XG Mobile Promotion Forum

Beyond 5Gホワイトペーパー
6G無線技術プロジェクト
無線センシングWG

2025年9月30日

Wireless Sensing Working Group

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無線センシングWG

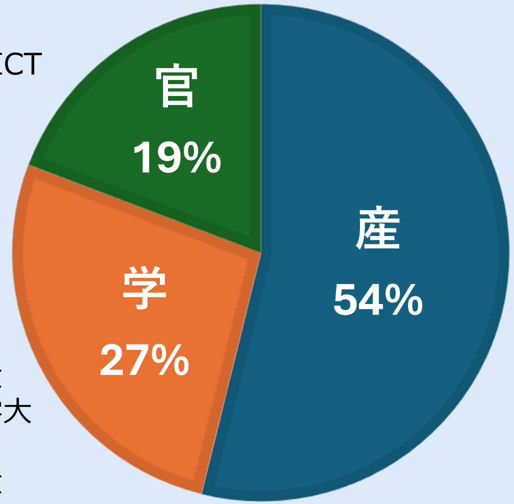
目的

- ✓ ユースケースの議論
- ✓ 標準化動向の把握
- ✓ 技術課題の整理
- ✓ 日本の独自性アピール
- ✓ 実用化につなげるPoCの推進
- ✓ 実験データの共有（データベース）
- ✓ 応用検討

体制

Chair：　須山（NTTドコモ）
Vice Chair：　村上（NTT）
　宗　（工学院大学）

委員：28名(2025年4月時点)



無線センシングWGの議論内容

第0回 2024/11/6

キックオフ
体制、目的、スケジュールの議論

第1回 2024/12/4

白書の作成方針
B5G白書共有、進め方議論
PoC議論

第2回 2025/1/15

3GPP標準化、調査方法
講演(ﾊﾟﾅｿﾆｯｸ様/ﾄﾞｺﾓ様)
技術動向調査方法の議論

第3回 2025/2/13

IEEE標準化、進捗共有
講演(上智大様)
技術動向調査の共有

第4回 2025/3/4

白書構成FIX、執筆分担
白書の章構成の決定、
執筆内容の分担

執筆期間

第5回 2025/4/25

白書執筆完了、測定器の紹介
白書の最終確認
測定器紹介(ｷｰｻｲﾄ様)

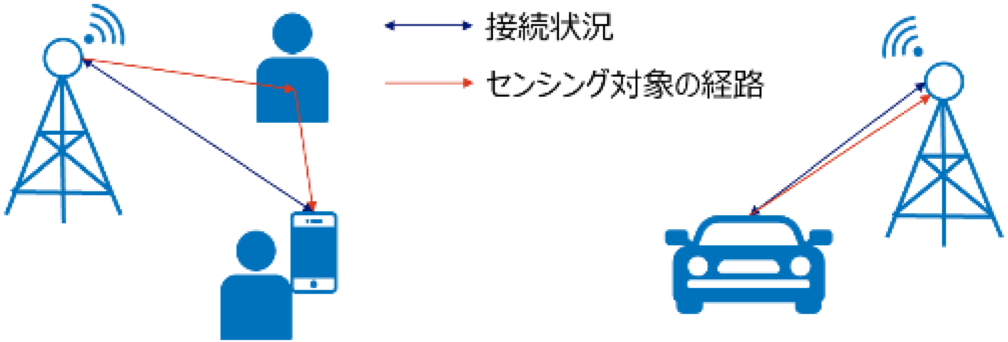
現在

WTP 2025/5/28-30

目次

ISACとは？

ISACとは、通信機能と電波を用いたセンシング機能を統合することで、基地局のコスト/サイズ/消費電力を低減させるとともに、高度な無線接続・センサ情報を提供可能な新たなシステム

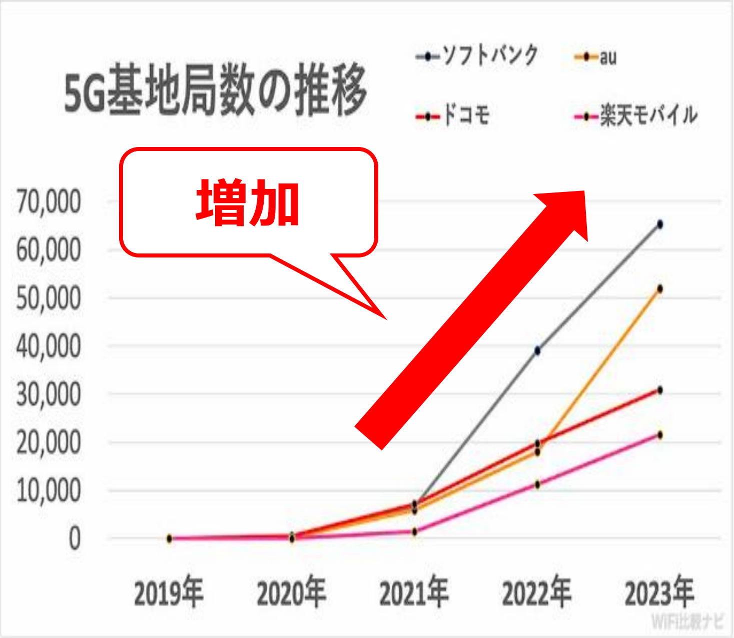


	無線	赤外線	カメラ
検出範囲	～100m	～10m	～100m
検出方向	全方向	特定方向	特定方向
見通し外	○	×	×
プライバシー	○	○	×

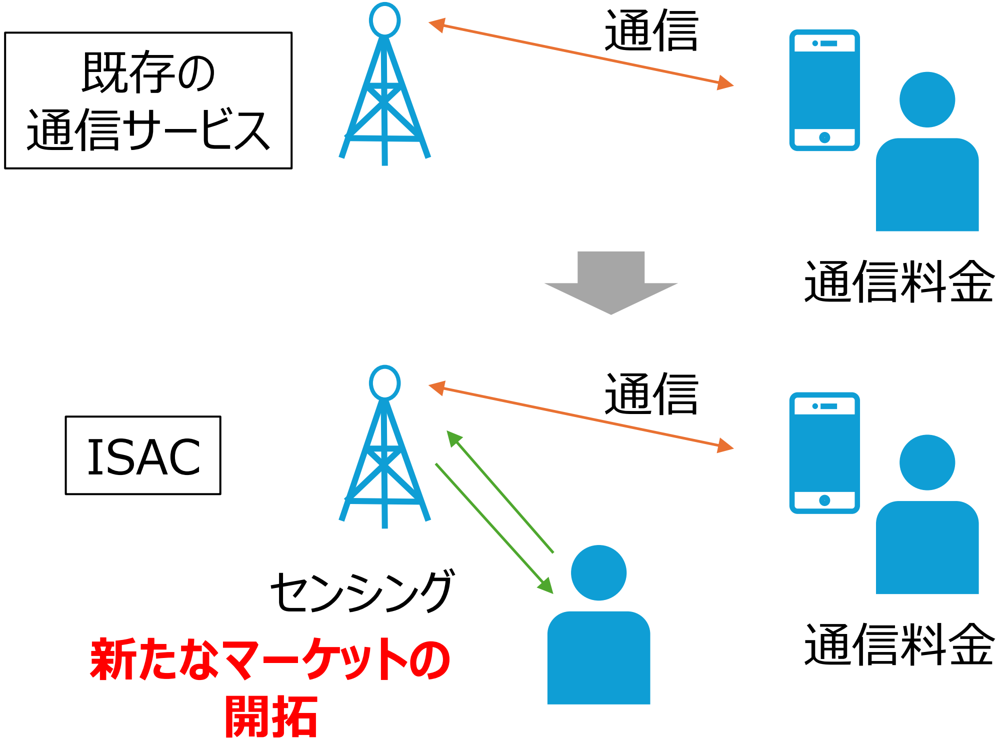
低コスト　高度化　付加価値

ISACの狙い

- 普及している基地局をセンサとして利用できるため、センサ範囲が大幅に拡大
- 通信サービスに加えて、新たなマーケットであるセンシングサービスに展開可能



引用:WiFi比較ナビ、https://hikaku-1234.com/basic/base-stations



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1. 無線センシングWGのご紹介

2. XGMF白書「Beyond 5Gホワイトペーパー」のご紹介
   - Integrated Sensing And Communications(ISAC)とは？
   - ISACの標準化動向
   - ISACの技術動向
   - 国内における研究開発の事例紹介

3GPP標準化の目的 [1]

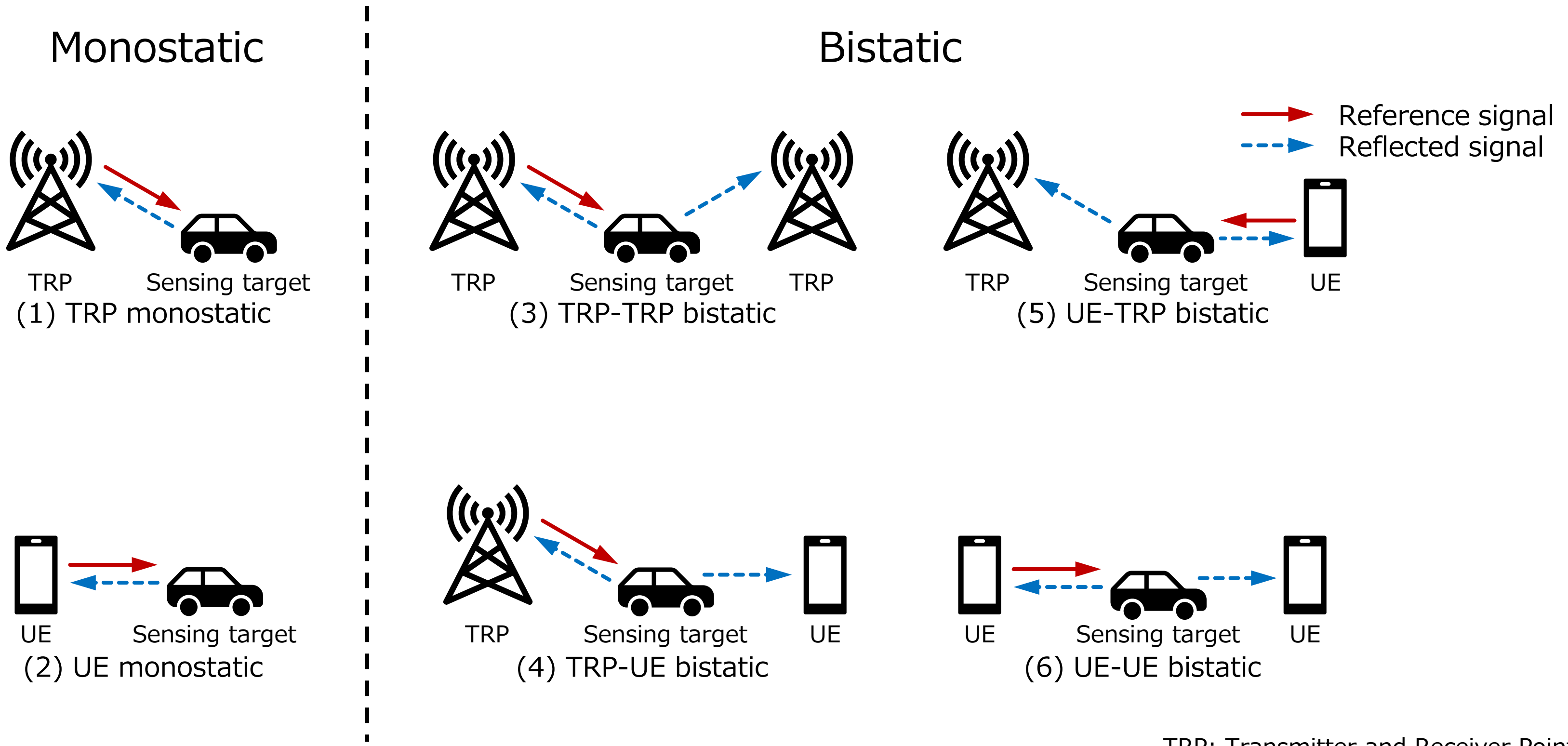
- Define channel modelling aspects to support object detection and/or tracking (as per the 3GPP Service and System Aspects 1 (SA1) meaning in the technical specification (TS) 22.137 [2])

- Construct a common modelling framework capable of detecting and/or tracking the following example objects (sensing targets) and to enable them to be distinguished from unintended objects:

1. Unmanned aerial vehicles (UAVs)
2. Humans indoors and outdoors
3. Automotive vehicles (at least outdoors)
4. Automated guided vehicles (AGVs e.g. in indoor factories)
5. Objects creating hazards on roads/railways

[1] 3GPP RP-242348, "Revised SID: Study on channel modelling for integrated sensing and communication (ISAC) for NR," RAN#105, Melbourne, Australia, Sept. 2024.
[2] 3GPP TS 22.137 V19.1.0, "Service requirements for Integrated Sensing and Communication; Stage 1 (Release 19)," Mar. 2024.

センシングモード [1]



TRP: Transmitter and Receiver Point
UE: User Equipment

[1] 3GPP RP-242348, "Revised SID: Study on channel modelling for integrated sensing and communication (ISAC) for NR," RAN#105, Melbourne, Australia, Sept. 2024.

チャネルモデル

- センシングターゲットとバックグラウンドのチャネルをベースとしたモデルから2024年3月RAN1会合より議論が開始[3][4]
- ターゲット，ターゲット以外の環境オブジェクト，バックグラウンドによるチャネルを詳細に議論
- ターゲットによる確率的なクラスタ生成，TRPとターゲットの決定論的パラメータは基本的に既存のTR38.901モデルを使用[5]
- ターゲット内の散乱点は単一および複数な場合に分けられ，単一な場合のセンシングは主にRCSの値を用いることが合意[6][7]
- ターゲットによる偏波，回折・遮蔽モデル，複数散乱点モデル等の残課題について2025年5月会合の合意に向け議論[8][9]

ISACチャネルモデルにおける基本的な考え方[3]

$$H_{ISAC} = H_{target} + H_{background}$$

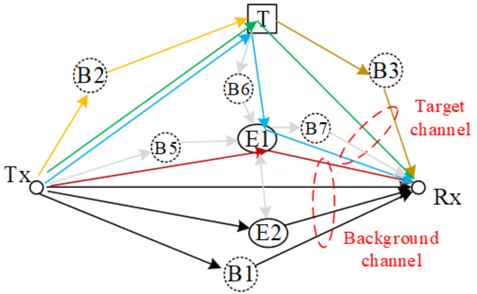
・H_{target}：ターゲットに影響を受ける伝搬チャネル

⇒ ターゲット＋ターゲット以外の環境オブジェクト（EO）

⇒ EO type-1：ターゲットと同等のサイズと形状（人，UAV，AGVなど）

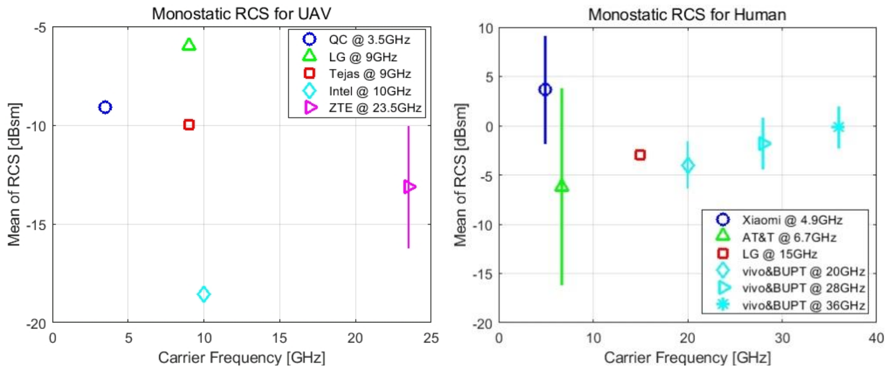
＋ EO type-2：ターゲットよりはるかに大きいもの（壁，建物，地面など）

・$H_{background}$：ターゲットの影響を受けない伝搬チャネル



T: Sensing target
E1, E2: Environment object (EO)
B1,⋯,B7: Stochastic clutter

ISACチャネルモデルの基本フレームワーク[3][4]



議論例：ターゲット別MonostaticセンシングのRCS値[5]

[3] 3GPP R1-2401937, TSG RAN WG1 #116, Athens, Greece, March 2024.
[4] 3GPP R1-2403716, TSG RAN WG1 #116bis, Changsha, China, April 2024.
[5] 3GPP R1-2404636, TSG RAN WG1 #117, Fukuoka, Japan, May 2024.
[6] 3GPP R1-2409280, TSG RAN WG1 #118bis, Hefei, China, Oct. 2024.
[7] 3GPP R1-2410014, TSG RAN WG1 #119, Orlando, US, Nov. 2024.
[8] 3GPP R1-241041 (NTT DOCOMO, INC.), TSG RAN WG1 #119, Orlando, US, Nov. 2024.
[9] 3GPP R1-2501002, TSG RAN WG1 #120, Athens, Greece, Feb. 2025.

センシングターゲットとユースケース [10]

1. UAVs
- UAV flight trajectory tracing
- Network assisted sensing to avoid UAV collision
- Sensing for UAV intrusion detection
- UAVs/vehicles/pedestrians detection near Smart Grid equipment

2. Humans indoors and outdoors
- Intruder detection in smart home
- Contactless sleep monitoring service
- Health monitoring at home
- Service continuity of unobtrusive health monitoring
- Roaming for sensing service of sports monitoring
- Immersive experience based on sensing
- Use case public safety search and rescue or apprehend

3. Automotive vehicles (at least outdoors)
- Sensing assisted automotive maneuvering and navigation
- Sensing for parking space determination
- Vehicles sensing for ADAS
- Sensing for automotive manoeuvring and navigation service when not served by RAN
- Blind spot detection

4. Automated guided vehicles (AGVs e.g. in indoor factories)
- AGV detection and tracking in factories
- Autonomous mobile robot (AMR) collision avoidance in smart factories

5. Objects crating hazards on roads/railways, within a minimum size dependent on frequency
- Pedestrian/animal intrusion detection on a highway
- Sensing for railway intrusion detection
- Sensing at crossroads with/without obstacle
- Accurate sensing for automotive manoeuvring and navigation service
- Integrated sensing and positioning in factory hall

(Combination of targets mentioned above and others)
- Rainfall monitoring
- Transparent sensing use case
- Sensing for flooding in smart cities
- Intruder detection in surroundings of smart home
- Sensing for tourist spot traffic management
- Protection of sensing information
- Sensor groups
- Seamless XR streaming
- Coarse gesture recognition for application navigation and immersive interaction

[10] 3GPP TR 22.837 V19.4.0, “Feasibility study on integrated sensing and communication (Release 19),” June 2024.

【参考】UAVの侵入検出

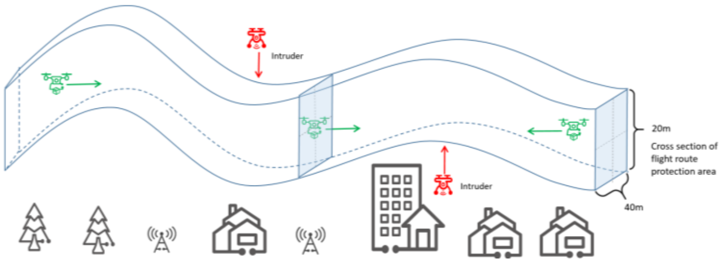
Description

- Low-altitude UAVs in smart cities have characteristics as large number, small size, wide flying zone, widely used to execute complex and diverse tasks.

⇒ Makes UAV supervision difficult if only using the traditional radar system

- Non-cooperative UAVs intruding some no-fly zone (e.g. airport, military base) would lead to serious consequences, e.g. exposing private information using the camera, blocking other UAV traffic on the flying route.

⇒ 5G System could be used for sensing the UAV intrusion in restricted area



UAV intrusion over flight routes [3]

Potential new requirements

1. The 5G system shall be able to provide a sensing service by using RAN to collect 3GPP sensing data.
2. The RAN shall be able to sense a target object by obtaining 3GPP sensing data without active involvement of the target object.
3. The 5G system shall provide mechanisms for an operator to transport 3GPP sensing data from RAN towards the core network.
4. The 5G system shall be able to provide a mechanism for a trusted third-party to request the sensing service, and the base station shall be able to operate sensing periodically or continuously in certain location area for a certain amount of time.
5. The 5G system shall be able to periodically expose sensing results to a trusted third-party application.
6. The 5G system shall provide a mechanism controllable by the operator, according to a business agreement, to report sensing result to a trusted third-party about a target object and multiple target objects when specific conditions are met.

【参考】ヘルスモニタリング

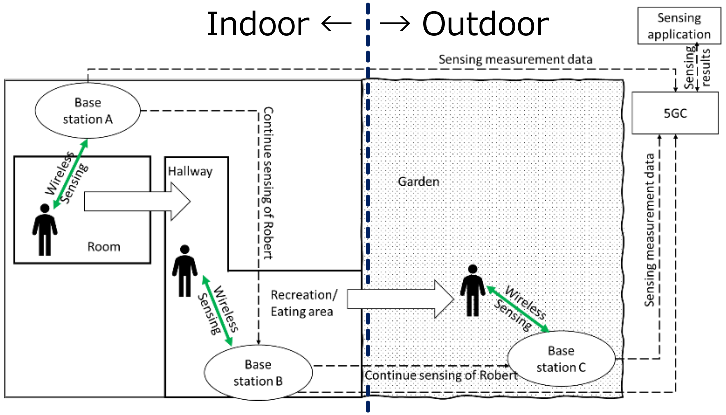
Description

- The deployed 5G system (installed in hospital or elderly home) includes multiple sensing devices.

⇒ Can perform health monitoring (one or more persons)

- ➢ Fall / activity detection of vital signs (e.g. heart rate or breathing rate)
- ➢ Wireless sensing of vital signs

- No need to recharge / replace the batteries of body worn sensors
- No need to remind / help people to wear them after they took them off (e.g. After take a shower).
- Installing cameras as an alternative has privacy concerns.



Service continuity between base stations A, B, and C [3]

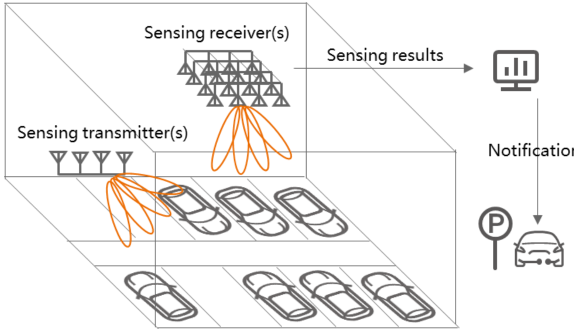
Potential new requirements

1. The 5G system shall support continuity of sensing of a target that may move across a sensing area that may be bigger than the coverage area of a single sensing transmitter.
2. The 5G system shall support simultaneous wireless sensing of a target by means of multiple sensing devices.
3. Subject to operator's policy, the 5G network may provide secure means for the operator to expose information on sensing service availability in a desired sensing service area location to a trusted third-party.

【参考】駐車場の空き検出

Description

- Sensing technology can improve the user experience in parking garage via enabling the vehicle and parking garage to get more information.
- Connectivity is an important component in automatic parking e.g. [1]AVP and [2]AFP.
- 3GPP sensing technology can serve as the way to determine available parking spaces and the best route for a car to reach it.



Parking space determination (indoor deployment) [3]

Potential new requirements

1. The 5G system shall be able to provide sensing services in licensed and unlicensed spectrum.
2. The 5G system shall be able to authorize sensing receiver(s) and sensing transmitter(s) to participate in a sensing service.
3. Based on operator's policy, the 5G system shall enable a trusted third-party to request the activation of the sensing service with specific KPI requirement, as well as deactivation of the same service.
4. The 5G system shall be able to support charging for the sensing services.
5. The 5G system shall be able to provide a sensing service considering the interference to the sensing service caused by the sensing operations between multiple sensing transmitter(s) and sensing receiver(s).

[1]AVP: Automated Valet Parking [2]AFP: Automatic Factory Parking

【参考】AMRの衝突検知

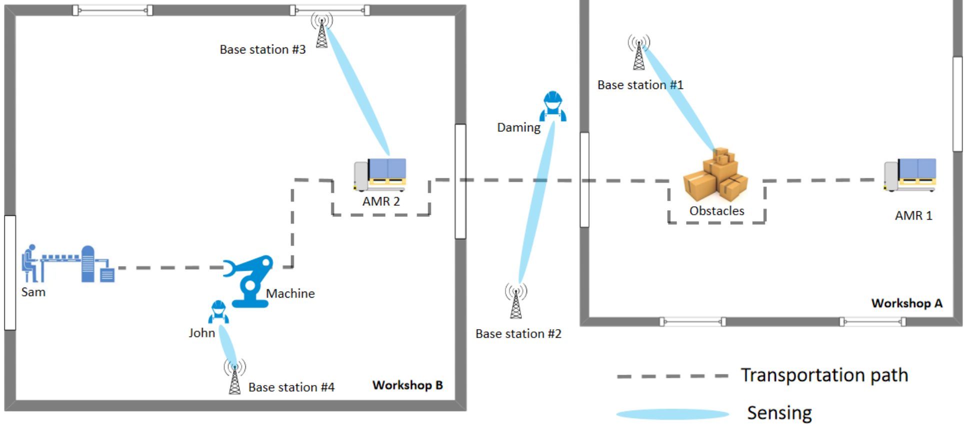
Description

- AMRs can travel automatically without derivatives or guides by the central unit (scheduling, routing, and dispatching decisions).

⇒ Currently being introduced in many logistics operations

e.g. manufacturing, warehousing, cross-docks, terminals, and hospitals

- During the AMR working process, the sensing range of a single AMR is limited and the surrounding environment status may not detected in time.



Sensing people or obstacles detection in smart factory [3]

- 5G base stations deployed in a factory can not only provide communication capabilities for equipments in the factory but also sense the surrounding environment.

⇒ Sensing result can be utilized to improve efficiency and driving safety of AMRs.

Potential new requirements

- The 5G system shall be able to provide the continuity of sensing service for a specific target object, across indoor and outdoor.
- The 5G system shall be able to provide a secure mechanism to ensure sensing result data privacy within the sensing service area.

*AMR: Autonomous Mobile Robot

【参考】交差点における障害物検知

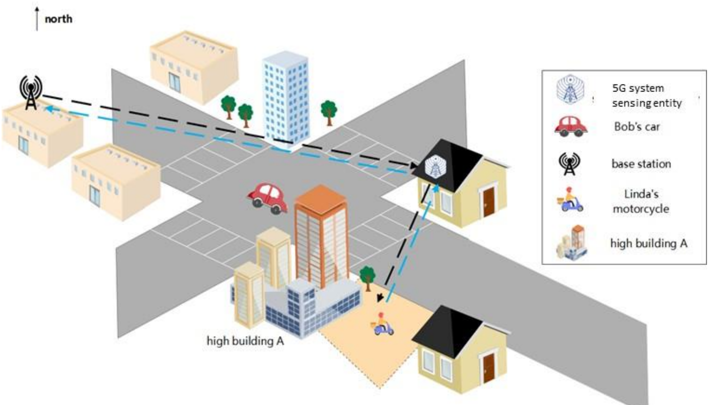
Description

- Traffic accidents often happen at the crossroads, for example owing to sudden appearance of the pedestrians from invisible place.

⇒ An urgent need to monitor the real-time road status for all days

- With the collaboration of trusted third-party (e.g. map service provider or ITS management platform), driving warning or assistant driving information can be provide timely to vehicles.
- The cameras and radars on *RSU always has some blind points.

⇒ 5G based sensing can provide sensing information to fill these gaps.



Sensing at crossroads with/without obstacle [3]

*RSU: Road-Side Unit

Potential new requirements

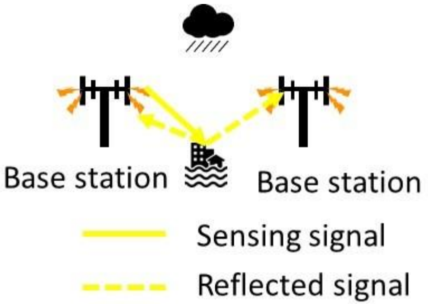
1. The 5G system shall be able to support a mechanism to provide available sensing service in a target sensing service area.
2. The 5G RAN shall be able to collect 3GPP sensing data from requested target sensing service area according to the operator’s policy.
3. The 5G system shall be able to report the sensing result to the trusted third-party (e.g. the map service provider) with refresh rate, and controllable by the operator, according to a business agreement.
4. The 5G system shall support means for a trusted third-party application e.g. a map service provider to configure sensing per location.

【参考】洪水検知

Description

- Due to the recent climate change in recent years, it can be difficult to recognize places where flooding is expected to occur by using cameras and other sensors.

⇒ Using radio waves, it is possible to recognize places where flooding occurs in an efficient way.

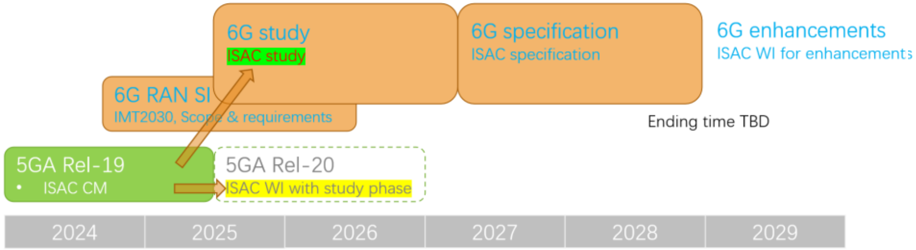


Sensing for flooding in smart cities [3]

Potential new requirements

1. Subject to operator policy, the 5G system shall be able to provide sensing result indicating disasters or other emergencies (e.g. flooding) in a given geographic area to authorized third parties in a timely manner.
2. Subject to regional or national regulatory requirements and operator policy, the 5G system shall be able to provide its public warning system with a warning notification based on sensing result indicating disasters or other emergencies in a given geographic area in a timely manner.
3. Subject to operator policy, it shall be possible for an authorized third party to configure the 5G system to initiate sensing for disasters or other emergencies in a given geographic area.

3GPPにおけるISACの進捗状況



An example of a roadmap for 3GPP ISAC standardization [11]

- Discussions will focus on the ISAC channel modelling for 5G-Advanced (5G-A) until the middle of 2025 [11], [12].
- The specifications for the commercial and industrial use of UAVs are prioritized owing to the rapid growth in the business and industrial demands [11]–[13].

Status of ISAC in 5G-A Release 19 [14]

TSG Tdoc of latest approved WI/SI description	RP-242348 [11]
Target completion date	Study item: June 2025
Overall completion level	70%: Normal progress
Rapporteur	Yingyang Li (Xiaomi) and Jerome Vogedes (AT&T)

Completed (Service Aspect 1)

- [Study Item] Feasibility study on ISAC [10]
- [Work Item] Service requirements for ISAC [11]

Ongoing [14]

1. ISAC deployment scenarios
   - Calibration parameters, calibration results collection/analysis
2. ISAC channel modelling
   - Physical object model, polarization, power normalization, spatial consistency, angular correlation, blockage model, micro-Doppler, etc.

[11] 3GPP RP-242803 (Xiaomi), "Views on ISAC in 5GA Rel-20," RAN #106, Madrid, Spain, Dec. 2024.
[12] 3GPP RP-242863 (China Telecom), "Motivation on integrated sensing and communication for 5G-A Rel-20," RAN #106, Madrid, Spain, Dec. 2024.
[13] 3GPP RP-243151 (ZTE), "Support of ISAC in 5G-A Rel-20," RAN #106, Madrid, Spain, Dec. 2024.
[14] 3GPP RP-250241, "Status report for SI: Study on channel modelling for Integrated Sensing And Communication (ISAC) for NR," RAN #107, Incheon, South Korea, Mar. 2025.

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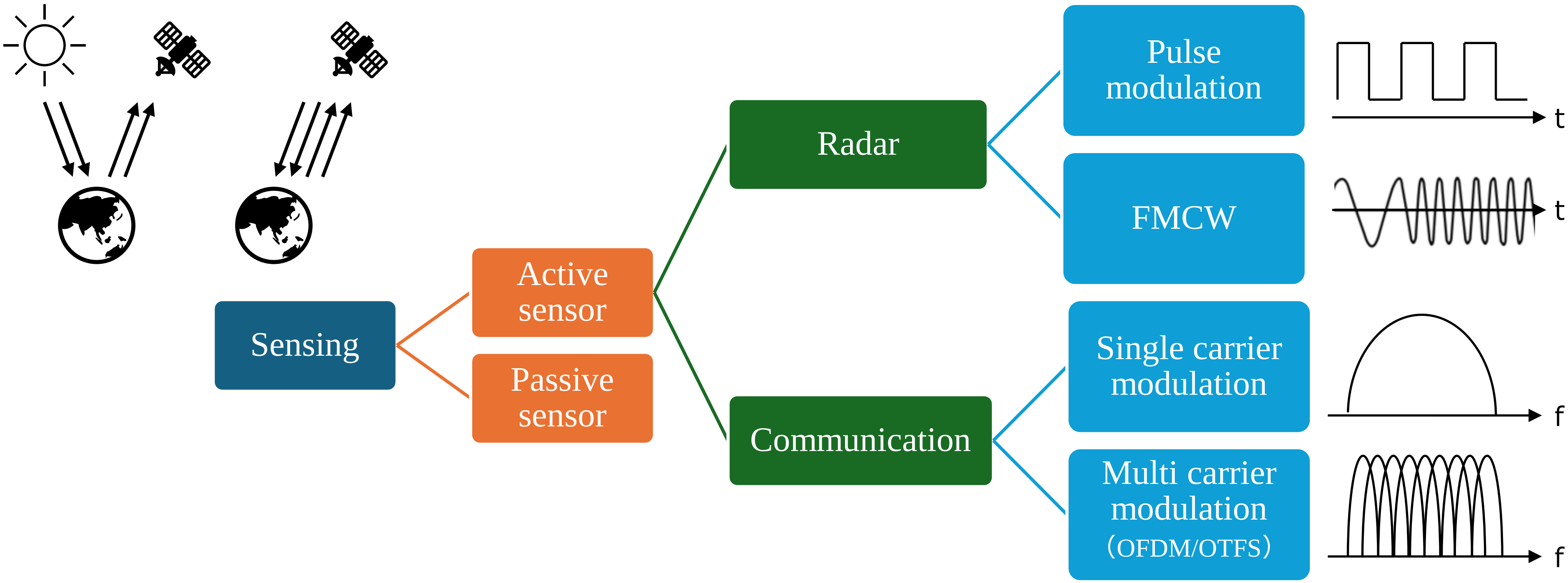
- ➢ 国内における研究開発の事例紹介

センシング方法の分類

- センシングは自然発生する電磁界をセンシングするPassive型と電波を放射するActive型に分類
- レーダと通信で様々な変調方式が存在する



調査した論文とユースケースの関係

- 屋外、屋内問わず、多様なターゲットとユースケースの検討が進んでいる
- 理論検討から実験検証のフェーズに徐々に移行している

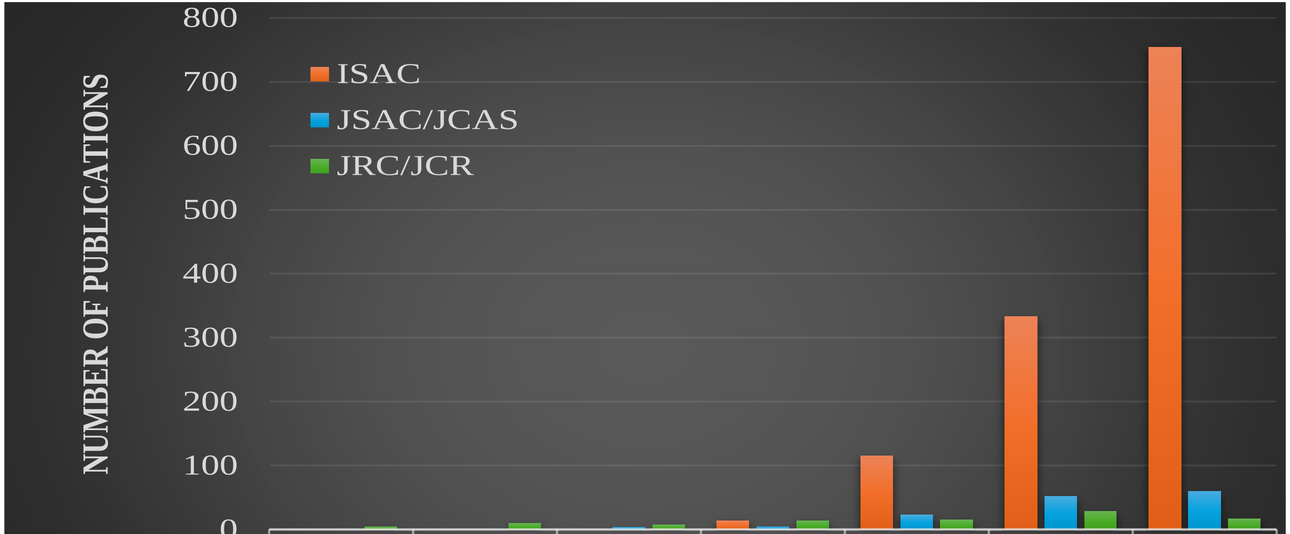
Use case		Publications
Outdoor	Human	[23][25][35][36][37][44][47][48][49][54][55][56][58][59][60]**[II-1][II-4][II-7][II-8][II-10]**
	Animal	
	Vehicle	[20][22][23][26][28][29][30][37][40][41][35][47][48][50][54][55][57]
	UAV	[23][24][32][38][39][43][48][61][62][63][64][65]
	Weather	[66][67][68][69][70][71][72][73][74][75]
Indoor		[21][27][31][33][34][42][46][50][51][52][53][76]**[II-2][II-3][II-9][II-10]**
Other		**[II-5][II-6]**

（灰色）実験結果が含まれる記事

（黄色）白書に記載される記事

採択論文の推移

- IMT2030にてISACが定義されて以来、急激に論文数が上昇
- JSAC/JCASやJRC/JCRも一定数があるが、ISACが圧倒的に多い状況



	2018	2019	2020	2021	2022	2023	2024
ISAC				14	115	333	754
JSAC/JCAS	0	0	3	4	23	52	60
JRC/JCR	4	10	7	14	15	29	17

JSAC/JCAS: Joint Sensing And Communication/Joint Communication And Sensing
JRC/JCR: Joint Radar Communication/Joint Communication Radar

関連キーワード

Keyword	Count			
ISAC	800		NOMA	77
sensors	361		deep learning	76
wireless communication	294		signal processing	75
radar	284		real-time systems	75
simulation	274		costs	74
array signal processing	266		bandwidth	68
OFDM	247		beamforming	66
6G	247		precoding	66
optimization	227		signal processing algorithms	66
signal to noise ratio	211		radar tracking	64
receivers	189		antenna arrays	63
interference	185		millimeter wave communication	63
autonomous aerial vehicles	180		channel models	63
estimation	167		quality of service	61
channel estimation	156		training	61
reconfigurable intelligent surfaces	155		transmitting antennas	59
transmitters	142		imaging	58
wireless sensor networks	137		parameter estimation	56
location awareness	131		radio frequency	55
time-frequency analysis	130		throughput	55
conferences	124		performance evaluation	54
symbols	116		heuristic algorithms	54
resource management	113		approximation algorithms	54
base stations	110		delays	52
object detection	102		waveform design	51
spectral efficiency	101		protocols	50
hardware	101		system performance	47
downlink	99		robot sensing systems	47
radar antennas	96		MIMO	46
interference cancellation	92		radar signal processing	46
uplink	89		antenna measurements	44
vehicular and wireless technologies	87		full-duplex system	44
wireless networks	85		physical layer security	43
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ユースケースのワード

技術のワード

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国内における研究開発の事例紹介

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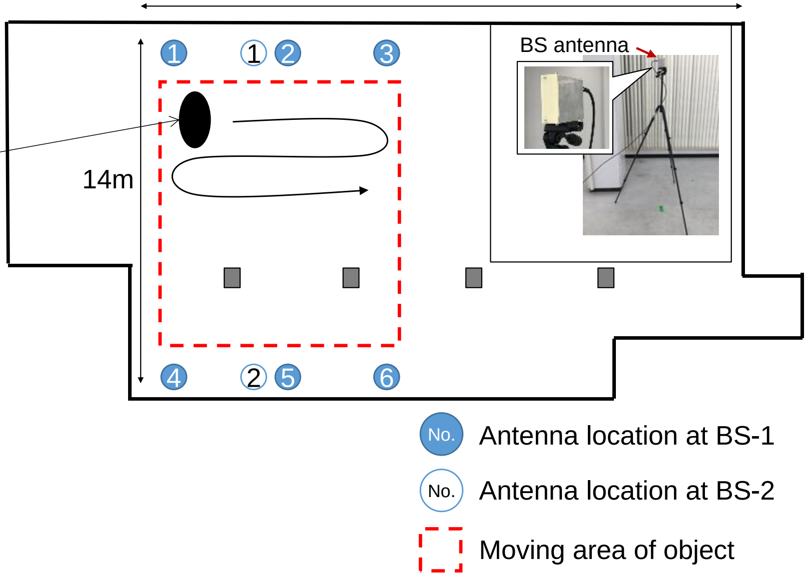
CSI-Based Device-Free Sensing Using Deep Learning with 5G NR 28 GHz Band

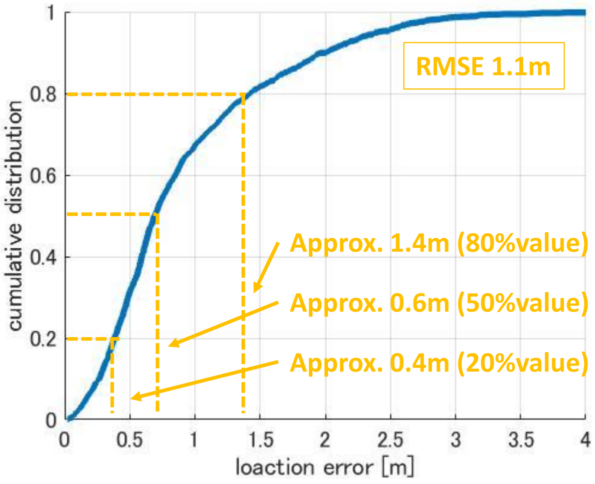
NTT Corporation, NTT DOCOMO, INC., NEC corporation

Integrated Sensing and Communication (ISAC) is gaining attraction as it aims to bring added value to next-generation mobile communication networks. This paper offers an overview of the device-free sensing technology, which detects target object without the need for mobile terminals, utilizing deep learning. It further introduces the effectiveness of this technology based on our experiments conducted on a radio testbed equipped with the physical layer specifications of the 5G (NR) 28 GHz band.

Object



Experimental environment

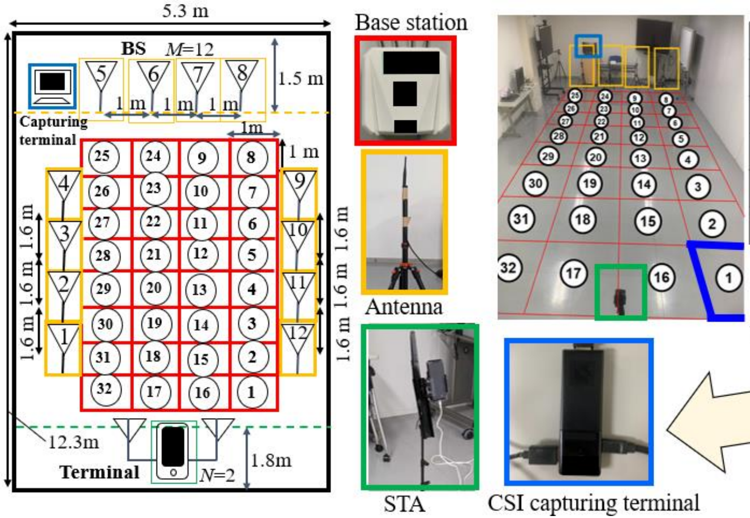


Experimental results

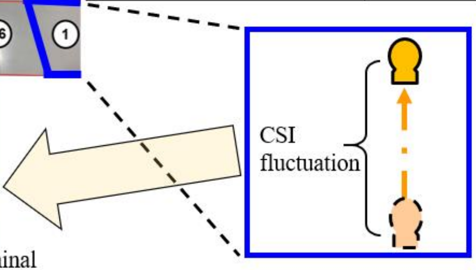
II-2 Indoor Experimental Evaluation of Device-free Localization Schemes Using Channel State Information in Distributed Antenna Systems

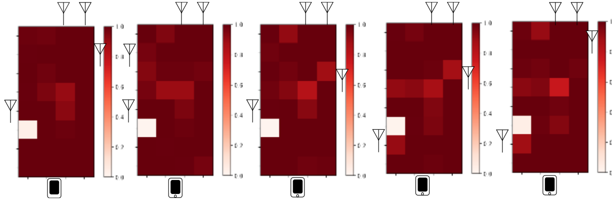
Kyushu University, NTT Corporation

Wireless communication system-based localization techniques that use channel state information (CSI) have attracted much attention. Performance of the CSI-based localization schemes depends strongly on the selected feature information and antenna placement. Herein, we present a real-time CSI-based device-free localization scheme for distributed antenna systems, where CSI feedback frames are collected and used as a dataset for machine learning (ML)-based localization. Experimental results confirmed that the developed localization scheme is effective for detecting a target in an indoor environment. We also discuss how much performance improvement can be expected when antenna placement is given properly.

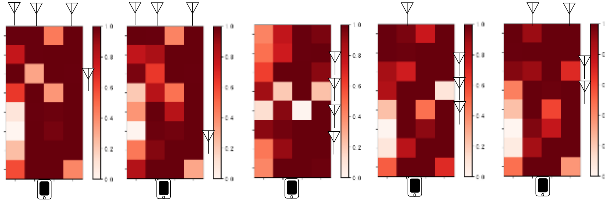


Number of antennas at AP	M=4
Number of antennas at STA	N=2
Antenna height	1m
Bandwidth	20MHz
Carrier frequency	5.18GHz
Number of subcarriers	52





(b) The best 5 detection probability (heatmap)



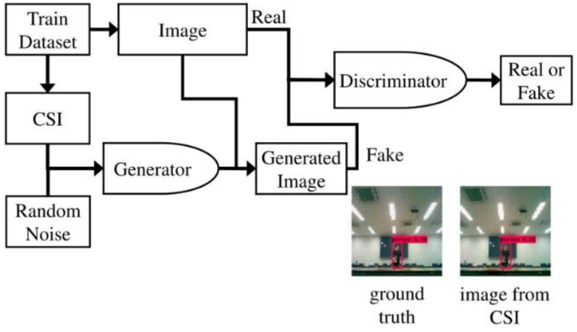
(c) The worst 5 detection probability (heatmap)

Experiment scenario and setup

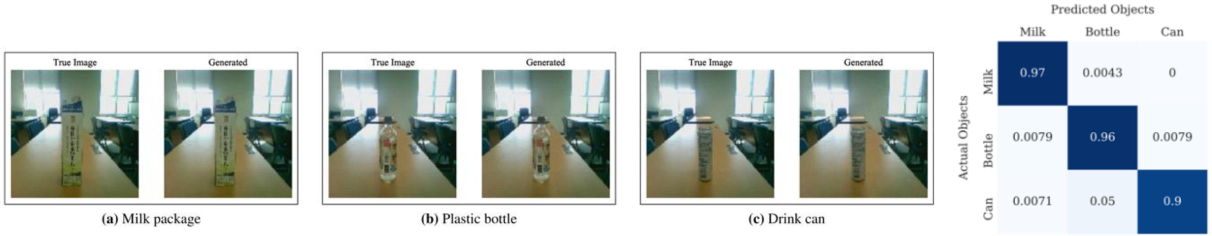
CSI2Image: CSI-to-Image Conversion using a Generative Model

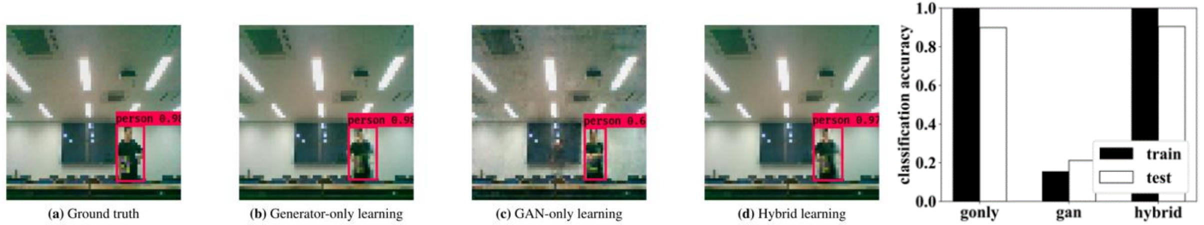
Osaka University, NTT Corporation

Wireless sensing studies based on channel state information (CSI) continue to be successful in various sensing tasks. However, we still have no clear answer to what extent we can extract the environmental parameters of physical space from CSI. We proposed CSI2Image to address such a challenging issue. It converts CSI observations into RGB images corresponding to the physical space using generative adversarial network (GAN) architecture. The generated RGB images intuitively show the relationship between the CSI observations and the physical space and potentially help us to extract many environmental parameters for multi-purpose sensing system.



Overview of CSI2Image



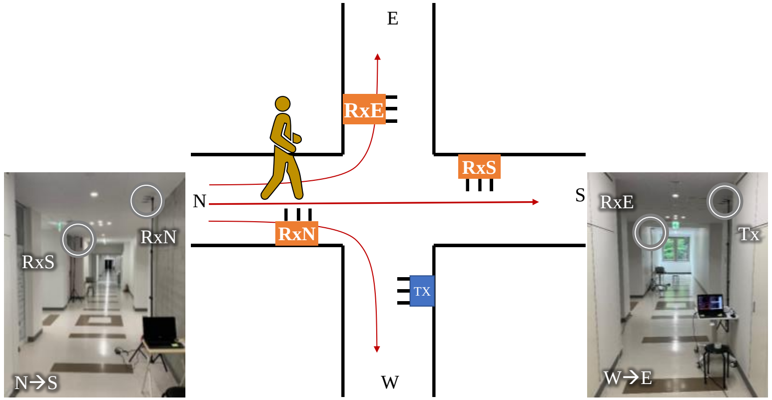


Qualitative and quantitative evaluation for different sensing tasks

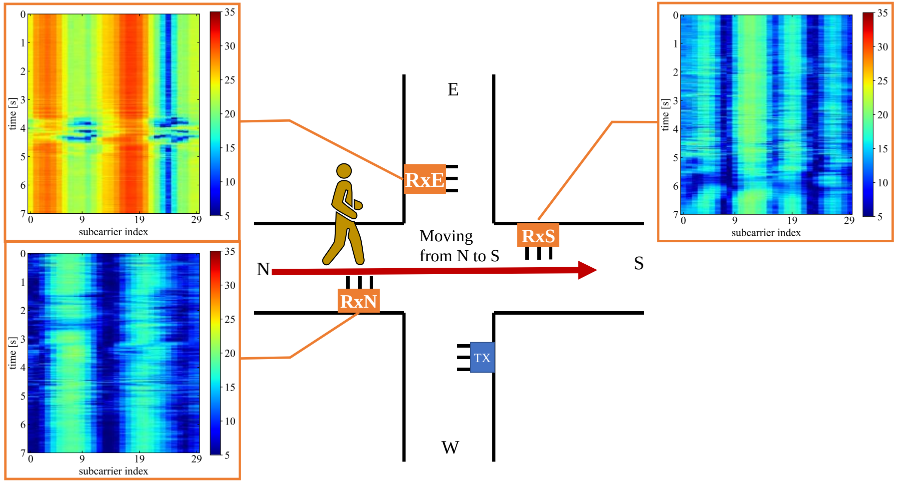
Use Cases for CSI Sensing with an Example of Pedestrian Movement Direction Identification

Sophia University

The original purpose of communication is to convey information. Channel state information (CSI) is used for high-speed transmission and can also function as a sensor. Adding sensing ability to the communication function is expected to open up new services and applications. This paper describes use cases for CSI sensing from the perspectives of commercial products and my research, specifically pedestrian movement direction identification.



Experimental environment



CSI at each receiver

Integrated Sensing and Communication (ISAC)

Huawei Technologies, Huawei Technologies Japan

6G will serve as a distributed neural network for the future Intelligence of Everything. Network Sensing and Native AI will become two new usage scenarios in the era of connected intelligence. 6G will integrate sensing with communication in a single system. Radio waves can be exploited to "see" the physical world and make a digital twin in the cyber world. This paper introduces the concept of integrated sensing and communication (ISAC) and typical use cases, and provides two case studies of how to use 6G ISAC to improve localization accuracy and perform millimeter level imaging using future portable devices. The research challenges to implementing ISAC in practice are discussed.

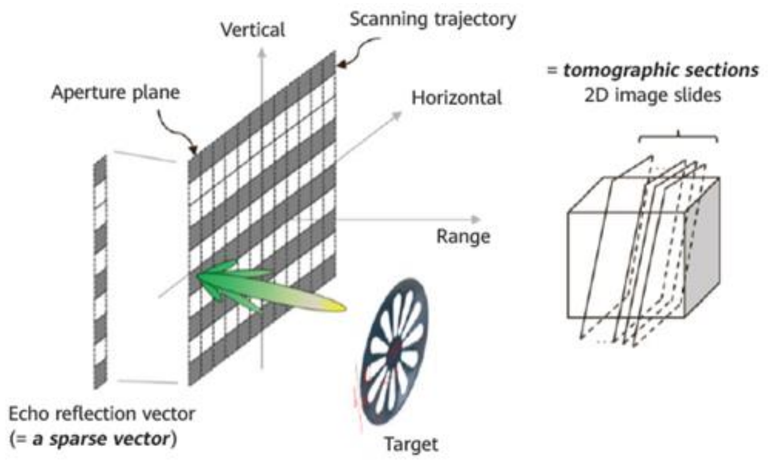
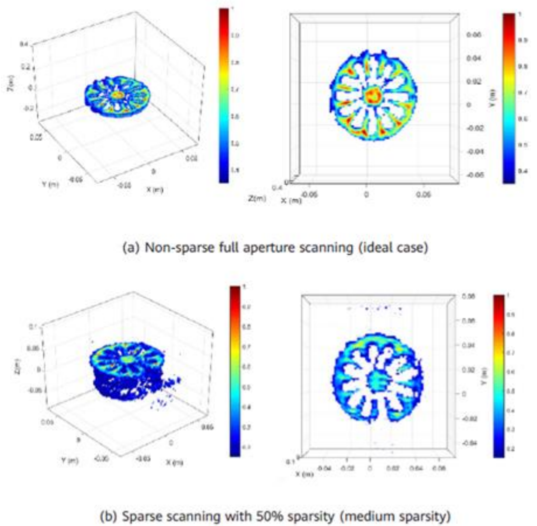


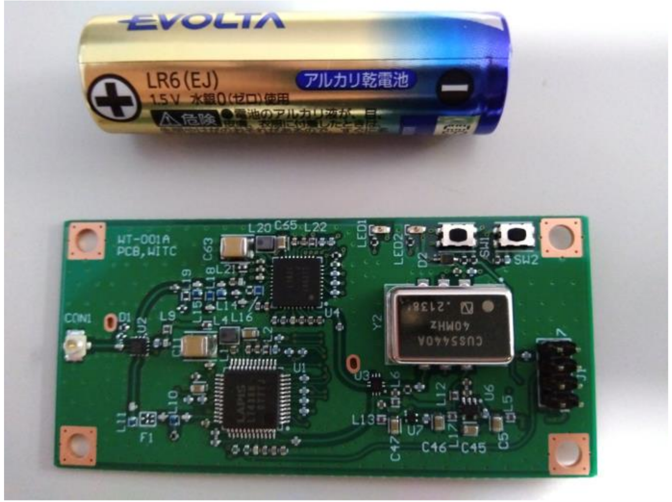
Illustration of the sparse scanning approach and the tomographic imaging techniques



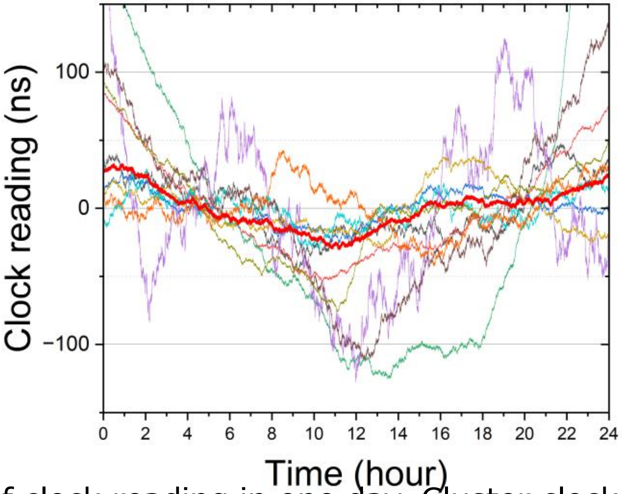
Imaging results at different sparsity configurations

Space-Time Synchronization

For mobile communication technology to transform from a means of man-to-man communication to an infrastructure for various vertical sectors in society, the method of the time synchronization should shift from the traditional leader-follower structure to autonomous distributed synchronization. Furthermore, synchronization must not only be limited to time but also extend to space, entailing the sharing (synchronization) of spatial coordinate axes. This would be realized by three basic technologies, namely compact atomic clocks, wireless time synchronization, and cluster clock systems. The combination will eventually acquire sensing capabilities like distance measurement through radio wave propagation time.



Wi-Wi module

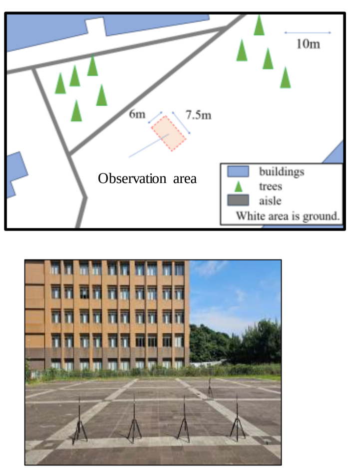


Records of clock reading in one day. Cluster clock (red curve) shows an enhanced stability, whereas ten thin curves are those of each clock.

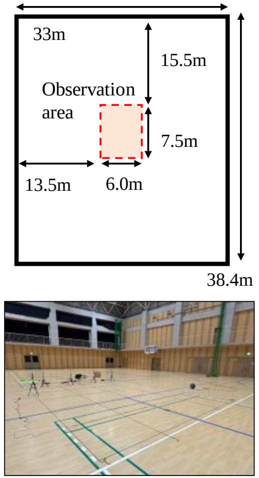
II-7 Experimental Evaluation of WLAN-based Device-Free Localization Using CSI in Outdoor and Large-scale Indoor Environments

Kyushu University, NTT Corporation

Wireless local area network (WLAN)-based device-free localization techniques using channel state information (CSI) have been investigated, where CSI feedback frames are collected and used as a dataset for machine learning (ML)-based localization. However, CSI-based localization scheme performance depends strongly on radio propagation environments such as the existence of reflective obstacles and WLAN antenna positions. This article introduces our recent studies with experimentation on WLAN-based device-free localization in outdoor and large-scale indoor environment scenarios. Experiment results confirmed that the developed localization scheme enhances the localization accuracy in specific areas effectively by properly positioning the access point (AP) and the terminal. We also discuss the degree to which performance difference is observed in various scenarios with different AP and terminal positions.

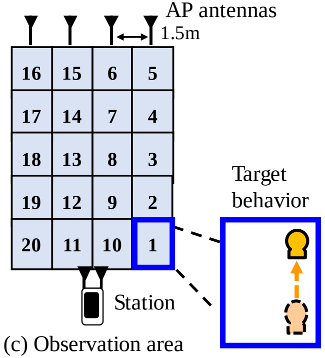


(a) Outdoor (university campus)



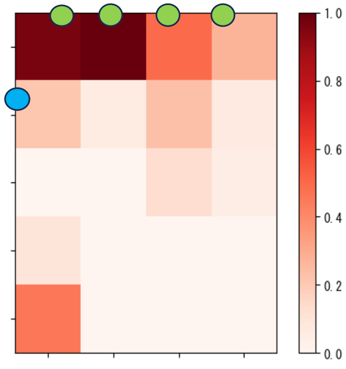
(b) Gymnasium

Number of antennas at AP	M=4
Number of antennas at STA	N=2
Antenna height	1m
Bandwidth	20MHz
Number of subcarriers	52

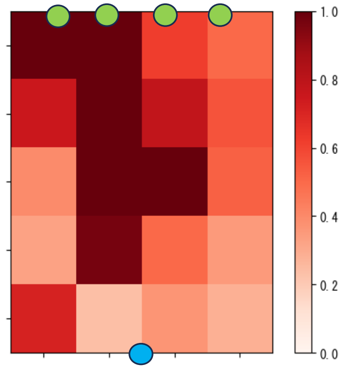


(c) Observation area

Experiment scenario and setup



Area-wise detection probability



Area-wise detection probability

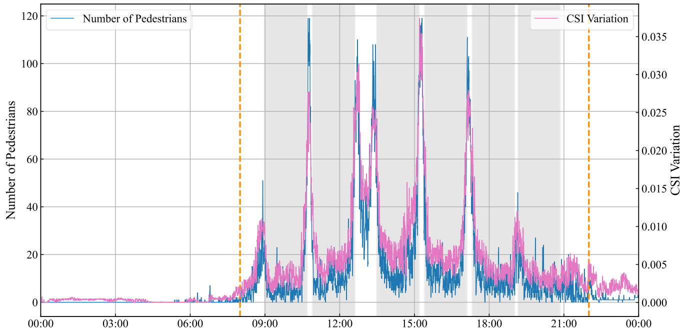
Average detection probability for large-scale indoor experiment scenario

II-8 A Fundamental Study on the Relationship Between Pedestrian Traffic and Wi-Fi CSI with Existing Outdoor Access Points

Sophia University

This article describes the relationship between pedestrian traffic and Wi-Fi channel state information (CSI) with existing outdoor access points (APs). Conducted on a university's main street, pedestrian traffic was measured using YOLOv8, and CSI variation was analyzed. The results show a correlation between CSI variation and congestion conditions, demonstrating the feasibility of estimating pedestrian traffic using CSI variation from existing Wi-Fi APs.

Measurement environment



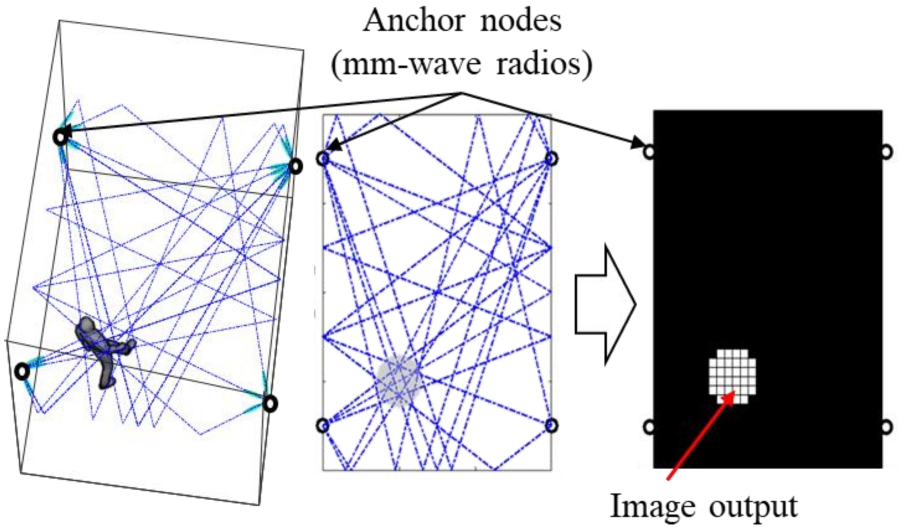
Number of pedestrians and CSI variation

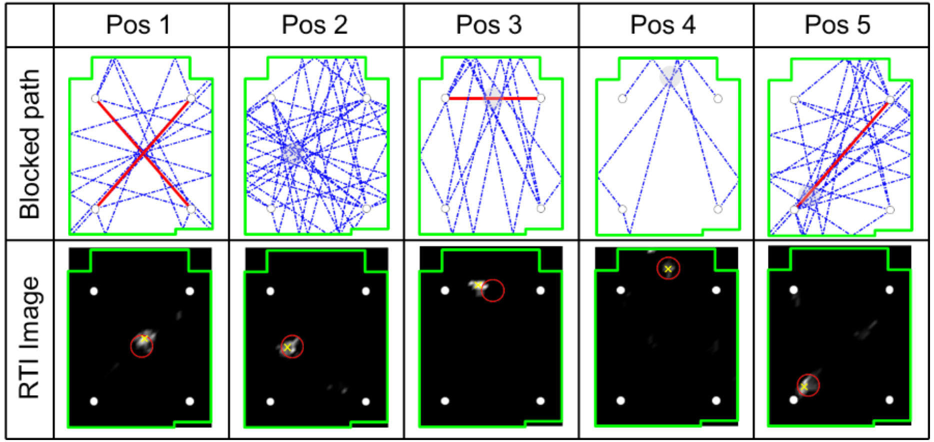
II-9

Multipath-RTI: Millimeter-Wave Radio Based Device-Free Localization

Niigata University

This work developed Multipath-RTI, a novel radio tomographic imaging (RTI) method utilizing millimeter-wave (mmWave) signals for device-free localization (DFL). Unlike conventional RTI approaches that struggle with multipath fading and require many physical anchor nodes, Multipath-RTI leverages virtual anchor nodes formed by multipath reflections. The study introduces compressed sensing-based image reconstruction, automatic parameter tuning, and DBSCAN clustering for multi-target location estimation. Results from simulations and mmWave channel sounding measurements show sub-0.5 m accuracy in complex indoor environments.



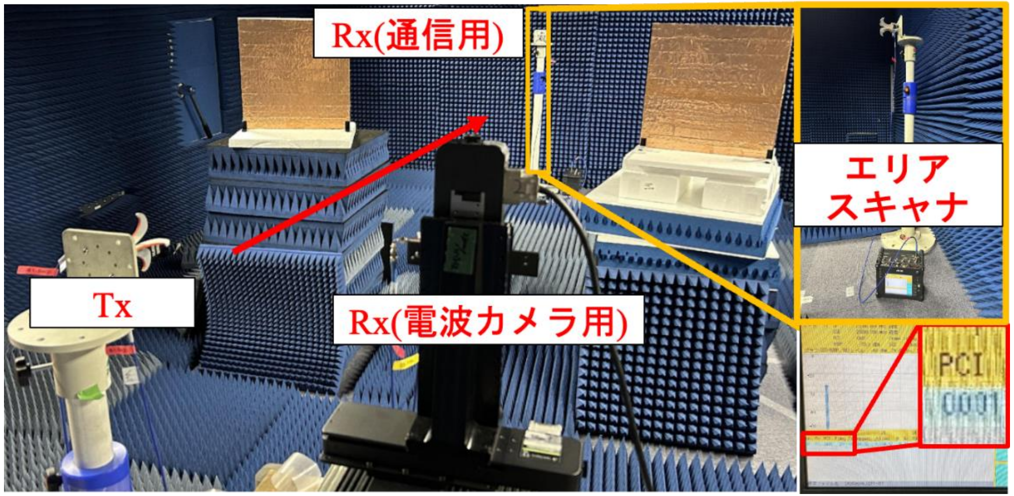


Measurement and evaluation

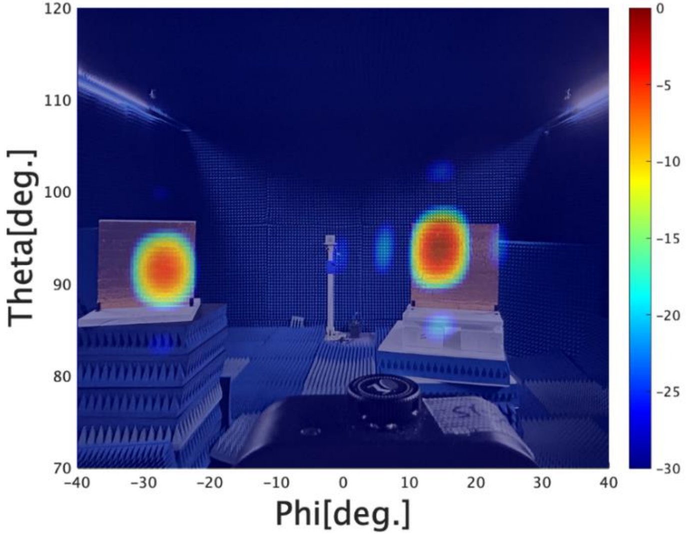
II-10 Verification in an anechoic chamber toward the realization of a radio wave camera using a mobile communication system

SoftBank Corp. Research Institute of Advanced Technology

As part of a preliminary study toward sixth-generation (6G) mobile communications, in which integrated sensing and communication (ISAC) is expected to be a key topic, the authors are investigating target direction estimation using reference signals embedded in a 3GPP-compliant waveform. This paper reports on measurements conducted in an anechoic chamber as part of a basic verification study. Specifically, a reflected 5G NR signal from the installed target is received using a virtual array antenna, and a direction estimation algorithm is applied to the demodulated reception characteristics. The results demonstrate that the target direction can be accurately determined.



Measurement environment



Measurement result