3GPP TSG RAN Meeting #102
Edinburgh, Scotland, December 11 - 15, 2023
Agenda Item: 9.1.1.7
Source: Apple

RP-233384

Views on Integrated Sensing and Communications for Rel-19

Apple

ISAC Overview | Integrated Sensing and Communications (ISAC)

- Justification:
  - 5G/5G Advanced has done a lot of work on positioning.
  - A new category of use-cases to enable co-existence of sensing and communication in the same frequency band or hardware for new use cases identified in SA1 study
    - Both functions coexist by sharing the resources within the same band with a goal of minimizing the interference between each other and improving the coexistence efficiency.
  - Goal: Focus on channel modeling for Rel-19 with additional study after check in Sept 2024

- **P1:** RAN plenary-level study on Spectrum (frequency ranges) and RAN1 study item on all other aspects of study
  - Phase 1:
    - RAN: Spectrum (frequency range), Use cases, Scenarios, ISAC Modes
    - RAN1: Channel Measurements and Modeling
  - Phase 2 (beyond Channel Model after Sept 2024): Metrics/KPIs, Requirements, Evaluation methodologies, Sensing Architecture, Potential Solutions for ISAC

Phase 1 (RAN)| Spectrum, Use cases, Scenarios and Modes

- **Spectrum:**
  - **P2:** Channel Model should cover the entire frequency range modeled in 38.901 i.e. up to 100GHz
    - Specific frequencies modeled may depend on measurements available e.g. for FR1, FR2 and 7-24GHz

- **Use cases and scenarios**
  - Use cases can be selected from TR 22.837. The scenarios will be obvious on down-selection of the use cases
  - To prioritize use cases:
    - Option 1: Classify based on sensing type
      - Categories: Object detection and tracking, Environmental monitoring, Motion monitoring
    - Option 2: Classify based on Application type
      - Intruder Detection, Immersive Experience, Public Safety, Transportation/traffic management, UAV Sensing, Smart Factory, Environmental Monitoring, Motion Monitoring
  - **P3:** Use cases can be classified based on sensing type or application type
    - Option 1: sensing type classification should select on object detection category of use cases
    - Option 2: Application type classification should select Intruder detection, Immersive experience and Public safety use case applications

Phase 1 (RAN)| Spectrum, Use cases, Scenarios and Modes

Scenairo	Sensing Service Category	Use Case Index	Use Case	Preferences
Object Detection and Tracking	1	5.1	Use case of intruder detection in smart home	
		5.13.	Use case on sensing for UAV intrusion detection (level 1)	
	2	5.6	Use case on intruder detection in surroundings of smart home	
		5.13.	Use case on sensing for UAV intrusion detection (level 2)	
		5.14.	Use case on sensing for tourist spot traffic management	
	3	5.2	Use case on pedestrian/animal intrusion detection on a highway	
		5.7	Use case on sensing for railway intrusion detection	
		5.10	Use case on UAV flight trajectory tracing	
		5.11	Use case on sensing at crossroads with/without obstacle	
		5.12	Use case on Network assisted sensing to avoid UAV collision	
		5.23	Use case on AMR collision avoidance in smart factories	
	4	5.20	Use case of Sensing for Parking Space Determination	
		5.22	Use case of UAVs/vehicles/pedestrians detection near Smart Grid equipment	
		5.25	Use Case on immersive experience based on sensing	
		5.32	Use case of integrated sensing and positioning in factory hall	
	5	5.27	Use case public safety search and rescue or apprehend	
		5.28	Use case on Vehicles Sensing for Advanced Driving Assistance System(ADAS)	
		5.30	Use case on sensing for automotive manoeuvring and navigation service when not served by RAN	
Envionment Monitoring	6	5.3	Use case on rainfall monitoring	
		5.4	Use Case on Transparent Sensing Use Case	
Motion Monitoring	7	5.15	Use case on contactless sleep monitoring service	
		5.24	Use case on roaming for sensing service of sports monitoring	
	8	5.29	Use case on Coarse Gesture Recognition for Application Navigation and Immersive Interaction	

Application	Application Category	Use Case Index	Use Case	
Intruder Detection	1	5.1	Use case of intruder detection in smart home	
		5.6	Use case on intruder detection in surroundings of smart home	
		5.7	Use case on sensing for railway intrusion detection	
		5.22	Use case of UAVs/vehicles/pedestrians detection near Smart Grid equipment	
Immersive Experience	2	5.25	Use Case on immersive experience based on sensing	
Public Safety	3	5.27	Use case public safety search and rescue or apprehend	
Transportation/Traffic management	4	5.14.	Use case on sensing for tourist spot traffic management	
		5.11	Use case on sensing at crossroads with/without obstacle	
		5.2	Use case on pedestrian/animal intrusion detection on a highway	
		5.2	Use case of Sensing for Parking Space Determination	
		5.22	Use case of UAVs/vehicles/pedestrians detection near Smart Grid equipment	
		5.28	Use case on Vehicles Sensing for Advanced Driving Assistance System(ADAS)	
		5.30	Use case on sensing for automotive manoeuvring and navigation service when not served by RAN	
UAV	5	5.13.	Use case on sensing for UAV intrusion detection (level 1)	
		5.13.	Use case on sensing for UAV intrusion detection (level 2)	
		5.10	Use case on UAV flight trajectory tracing	
		5.12	Use case on Network assisted sensing to avoid UAV collision	
		5.22	Use case of UAVs/vehicles/pedestrians detection near Smart Grid equipment	
Smart Factory	6	5.23	Use case on AMR collision avoidance in smart factories	
		5.32	Use case of integrated sensing and positioning in factory hall	
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Phase 1 (RAN)| Spectrum, Use cases, Scenarios and ISAC Modes

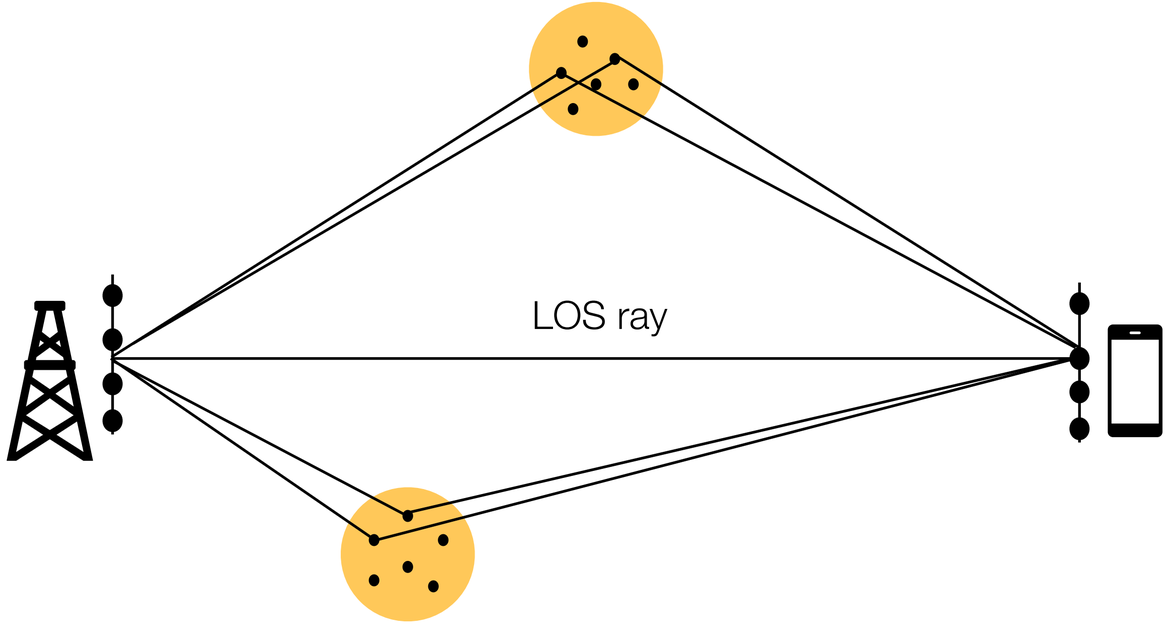
- ISAC Modes:
  - Sensing may have the following modes:
    - Mono-static: same transmitter and receiver
    - Bi-static: different transmitter and receiver
  - **P4:** Phase 1 supports both mono-static and bi-static sensing modes. Phase 2 support only bi-static sensing

Phase 1 (RAN1) | Channel Measurements and Modeling

- **P5:** Study and define a statistical/deterministic channel model for both sensing and communications based on TR 38.901 [RAN1]
  - Identify ISAC channel measurements for the selected use cases
  - Update stochastic and deterministic models in 38.901 to accommodate sensing
    - Update CDL and TDL for communications, target sensing or both.
      - Need both target and environment channel for sensing channel model
    - Model target Radar Cross Section (RCS), shape and pattern.
    - Model spatial and temporal consistency

Phase 1 (RAN1) | Channel Modeling based on TR 38.901

- 3GPP TR 38.901 supports stochastic and deterministic channel modeling for a communications channel between a gNB and UE (and vice versa)
  - In the stochastic channel model the geometric description covers arrival angles from the last bounce scatterers and respectively departure angles to the first scatterers interacted from the transmitting side.
  - The propagation between the first and the last interaction is not defined and we model multiple interactions with the scattering media. Also, the delay of a multipath component cannot be determined by the geometry
  - For a sensing target, the channel model should contain information (stochastic or deterministic) to enable sensing of the target



Communications Channel Model

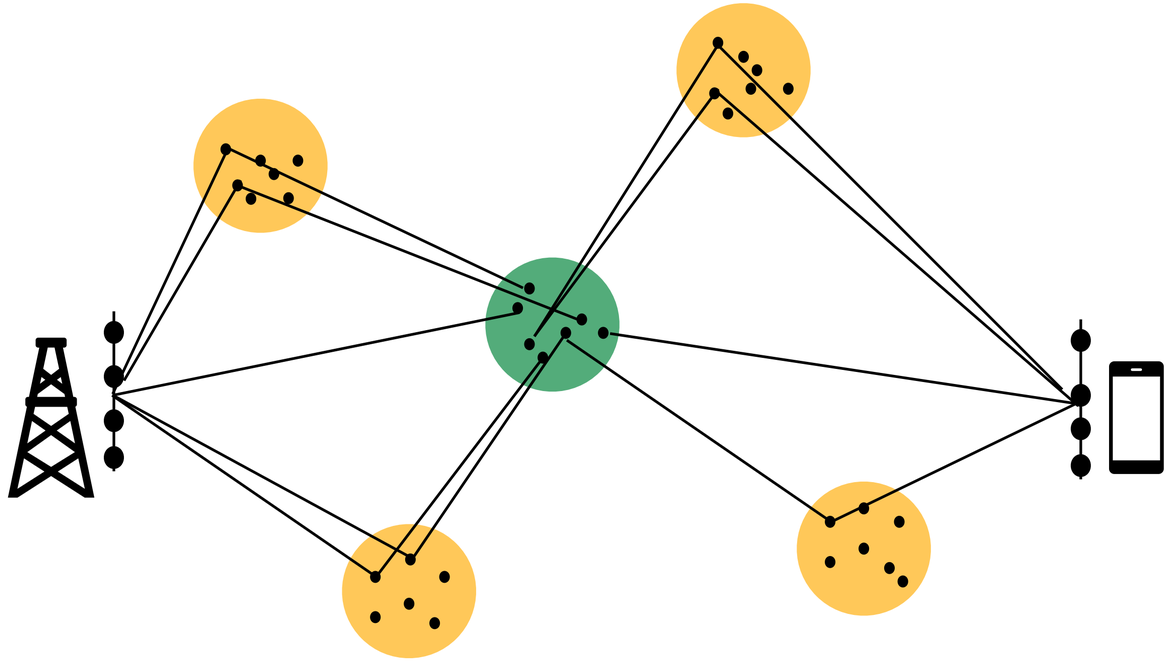
Communications cluster

Channel Modeling | Gaps in 38.901 for Sensing

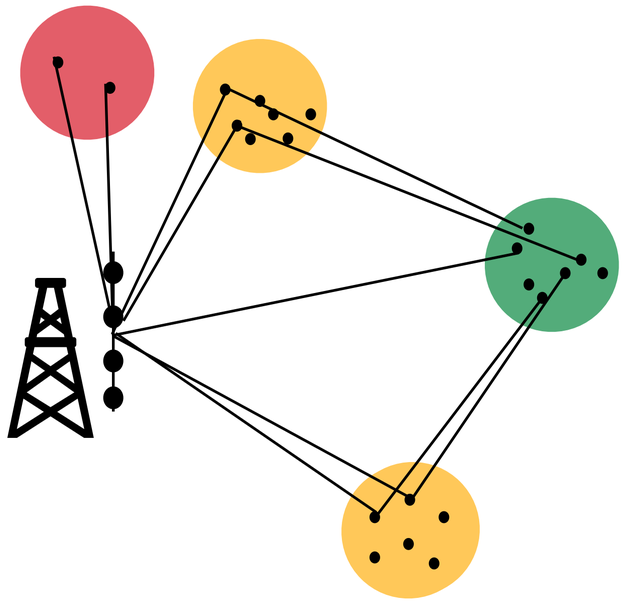
	Support	Update
mono-static sensing support	Not supported	• mono-static gNB sensing • mono-static UE sensing
bi-static sensing support	Not supported	• bi-static gNB-to-UE sensing • bi-static UE-to-gNB sensing • bi-static UE-to-UE sensing • bi-static gNB-to-gNB sensing

sensing target modeling	Not supported	• Stochastic vs deterministic sensing target modeling
		• Clutter/Cluster modeling
		  • Communications clusters, sensing clusters, target clusters, joint communications/ sensing clusters
		• LOS/NLOS modeling
		  • Path loss in LOS vs NLOS environment
		• Single-hop vs multi-hop channel modeling
		• Effect of mobility
		  • Device (gNB/UE) mobility
		  • target mobility
		• Consistency
		  • Spatial Consistency
		  • Temporal Consistency

Channel Model | Sensing Modeling



Bi-static Sensing Model



Mono-static Sensing Model

Target cluster

Sensing cluster

Sensing Interference cluster

- **Conclusion:** Updates needed to 38.901 model to accommodate sensing
  - May need validation of model using measurements

Phase 2 | KPIs, Metrics and Accuracy Requirements

- **P6:** Map KPIs identified in SA to specific metrics and accuracy requirements:

	Uu Positioning	Sidelink Positioning	NR Sensing
3GPP NR Release	Rel-16/Rel-17/Rel-18/Rel-19	Rel-18/Rel-19	Rel-19
Metrics	Absolute Horizontal Position Absolute Vertical Position Latency	Absolute Horizontal Position Absolute Vertical Position Latency Relative Horizontal Position Relative Vertical Position Local Coordinate System (LCS)/ Global Coordinate System (GCS) Angle	Absolute Horizontal Position Absolute Vertical Position Latency Relative Horizontal Position Relative Vertical Position LCS/GCS Angle Speed/Doppler target detection/discrimination pattern detection/discrimination
Accuracy Requirements	Absolute Positioning Accuracy (Horizontal or Vertical), latency	Ranging Accuracy, Relative/ Absolute Positioning Accuracy (Horizontal or Vertical), latency	Ranging Accuracy, Relative/ Absolute Positioning Accuracy (Horizontal or Vertical), latency, speed accuracy, target detection/ discrimination accuracy, pattern detection/discrimination accuracy,

Phase 2 | Evaluation, Architecture

- **P7** Define a representative number of evaluation scenarios for indoor and outdoor [RAN1]

- **P8:** Define evaluation methodologies considering the evaluation scenarios [RAN1]

- **P9:** Study the sensing architecture for sensing services, functional interfaces, protocols, and procedures to support NR based sensing technologies [RAN2, RAN3, SA]
  - A Sensing Management Function (SensMF) with an associated sensing protocol similar to or merged with the Location Management Function (LMF) and LPP/NRPPa can be used as a starting point.
  - Solutions should consider the privacy and security implications of sensing

Phase 2 | Potential Solutions

- **P10:** Study and evaluate potential solutions of sensing technologies based on the identified requirements, evaluation scenarios and methodologies [RAN1, RAN2, RAN3]
  - Study NR-based sensing, non-NR based sensing and Hybrid Schemes [RAN1,RAN2]
    - NR-based sensing uses existing NR architecture with NR signals, channels, and higher layer signaling for sensing
    - non-NR based sensing uses other technologies (e.g. radar) within the existing NR framework for sensing (similar to RAT-independent positioning)
      - Study at what layer the non-NR based sensing is incorporated into the NR network.

    - The solutions should consider support for sensing in both FR1 and FR2.
    - The solutions should consider the use of existing or new (if needed) signals and existing or new (if needed) measurements, measurement data and reporting to support ISAC.
      - Overhead of any new sensing signal (if needed) or increase in overhead of existing signals for sensing (if any) should be considered
    - The solutions should consider the interaction between communications and sensing
      - Communications capacity and sensing accuracy: immersive experience applications require high reliability and low latency type communications while supporting high positioning accuracy, velocity accuracy, and range resolution with low latencies and refreshing rates
      - For Joint communications and sensing, interference between communication and sensing signals should also be considered

Phase 2 | Potential Solutions

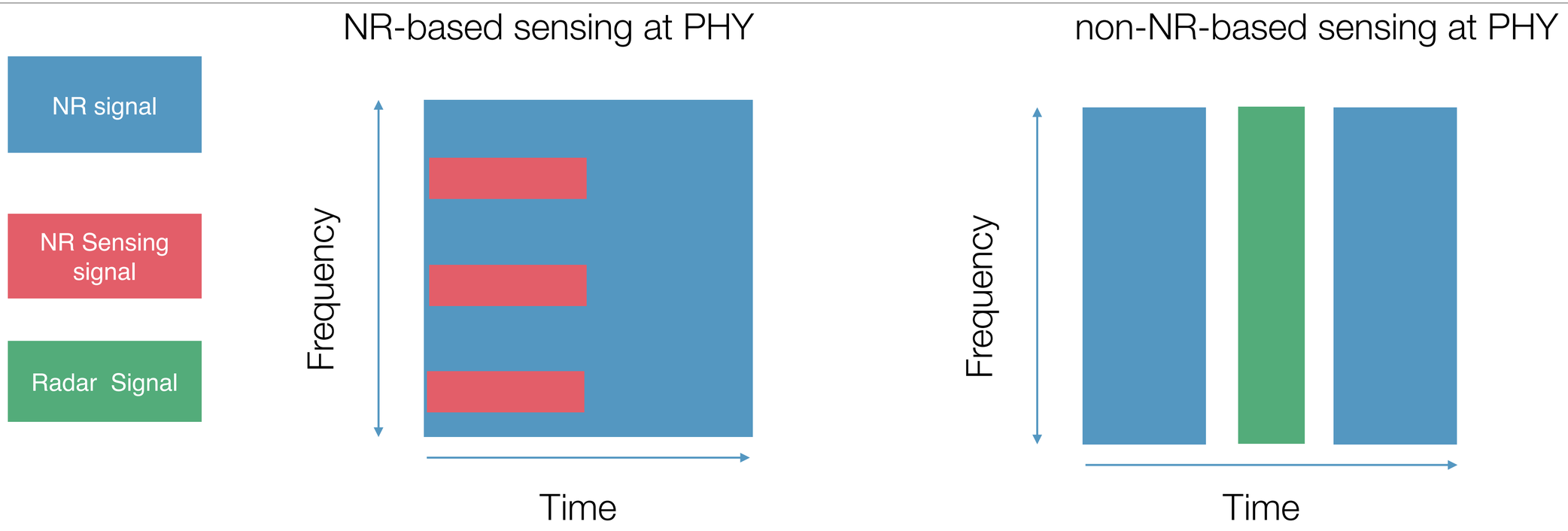


Table 5.7.4-1: Standardized 5QI to QoS characteristics mapping : TS 23.501

5QI Value	Default Priority Level	Packet Delay Budget (NOTE 3)	Packet Error Rate	Example Services
80	68	10 ms	10^{-6}	Low Latency eMBB applications Augmented Reality

Communications characteristics for AR

Scenario	Sensing service area	Confidence level [%]	Accuracy of positioning estimate		Accuracy of velocity estimate		Sensing resolution		Max sensing service latency[ms]	Refreshing rate [s]	Missed detection [%]	False alarm [%]
Immersive experience	Indoor	95	0.5	0.5	0.1	N/A	0.5	N/A	250	0.25	5	5

Sensing Characteristics for Immersive Experience, e.g. AR (agreed SA1 KPI)

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