizing already-available NR air interface for communications with Tx/Rx from/at NR base stations and UEs.
  - For many use-cases with existing sensors, RF sensing can offer additional reliability via diversity.

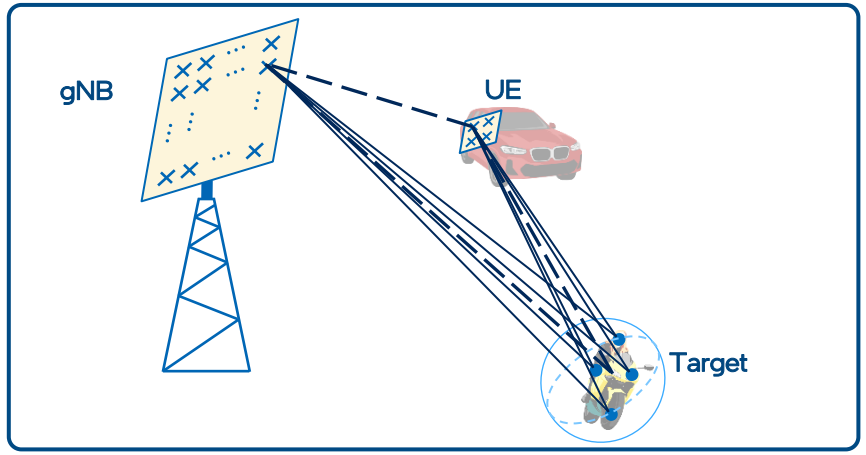
- NR systems offer ubiquitous availability spanning outdoor and indoor environments, LOS and NLOS links, use-cases spanning larger areas and mobility, collaboration between multiple NR BSs and UEs for accurate sensing, etc.

NR Sensing: Evolution of NR Positioning

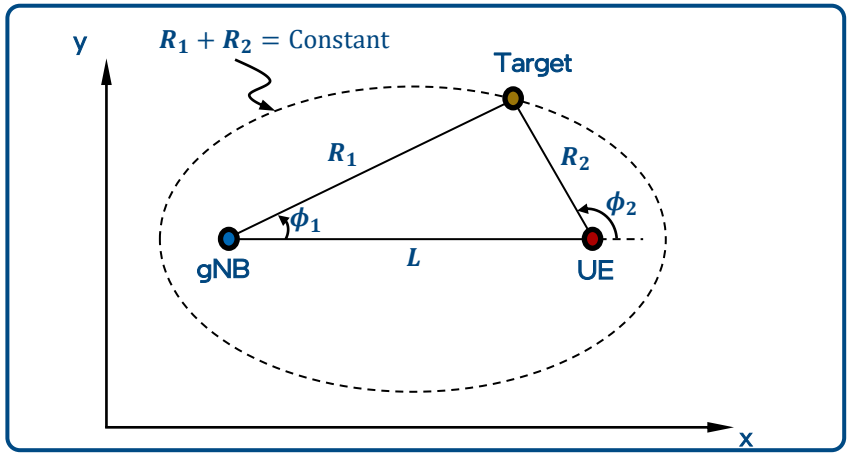
The NR positioning framework is the most suitable starting point to enable NR-based sensing

- Ranging, localization, and object movement detection are important for sensing which belong to positioning scope.
- For coordination among UEs, and between UE and network, NR architecture/protocols for positioning/ranging could be the starting point.
  - CN or discovery can be used to detect peer UEs.
  - SLPP/LPP/NRPPa can be used to share the sensing results (RF based and non-RF based) to anchor UE or LMF for further calculations/post-processing.

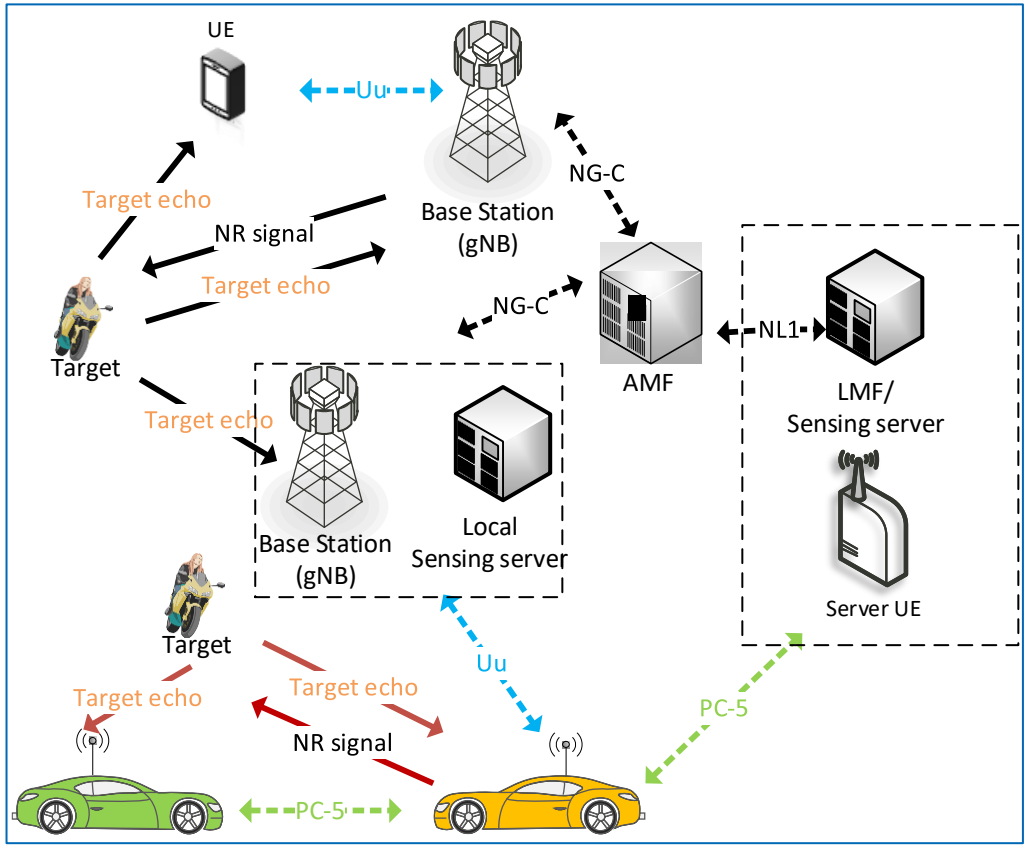


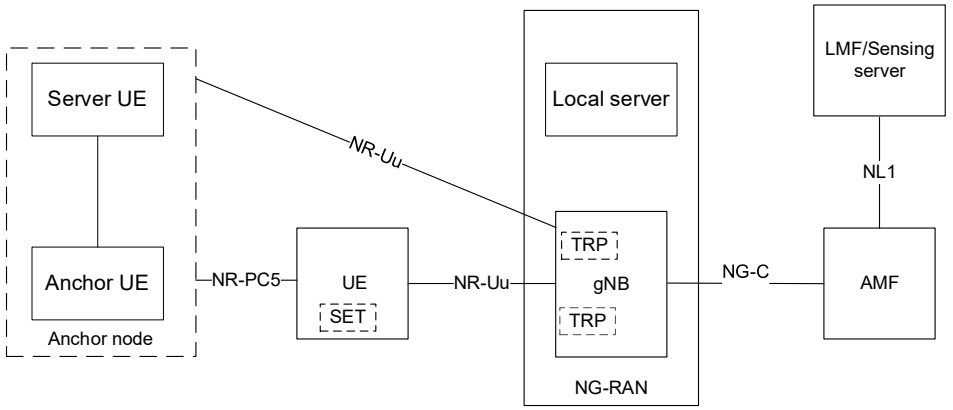


In this example, the position of the target can be determined using AOA and TDOA measurements



NR-based RF Sensing - Architecture





- For UE-involved sensing, consider both in-coverage and out-of-coverage UEs.

- Target: Object to be detected.
- Anchor/Server UE: A UE who supporting sensing management and/or calculation for UE out of coverage, e.g., manage the sensing group, resources, providing positioning-related information, sensing results calculation etc., over the SL interface.
- Local Sensing Server: Integrated in a gNB or collocated with a gNB.

Channel modeling for Integrated Communication & Sensing (ICAS)

Use Cases & KPIs

Potential use-cases and Deployment Scenarios

- Smart transportation and 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

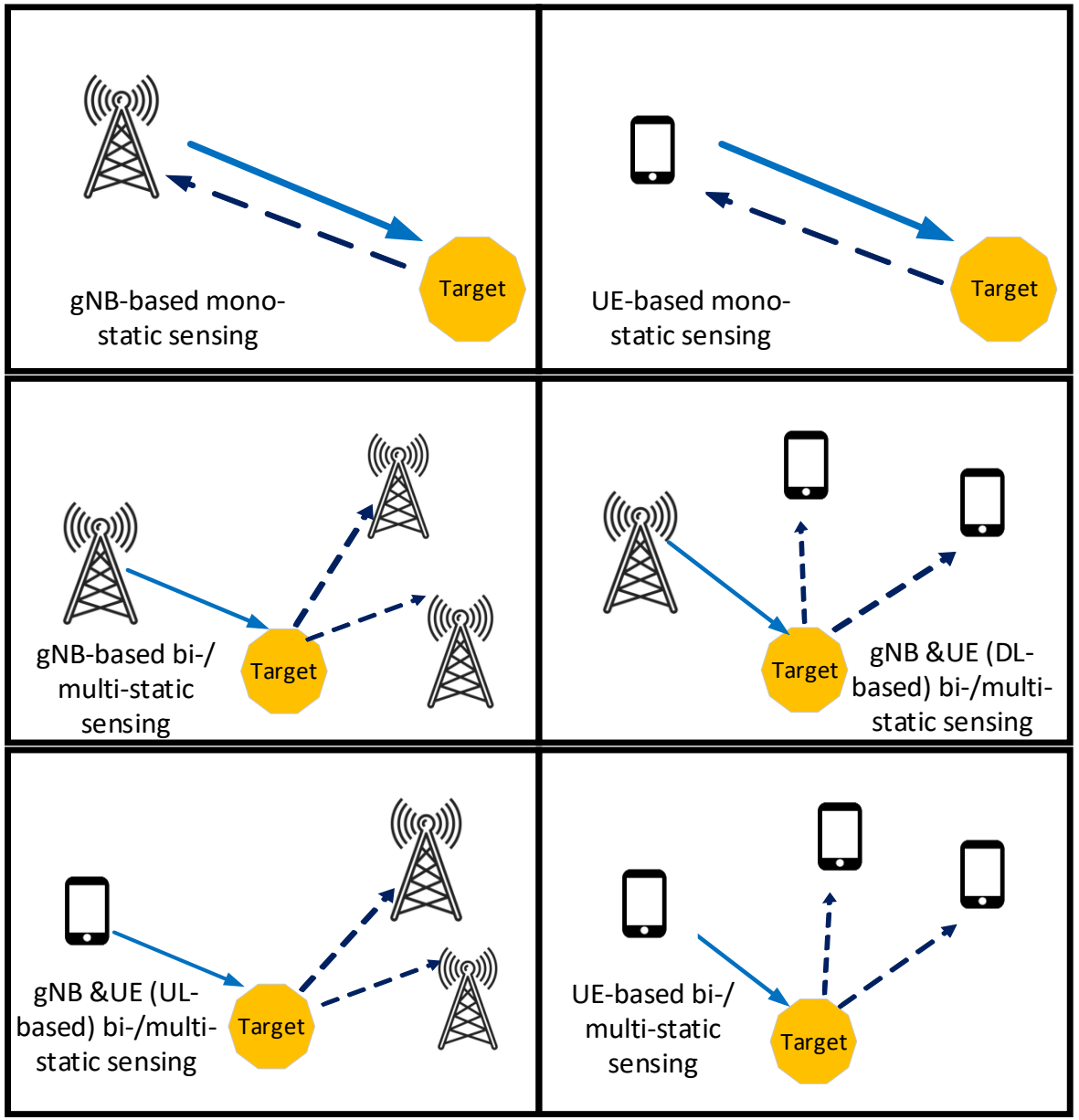
RF Sensing Types

Different sensing types are relevant depending on use cases

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

For mono-static sensing, duplex constraints need careful consideration.

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



Some specific considerations for initial studies on ICAS

For mono-static sensing, duplex constraints should be considered as part of the study on identification of scenarios, use-cases, and KPIs for ICAS

- 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.

For initial studies on ICAS, focus on enabling wireless sensing capabilities using NR deployments

- Use of sensing results to aid communications may be realized by advanced implementations.
  - Enabling availability of suitable sensing results at gNBs (e.g., from location/sensing server) may be considered.
- Further studies on optimized support of sensing to aid communications can be deferred to a future release.

Potential metrics of interest for wireless sensing (1/2)

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

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

Potential metrics of interest for wireless sensing (2/2)

KPIs and target performance requirements for sensing

- Two general category of problems: (1) Detection; (2) Object property estimation (e.g., location, shape, size, velocity, etc.)

Scenario	Sensing service area (indoor, outdoor, etc.)	Confidence level [%]	Positioning accuracy by sensing (for a target confidence level)		Velocity estimation accuracy by sensing (for a target confidence level)		Sensing resolution		Service latency [ms]	Refreshing rate [s]	Missed detection	False alarm by sensing [%]	Motion rate accuracy
			Horizontal [m]	Vertical [m]	Horizontal [km/h]	Vertical [km/h]	Size resolution (horizontal/vertical) [m x m]	Velocity resolution (horizontal/vertical) [km/h x km/h]					
Outdoor Use Case1			≤0.5m		≤0.5m/s		≤0.5m	≤0.5m/s	50-100ms	33.3-50ms			
Outdoor Use Case2		95%	0.5m	1m	1km/h	1km/h	0.5m2	1 km/h×km/h	100ms	0.1s			
Indoor Use Case1		95%							10s	0.1Hz			<=2 times/min
Indoor Use Case2			0.01~0.1m	0.01~0.1m	0.01~0.1m/s	0.01~0.1m/s	0.01~0.1m	0.01~0.1m/s					

From: 3GPP S1-222108r5, "Pseudo-CR on consolidated potential KPIs for sensing scenarios".

Channel modeling for Integrated Communication & Sensing (ICAS)

Potential Scope & Objectives

Channel modelling for RF Sensing evaluations

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

- Study NR-based sensing [RAN Plenary-led]
  - Study use-cases, scenarios, and spectra considering use-cases identified in TR 22.837. Identify KPIs and target performance requirements for sensing
  - Candidate KPIs at RAN-level: Presence detection, Distance (range), direction (angle), Doppler (velocity) estimates for device-free target(s).
- Study NR-based sensing [RAN1-led]
  - Identify necessary modifications to NR channel modelling in TR 38.901 to incorporate reflection off device-free target objects for evaluation of radio-based sensing. 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)

- Timelines & Study Logistics
  - Suggest to start with use case/scenario SI in RAN Plenary for two quarters. This allows experts from other WGs other than RAN1 to be able participate and provide inputs on the use cases and scenarios.
  - Followed by channel modeling SI in RAN1. Align the study timing for the channel modeling SI for ICAS and channel modeling SI for 7 – 24 GHz.
  - RAN Plenary-led SI at start of Q1 2024 and complete by end of Q2 2024.
  - RAN1-led SI at start of Q3 2024 and complete by end of Q2 2025.

Appendix

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.

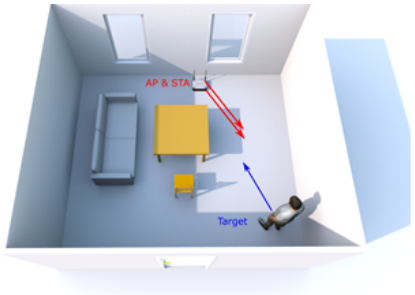


Figure 4. Deployment of living room

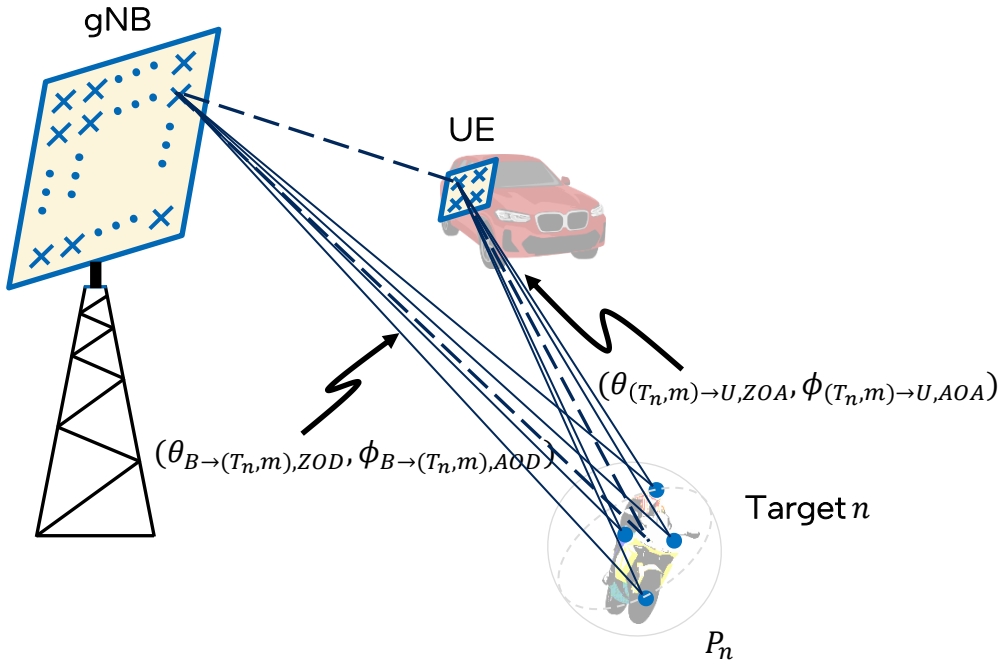
Table 1. Specific parameters of the indoor scenarios

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

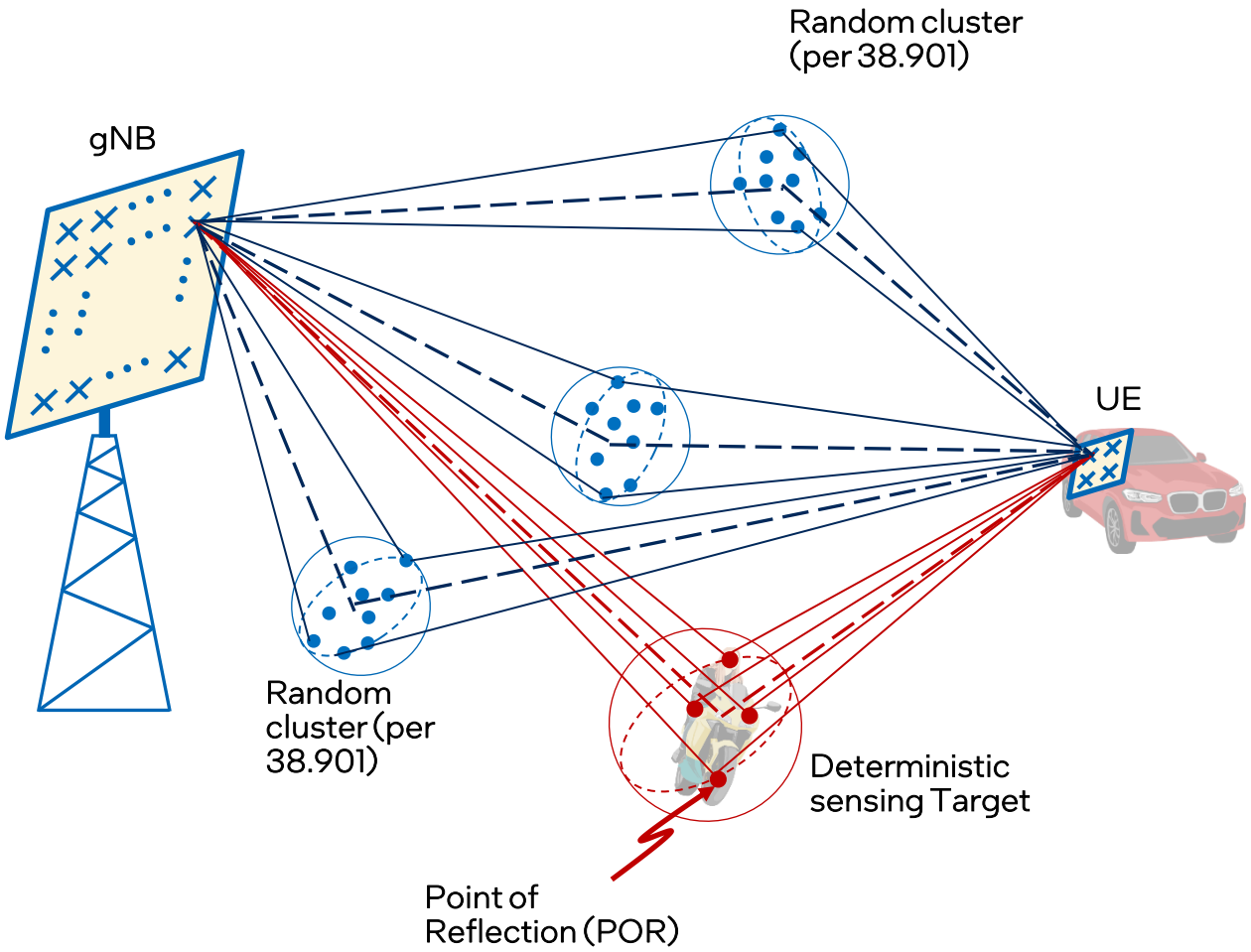
Potential approaches to channel modelling for RF Sensing Evaluations (2/2)

- 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*

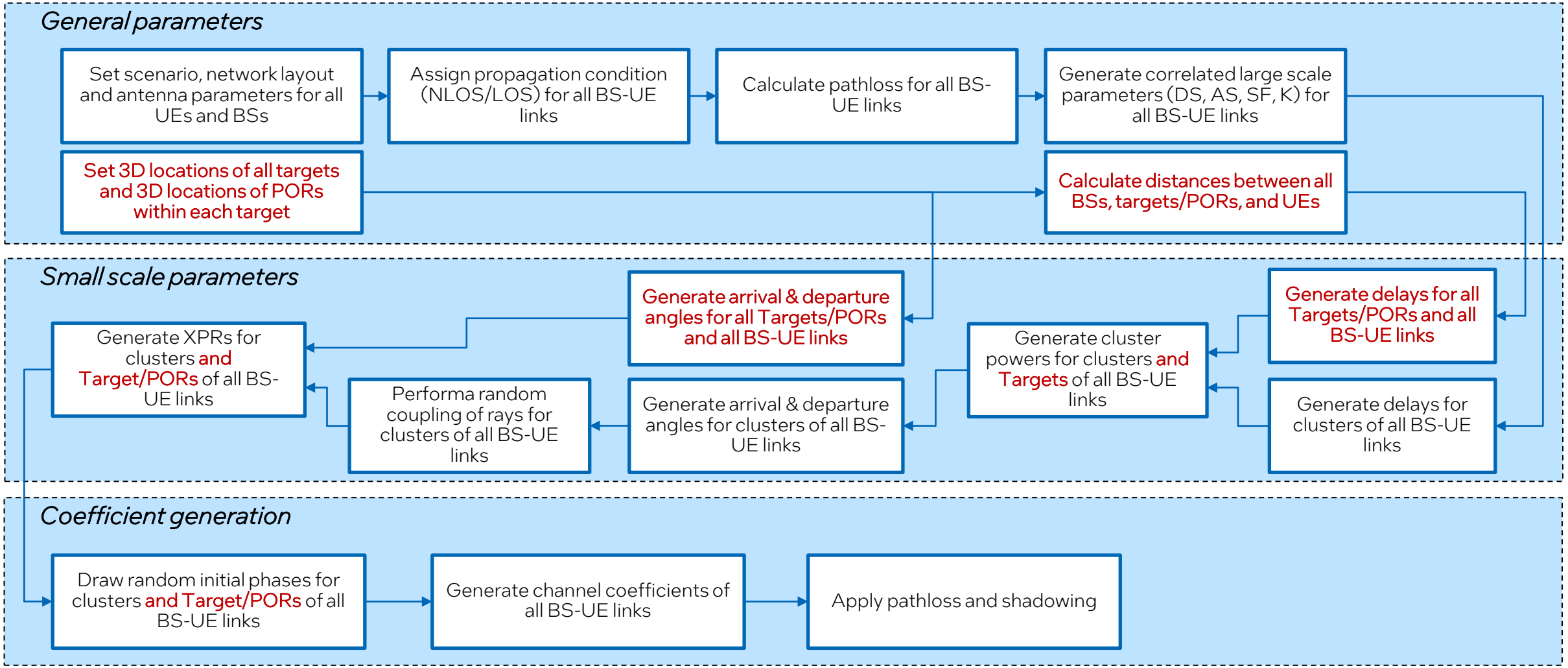


Adaptation of 3GPP SCM in TR 38.901 (1/2)

- 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)

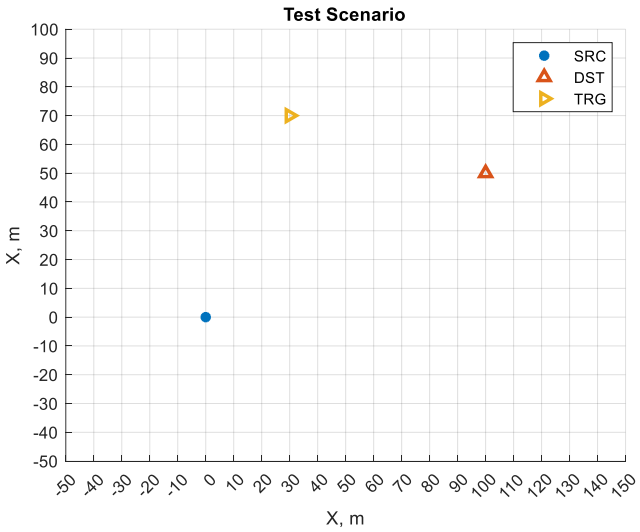


Initial examples of channel power distribution map

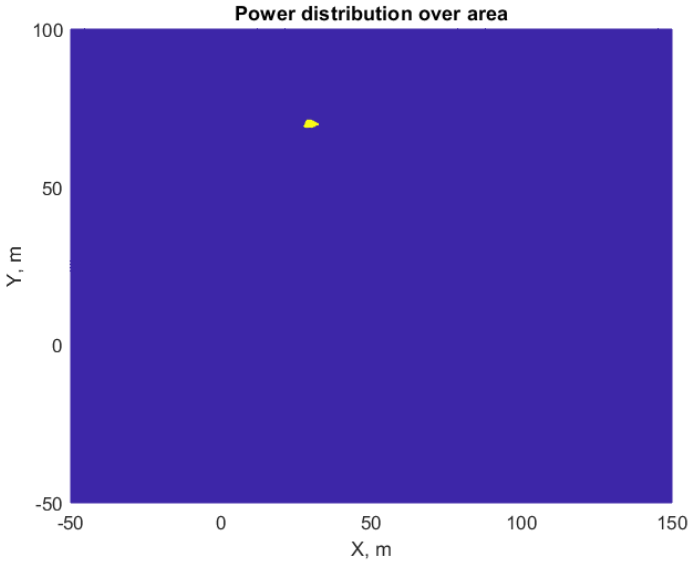
- Test scenario:
  - SRC = [0, 0, 10]
  - DST = [100, 50, 3]
  - TRG = [30, 70, 2]

  - #POR = 20
  - POR generation
    - X = [-2.5, 2.5]
    - Y = [-1.5, 1.5]
    - Z = [-1, 1]

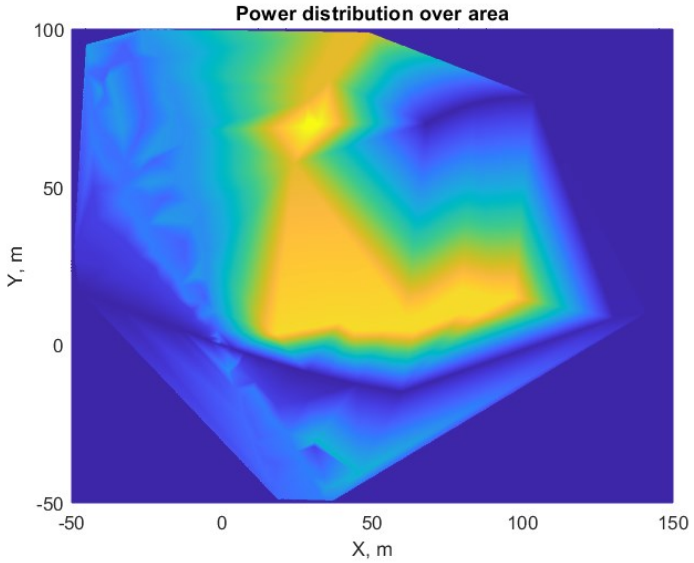
  - UMA NLOS/LOS O2O (Small Scale)
  - UMA Large Scale



- 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



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