3GPP TSG RAN Meeting #101 RP-232081
Bangalore, India, September 11-15, 2023
Agenda Item: 8A.2.11
Document for: Discussion

Views on channel modeling related topics in Rel-19

NTT DOCOMO, INC.

Overview on channel modeling related topics in Rel-19 (1/2)

- **RAN chair assessment on *Channel Modeling (& possibly additional aspects e.g. for ISAC) for further evolution* in RWS-320488**
  - *Strong interest in exploring study in new areas (RAN plenary involvement?)*
    - » *Very strong interest in channel modeling for integrated sensing and communication (ISAC), and also interest in other possible areas (e.g., use cases, scenarios, key performance metrics (KPIs), potential spec impact, etc.)*
    - » *Reasonable interest in exploring study in new spectrum, such as 7-24GHz*
      - – *Channel modeling study only?*
    - » *Reasonable interest in RIS (Reconfigurable Intelligent Surface) related study*
      - – *Channel modeling study only?*
  - *Very challenging if study is to be carried out for all the above items*
    - » *Which one(s) should be the focus? Necessity for future standard evolution?*
- **Observations**
  - Which ones should be included in the Rel-19 scope should be decided considering "overall Rel-19 package" not only channel modeling related topics.
  - According to our assessment in RP-232071 (Rel-19 overview contribution), all three channel modeling related topics (not only the study on channel model but also other studies as proposed in the next page) can be included in the Rel-19 package without overflow of RAN1 workload.
- **DCM's view**
  - **ISAC:** Study on channel model + TSG-level study on deployment scenarios and corresponding KPIs
  - **RIS:** Study on channel model + WG-level study on system model, evaluation, and spec impact based on Rel-18 NCR
  - **FR3 (7-24GHz):** Channel model should be ready before 6G technical study

Overview on channel modeling related topics in Rel-19 (2/2)

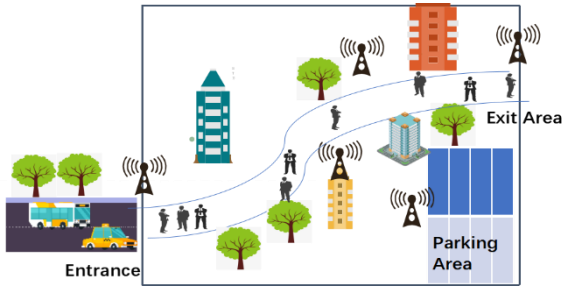
- **Proposal**
  - **Rel-19 package should include**
    - » **Study on ISAC deployment scenarios and corresponding KPIs [RAN]**
    - » **Study on channel model for ISAC, RIS, and FR3 (7-24GHz) [RAN1]**
    - » **Study on RIS for system model, evaluation, and spec impact based on Rel-18 NCR [RAN1, RAN2]**

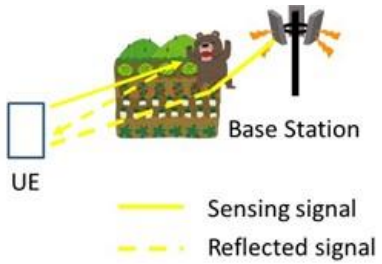
Study on ISAC

Introduction

Time to start treating wireless sensing in 3GPP RAN

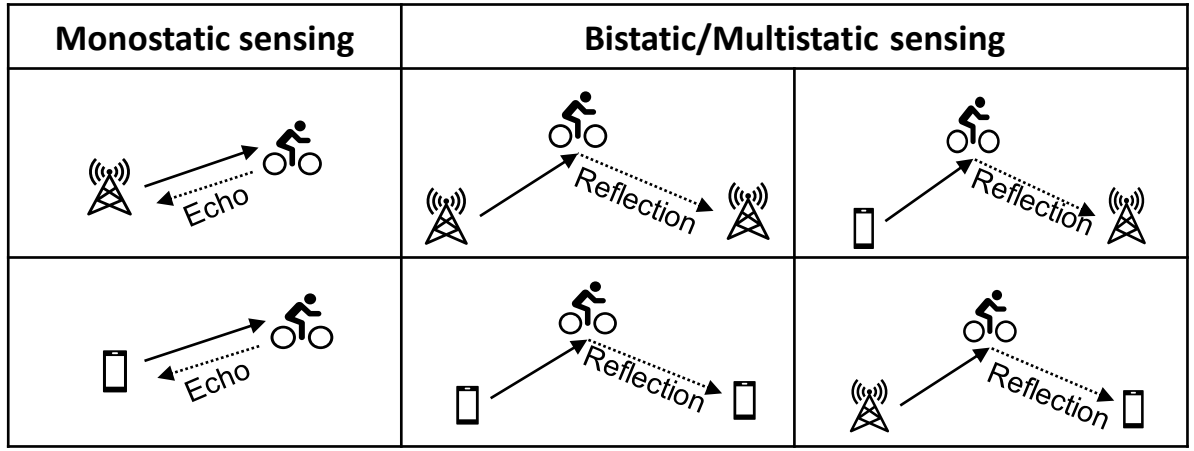
- **Motivation:**
  - » Good sensing performance by using various frequencies and cellular NW equipment
  - » Realizing new/enhanced services
  - » Optimizing NW parameters by analyzing real-time sensing data
- **Background: SA1 study on ISAC (integrated sensing and communication) in Release 19**
  - » Use cases and potential requirements for enhancement of the 3GPP system to provide sensing services addressing different target verticals/applications.
  - » Some use cases could also include non-3GPP type sensors (e.g. Radar, camera).





Human/intruder/vehicle/obstacle detection/counting in indoor/outdoor scenario

Use case examples



Sensing methods examples

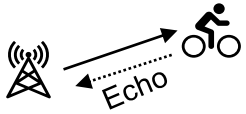
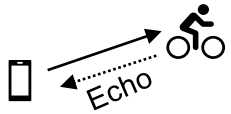
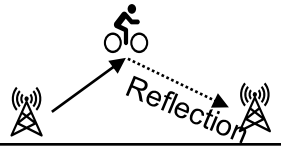
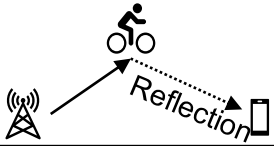
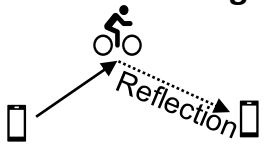
ISAC use cases

TR 22.837 V19.0.0

Sensing type	Usage scenario	Use cases in TR 22.837
Detection, localization and tracking	Smart home	Intruder detection in smart home
		Intruder detection in surrounding of smart home
	Smart transportation	Pedestrian/animal intrusion detection on a highway
		Sensing for railway intrusion detection
		Sensing at crossroads with/without obstacle
		Blind spot detection
		Sensing assisted automotive maneuvering and navigation
		Accurate sensing for automotive manoeuvring and navigation service
		Vehicles sensing for ADAS
		Sensing for automotive manoeuvring and navigation service when not served by RAN
	UAV	UAV flight trajectory tracing
		Network assisted sensing to avoid UAV collision
		Sensing for UAV intrusion detection
		UAVs/vehicles/pedestrians detection near smart grid equipment
	Smart factory	AGV detection and tracking in factories
		AMR collision avoidance in smart factories
		Integrated sensing and positioning in factory hall

Sensing type	Usage scenario	Use cases in TR 22.837
Detection, localization and tracking (Cont.)	Smart city	Sensing for tourist spot traffic management
		Sensing for parking space determination
		Public safety search and rescue or apprehend
		Rainfall monitoring
		Sensing for flooding in smart cities
Recognition	Smart health	Contactless sleep monitoring service
		Health monitoring at home
		Service continuity of unobtrusive health monitoring
		Roaming for sensing service of sports monitoring
	Smart entertainment	Gesture recognition for application navigation and immersive interaction
Reconstruction, imaging		Seamless XR streaming
		Immersive experience based on sensing
Others		Transparent sensing use case
		Protection of sensing information
		Sensor groups

Sensing methods

	Sensing method	Suitable scenario	Capability requirement	Sensing performance
Monostatic sensing	**gNB Monostatic sensing** 	• Sensing target near to sensing BS/UE • High or medium SNR of the echo signal	• Full duplex at BS or UE (High requirement)	• [gNB sensing] High precision due to no quantization • [UE sensing] Medium precision due to quantization of the feedback values • The precision is related to the SNR of echo signal • Short latency
	UE Monostatic sensing 			
Bistatic/Multi-static sensing	**gNB1-to-gNB2 sensing** 	• Extremely tight synchronization among BSs	• Half duplex (Low requirement) • Synchronization among BSs (High requirement)	• High precision due to no quantization • The precision is related to the synchronization error • Medium latency
	UE-to-gNB sensing 	• There is communication UE around the target	• Half duplex (Low requirement) • High UE positioning accuracy	• [gNB-to-UE/UE1-to-UE2 sensing] Medium precision due to quantization of the feedback values • [UE-to-gNB sensing] High precision due to no quantization • The precision is related to the allocated resources and UE location • Long latency
	gNB-to-UE sensing 		• Half duplex (Low requirement) • UE with high computation resources/ detection of reflection signal (High requirement) • High UE positioning accuracy	
	UE1-to-UE2 sensing 			

Proposals on objectives in Rel-19

NTT docomo

Observations

- To facilitate ISAC discussion in 3GPP RAN, enhancement on the channel model is necessary.
  - » The existing channel model in TR 38.901 is not designed to assess a link between Tx and Rx considering the reflection by sensing target and non-sensing target.
- Target scenario in RAN needs to be clarified.
  - » It is unclear how to categorize or which use cases, sensing methods, spectrum is the discussion scope in RAN.

Proposals

- **TSG-level SI: Study ISAC deployment scenarios and corresponding KPIs in RAN.**
  - » Clarify the discussion scope of deployment scenario(representative use cases, indoor/outdoor, sensing methods, spectrum) and corresponding KPIs for ISAC based on TR 22.837, towards WG-level SI (for channel modeling discussion).
  - » Note: No down-selection on deployment scenario from TR 22.837 is expected during TSG-level study.
    - – For future-proof, variety of scenarios should be the scope of RAN discussion.
- **WG-level SI: Study channel model in RAN1** (see page 19 for details)
  - » Study channel modeling enhancements for ISAC based on TR 38.901.
    - – Modeling of the sensing target objects considering RCS.
    - – Modeling of the transmission link and the reflection link reflected by sensing target objects.
    - – Modeling of sensing environment, if necessary.
  - » Normative works to specify basic functionalities of ISAC is expected to be in Rel-20 or later.

Appendix – Possible SI/WI schedule

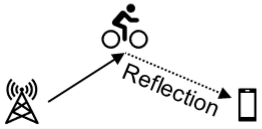
- Discussion points and Study/work schedule
  1) Use cases and requirements
  2) Architecture and sensing methods
  3) Channel model
  4) Detailed technical aspects
  4-1) For Basic use cases and architecture
     a. fundamental part (RS/ measurement/report) **based on NR waveform/frame structure**
  4-2) For Advanced use cases and architecture
     a. fundamental part (waveform/frame structure/RS/ measurement/report) **based on new design**
     b. enhanced part (AI/etc.) based on new design

Option	R19 TSG/WG-level SI	R20 WG-level SI	R20 WI	R21 or later WG-level SI	R21 or later WI
1	1) 2) 3)	4-1)4-2)			4-1)4-2)
2	1) 2) 3)	4-1)	4-1)	4-2)	4-2)
3	1) 2) 3) 4-1)		4-1)	4-2)	4-2)
4	1) 2) 3) 4-1)	4-2)	4-1)		4-2)

Appendix - Views on Basic/Advanced use cases and architectures of ISAC

- Basic use cases/architectures of ISAC
  - Use cases and requirements:
    - » Prioritize use cases with similar or easier functions with NR positioning, e.g., detection, positioning and tracking type use cases
  - Architecture and Sensing methods:
    - » At least 2 bistatic sensing methods, including gNB1-to-gNB2 bistatic sensing, UE-to-gNB bistatic sensing due to no hardware implementation efforts and limited spec. impacts.
    - » gNB-to-UE bistatic sensing can be included if UE complexity and spec impact can be minimized
  - Solutions
    - » NR-based architectures and techniques with minor enhancements, based on existing NR frame structure/waveform/RS/etc.
  - Channel modeling and Sensing metric
    - » At least stochastic channel modeling should be studied.
    - » Distance/angle/velocity estimation accuracy (e.g., mean square error), detection probability, false alarm probability, etc.

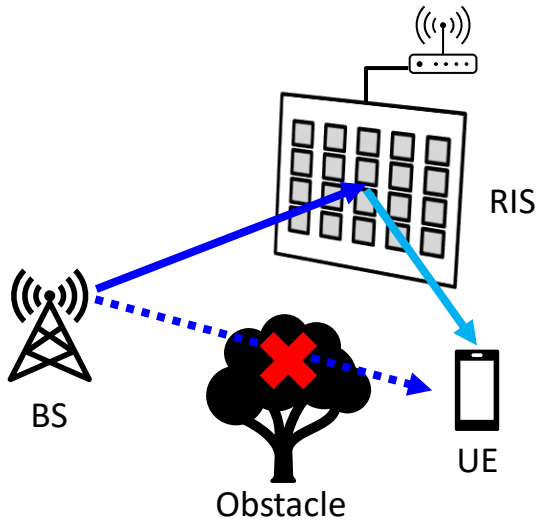
- Advanced use cases/architectures of ISAC
  - Use cases and requirements:
    - » All the potential ISAC use cases.
  - Architecture and Sensing methods:
    - » All the sensing methods, including gNB/UE monostatic sensing, gNB-to-UE bistatic sensing, UE1-to-UE2 bistatic sensing.
  - Solutions
    - » Fully new designs are acceptable for the fundamental part (new waveform/frame structure/RS/measurement/report) and/or enhancement part (AI/RIS/full duplex/massive MIMO/etc.)
  - Channel modeling and Sensing metric
    - » All the channel modeling of stochastic, deterministic or hybrid channel modeling should be studied
    - » Sensing/imaging resolution, target/posture/gesture recognition accuracy, etc.

Architecture and Sensing method					
Basic architecture and sensing method					
		Advanced architecture and sensing method			
Baseline: UE-to-gNB Bistatic/Multi-static sensing	**gNB1-to-gNB2 Bistatic/Multi-static sensing**	**gNB-to-UE Bistatic/Multi-static sensing**	**UE1-to-UE2 Bistatic/Multi-static sensing**	**gNB Monostatic sensing**	**UE Monostatic sensing**
					

Study on RIS

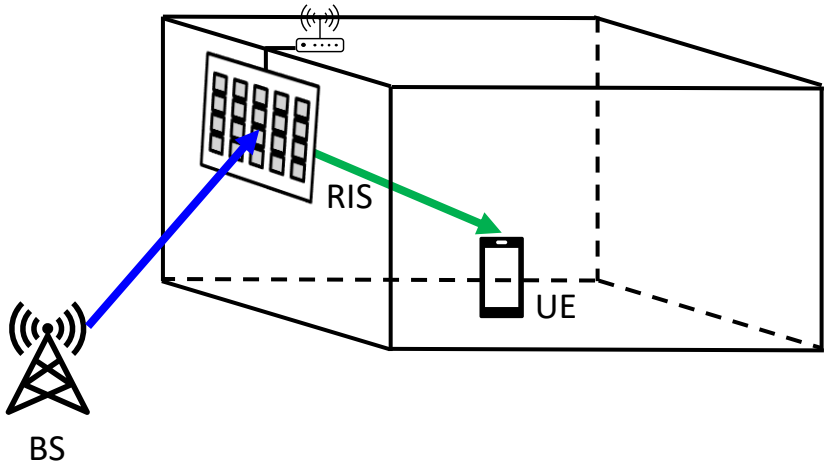
Background

- RIS is a new device for network deployment with flexible and cost-effective approach, comparing to other types of network nodes such as IAB, RF repeater, NCR
- RIS includes reconfigurable metamaterial components
  - Direction of forwarding signal can be controlled
  - Signal amplifier is not necessary
- Study of RIS is proposed by several companies for Rel-19
- After Rel-19 WS, further discussions are needed to clarify the scope of RIS channel modeling in Rel-19

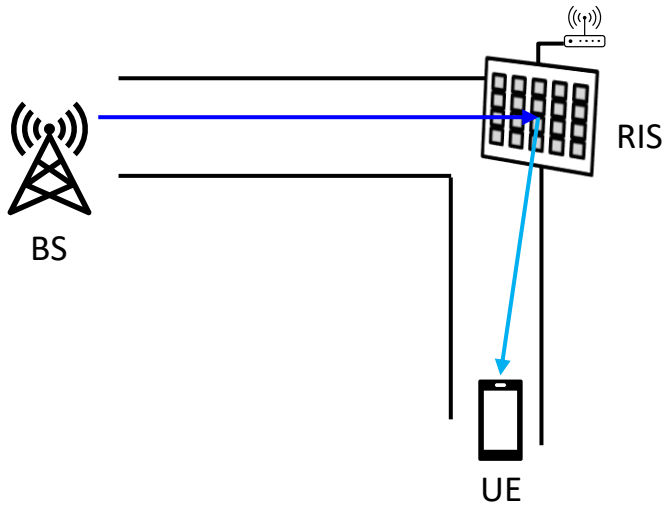


Outdoor scenario

RIS for coverage enh.



O2I scenario

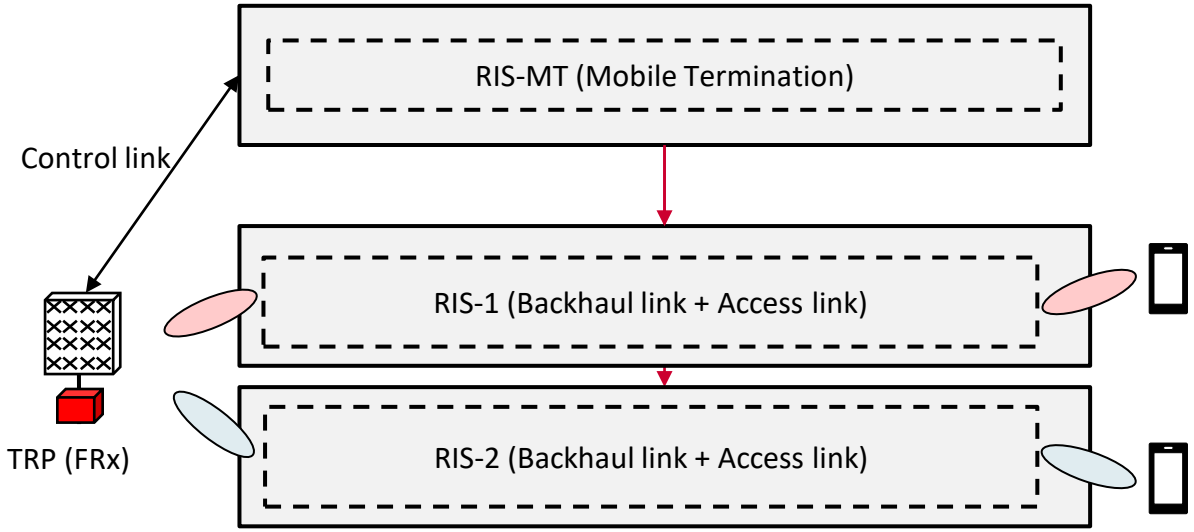


Indoor scenario

SI on RIS -Motivation-

RIS-type NCR

- RIS can be implemented based on the Rel-18 NCR framework, but there are several differences between the Rel-18 NCR and RIS-type NCR implementations.
- With accurate beamforming control that generates a beam from RIS to the dedicated UE, RIS-type NCR is expected to significantly improve the SNR for a coverage hole area. Thus, it can facilitate operation in high frequency band such as FR2.
- It is worth studying the system model of RIS-type NCR and its potential gain in practical networks and necessary specification enhancements to achieve such performance gain.



- Differences between NCR and RIS-type NCR

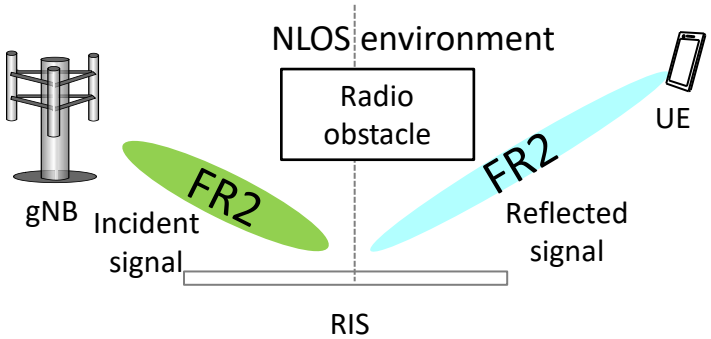
	Rel. 18 NCR	RIS-type NCR
Operation mode	Actively rx., amplify, and tx. the signal	Passive tune
RF chains	2 for backhaul and access links, respectively	No
Thermal noise	Present and be amplified during forwarding	No
Array scale	Small or medium array with limited beam number	Can be a large surface w/ ultra-large-scale array
Beamforming	Several beams to cover a designed area	Spotlight beams, each of which covers a small area

Proposal for RIS SI objectives

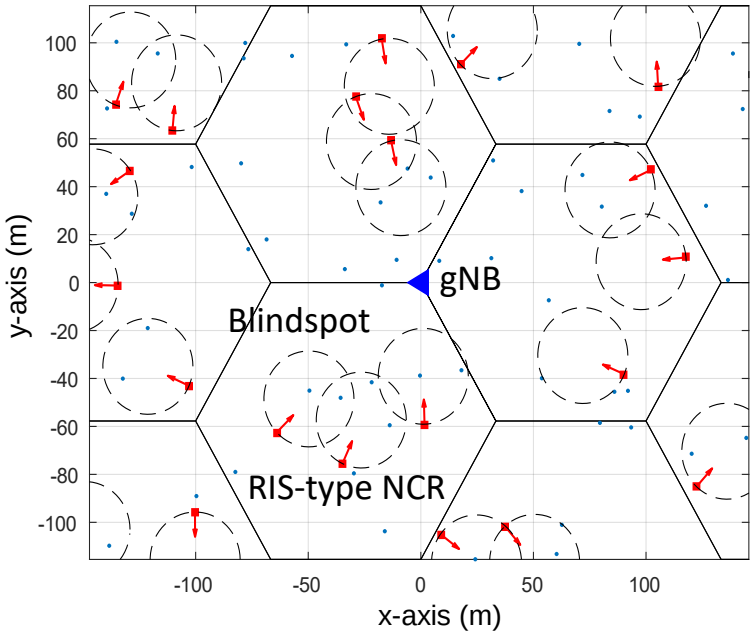
- Study system model
  - Study the differences between R18 NCR (and its enhancements) and RIS-type NCR, especially on how to model a RIS-type NCR [RAN1]
- Study evaluation methodology and performance evaluation
  - Study the link and system level scenarios and assumptions on evaluating the performance of RIS-type NCR [RAN1]
  - Identify the potential gain of RIS-type NCR [RAN1]
- Study potential specification impact based on Rel-18 NCR framework
  - Identify the specification impacts of RIS-type NCR. Some potentials may include:
    - » Enhanced beam management for RIS-type NCR beams [RAN1, RAN2]
    - » Enhanced SSB for RIS-type NCR beams [RAN1, RAN2]
    - » Enhanced RRC signaling for RIS-type NCR configuration reports [RAN1, RAN2]

[Appendix] FR2 Coverage Enhancements with RIS-type NCR

- FR2 coverage could be enhanced with the help of RIS-type NCR for blind-spot areas, e.g.,
  - RIS-type NCR with 0.5m x 0.5m can eliminate the blind spot effect
  - RIS-type NCR with 1m x 1m can achieve 8dB SINR improvement in average compared to deployment w/o RIS-type NCR

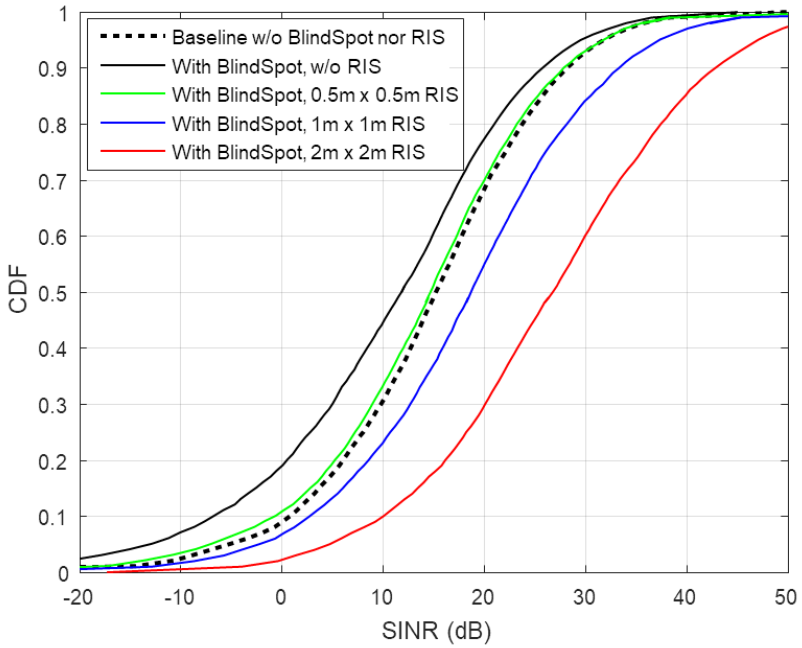


RIS-type NCR for area with blindspot



- mmWave Dense Urban scenario w/ 3 blind-spot areas (circles) per sector and 3 RIS-type NCRs (red dots w/ arrow indicating the orientation) deployed correspondingly

Geometry

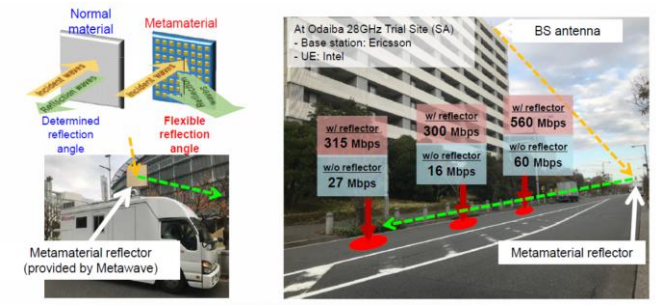


- 0.5m x 0.5m RIS-type NCRs eliminate the impact of blind-spot areas
- Larger aperture size further improves the performance

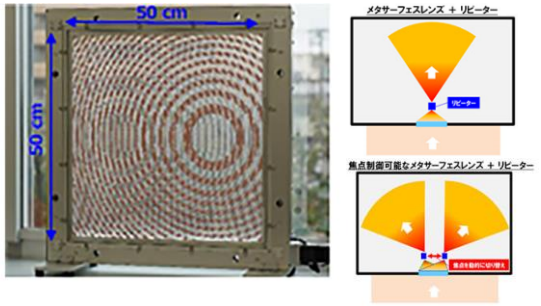
[Appendix] DOCOMO RIS Trails

- Between 2018 and 2021, DOCOMO conducted multiple experiments to validate metamaterial surface technology
  - In 2018, for the first time in an outdoor setting, a metamaterial reflective surface was used to achieve directed reflection of 28GHz millimeter waves, validating its ability in blind spot coverage
  - In 2020, transparent dynamic metamaterial surface was validated for the first time. Through this technology, full-refraction, semi-refraction, and reflection of millimeter waves were achieved, demonstrating its potential in different operation modes
  - In 2021, a metamaterial lens was employed to achieve electromagnetic wave focusing and focal control, enhancing coverage from outdoor to indoor areas

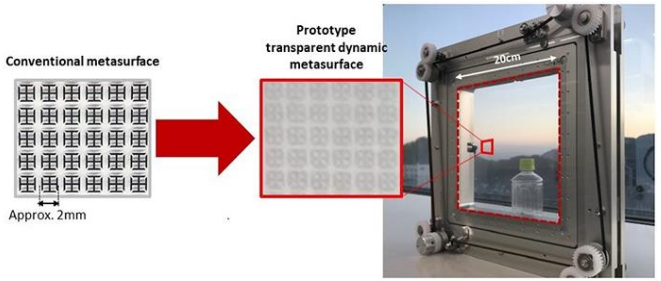
DOCOMO Trial, 2018
Metamaterial reflective surface
Outdoor coverage enh.



DOCOMO Trial, 2021
Focal controllable metamaterial lens
O2I coverage enh.



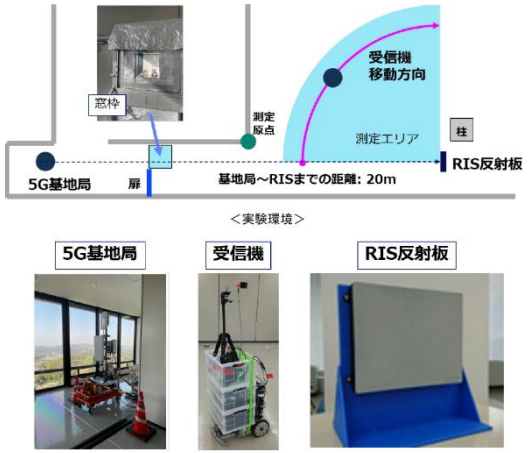
DOCOMO Trial, 2020
Transparent dynamic metamaterial surface
Support flexible coverage



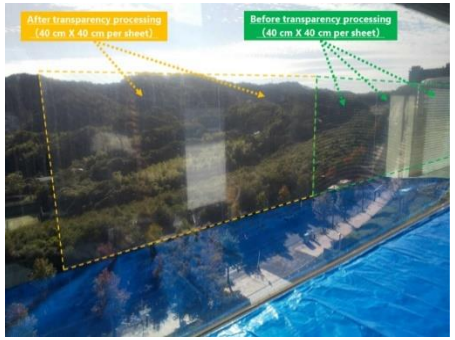
[Appendix] DOCOMO RIS Trails

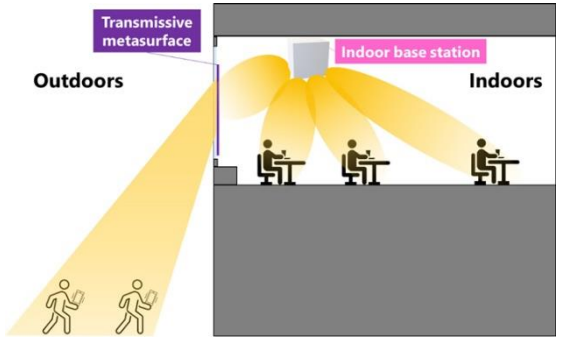
- Between 2018 and 2021, DOCOMO conducted multiple experiments to validate metamaterial surface technology
  - In October 2021, testing was conducted on a user-tracking metamaterial reflective surface capable of dynamically changing reflection direction with user movement, resulting in a successful 20dB increase in signal strength
  - In January 2023, the world's first experiment was completed using a thin-film refractive metamaterial surface to redirect 28GHz millimeter wave radio waves from inside a building to the underside of an outdoor building

DOCOMO Trial, 2021.10
User-tracking metamaterial reflective surface
Mobility coverage enh.



DOCOMO Trial, 2023.1
Thin-film refractive metamaterial surface
Coverage enh. at the bottom of buildings





Study on Chanel Model for ISAC/RIS/FR3

ISAC Channel Modeling

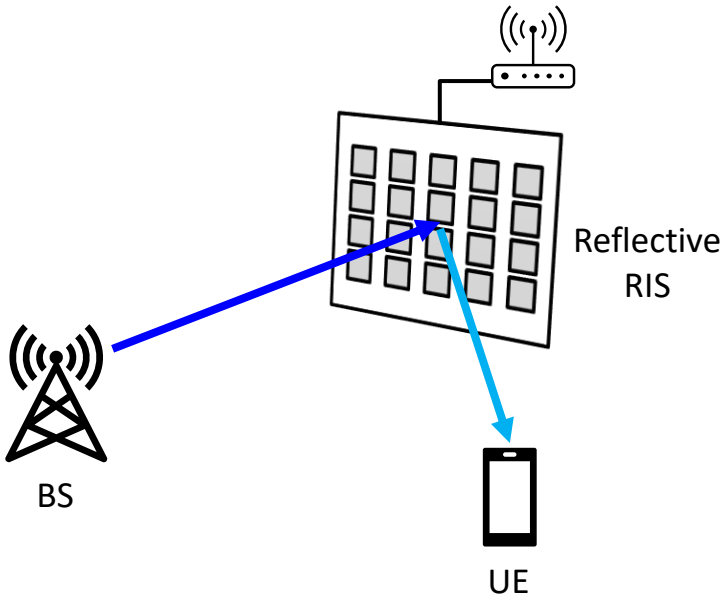
- For 3GPP sensing, the stochastic channel modeling should be the baseline and starting point for enhancement.
  - Parameters for enhancement: Path loss, LOS probability, fast fading model
  - New parameter: RCS (Radar cross section)
- The channel modeling of sensing target and sensing environment could be carried out independently or jointly.
  - Sensing environment may not be necessary to be modeled as same level as sensing target
- The parameter/required enhancements on channel model would be different depending on sensing type (localization, size, tracking, gesture recognition, counting number of objects), sensing environment (urban/rural/aerial etc.), sensing coverage (macro/micro) etc.

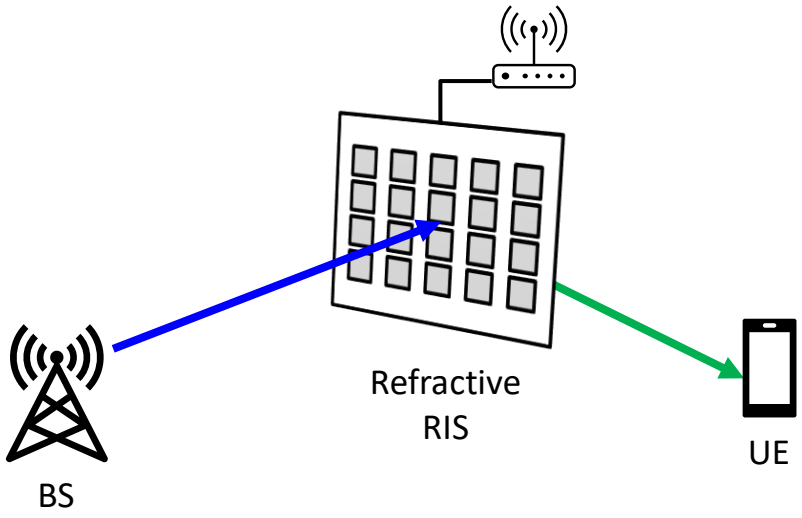
Channel modeling		Existing TR38.901	Updates for ISAC
7.4 Large-scale channel modeling	7.4.1 Path loss	One-way (Tx-Rx) path loss	Enhancement for sensing: - Cascaded modeling for path loss: Tx-Target, Target-Rx - Special case: Double path loss for monostatic sensing
	7.4.2 LOS probability	Different for various scenarios	Enhancement for sensing: - Cascaded modeling for LOS probability: Tx-Target, Target-Rx - Special case: Same LOS probability for Tx-Target and Target-Rx link in monostatic sensing
	7.4.3 Penetration loss	Depending on the material	Special case: No penetration loss for LOS-based sensing
	7.4.4 Shadow fading	Gaussian distribution	Reuse the shadow fading model in TR38.901
	RCS	None	New for sensing: - RCS is related to the size, material and shape of the target, as well as the FOV, frequency and polarization of the sensing signal, etc.
7.5 Fast fading model		CDL, TDL channel model: Cluster-based, ray-based	Enhancement for sensing: - Cascaded modeling for fast fading channel - Correlation between communication clusters and sensing clusters

For section 7.2 in TR38.901, it may need clarification whether the existing scenarios cover the target sensing scenario clarified in TSG-level study.

Channel model for RIS -Scope-

- Justification
  - Intensive investigations are conducted based on various assumptions and realizations of RIS
  - Down selection of characteristics and operating modes of RIS is necessary for the study in Rel-19
- Proposal:
  - Following scope should be included in the study on channel model for RIS
    - » Both FR1 and FR2
    - » passive RIS, i.e., w/o signal amplifier
    - » Reflective [and refractive] RIS

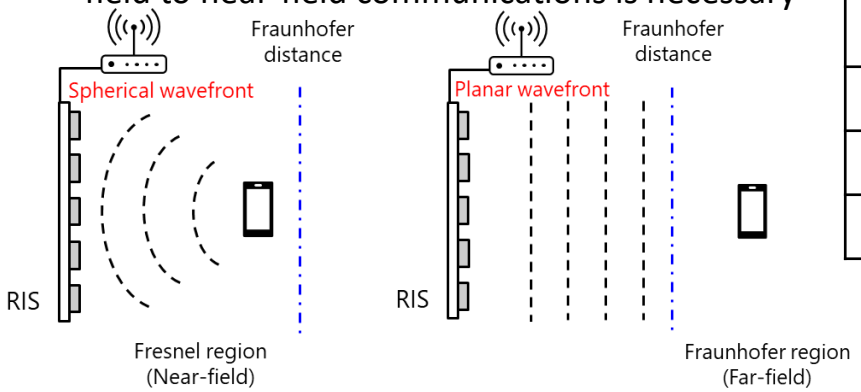




Channel model for RIS -Scope-(cont.)

- Proposal:
  - Following scope should be included in the study on channel model for RIS
    - » Define and classify beamforming capability of RIS
      - – Class A: Support dynamic beamforming
      - – Class B: Support semi-static beamforming
      - – Class C: Beamforming is not supported
    - » Consider both far-field and near-field channels
    - » The RIS panel can be modeled as a uniform planar array with M x N elements

- **Near-field and far-field**
  - The large aperture of RIS array means that spherical rather than planar wavefront must be considered, and a paradigm shift from far-field to near-field communications is necessary



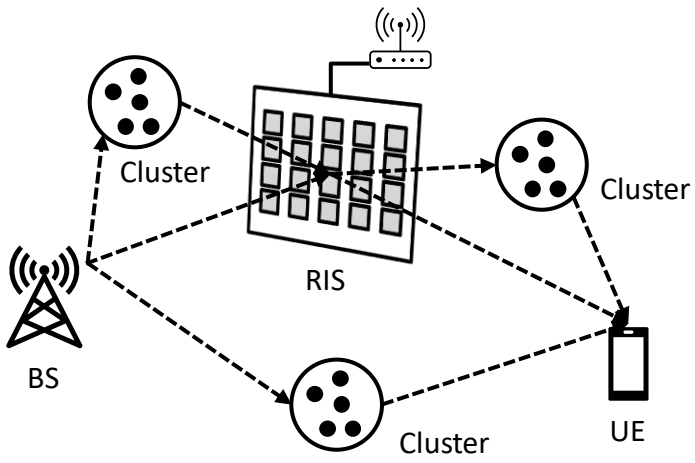
RIS near-field region estimation

3.5 GHz			28GHz		
Element #	RIS size[1]	Fraunhofer dist.	Element #	RIS size	Fraunhofer dist.
4 x 4	17.1cm x 17.1cm	1.4 m	32 x 32	17.1cm x 17.1cm	11.0 m
8 x 8	34.3cm x 34.3cm	5.5 m	64 x 64	34.3cm x 34.3cm	43.9 m
16 x 16	68.6cm x 68.6cm	21.9 m	128 x 128	68.6cm x 68.6cm	175.5 m

[1] Assuming half-wavelength element spacing

Channel model for RIS -Modeling Methodology-

- Justification
  - Proper modeling method with low complexity is required to model the cascaded RIS channel
  - Compatible and unified framework is needed for RIS and related technologies, such as NCR
- Proposal: Define the methodology of channel modeling of RIS in the study item using stochastic model based on TR 38.901
  - Study cascaded model
    - » Separately model the BS-RIS channel, the RIS-UE channel, and the RIS pattern



Cascaded RIS channel model

NTT docomo