SCIENCE CHINA
Information Sciences

• NEWS & VIEWS •

November 2024, Vol. 67, Iss. 11, 217301:1–217301:2
https://doi.org/10.1007/s11432-024-4172-8

Latest progress for 3GPP ISAC channel modeling standardization

Yuxiang ZHANG[1], Jianhua ZHANG[1*], Yuanpeng PEI[1], Yameng LIU[1] & Tao JIANG[2]

[1]*State Key Laboratory of Networking and Switching Technology, Beijing University of Posts and Telecommunications, Beijing* 100876*, China;*
[2]*Future Research Laboratory, China Mobile Research Institute, Beijing* 100053*, China*

Received 27 August 2024/Revised 21 September 2024/Accepted 9 October 2024/Published online 22 October 2024

Integrated sensing and communication (ISAC) is regarded as a promising technology for sixth-generation (6G) system. Accurate channel modeling is essential for designing and evaluating the performance of ISAC systems. In December 2023, the 3rd Generation Partnership Project (3GPP) established a new industry specification group dedicated to ISAC. The group's objective is to research ISAC channel modeling, laying the technical foundations for 6G standardization. Compared to the traditional 5G communication channel, 6G ISAC channel requires accurate modeling of new properties. These include the propagation paths influenced by the sensing target (ST), the radar cross section (RCS) of the ST, and other non-ST objects relevant to ISAC channel modeling [1,2]. However, the state-of-the-art 3GPP TR 38.901 5G channel model is unable to capture such new 6G channel properties [3]. Modeling these new properties across different scenarios, such as positioning, intrusion detection and environmental reconstruction, presents a significant challenge. The 3GPP technical specification group radio access network working group 1 (TSG RAN1) held meetings #116, #116bis, #117 and #118 (recently concluded in August 2024), to reach a consensus on these issues using TR 38.901 as a starting point [4–6]. The following sections will introduce and clarify important views and agreements during these discussions.

ISAC channel modeling framework. A common framework for the 6G ISAC channel model was established at the #116 meeting. As shown in Figure 1, the ISAC channel consists of two components: the target channel and the background channel. In the standardization process, the ISAC channel represents the sensing channel. The target channel includes all propagation paths impacted by ST, while the background channel encompasses other propagation paths not associated with the target channel [4].

Target channel. The propagation paths within the target channel can be divided into direct paths (DPs) and indirect paths (IDPs). DPs are those that travel directly from the transmitter (Tx) to the ST and then directly from the ST to the receiver (Rx). Alternatively, IDPs may undergo two or more bounces in the target channel. The current discussion has focused on three key areas.

• The first consideration is whether it is necessary to model IDPs. In scenarios like indoor hotspots and dense urban areas, numerous scatterers can lead to the presence of IDPs. Although IDPs undergo multi-bounce propagation, possibly resulting in power attenuation, their exact impact on the target channel is unclear. To address this, measurements were conducted using a human body as the target within an indoor scenario at 28 and 105 GHz [7]. The results revealed that the power contributed of IDPs exceeded 50%, substantiating the necessity of their inclusion in modeling.

• The second consideration is how to portray IDPs. One approach is to model IDPs statistically, similar to the method used for generating non-line-of-sight (NLoS) paths as described in TR 38.901. Conversely, deterministic environmental objects (EOs), such as street lamps and walls, may significantly influence the propagation path. By utilizing the geometric positions of EOs, IDPs can be more accurately determined, enhancing the precision of inferring the ST position and motion. Therefore, incorporation EOs into the target channel could improve sensing accuracy.

• The third consideration is how to model the target channel as a concatenation of the Tx-ST and ST-Rx channels. During the #118 meeting, it was agreed that this concatenation method effectively characterizes the ST properties. To validate this hypothesis, measurements at 6.9 GHz in an indoor scenario were conducted [7]. These measurements confirmed that, for large-scale fading, the Tx-Rx path loss can be represented as the linear superposition of the Tx-ST and the ST-Rx path losses. Furthermore, for small-scale fading, the Tx-Rx channel impulse response (CIR) can be represented as the convolution of the Tx-ST and ST-Rx CIRs.

RCS of a sensing target. RCS was first defined in radar systems to measure the ability of the ST to capture power from radar signals and re-radiate it back toward the radar [8]. In ISAC systems, RCS is similarly used to characterize the radiative capability of the ST for sensing signals across different scenarios and modes.

• The RCS value can be generated by combining deterministic and random components. For a specific ST, the deterministic component represents the average value from multiple measurements, while the random component is a statistical random variable fitted based on these results, following a certain distribution. For example, STs such as

* Corresponding author (email: jhzhang@bupt.edu.cn)

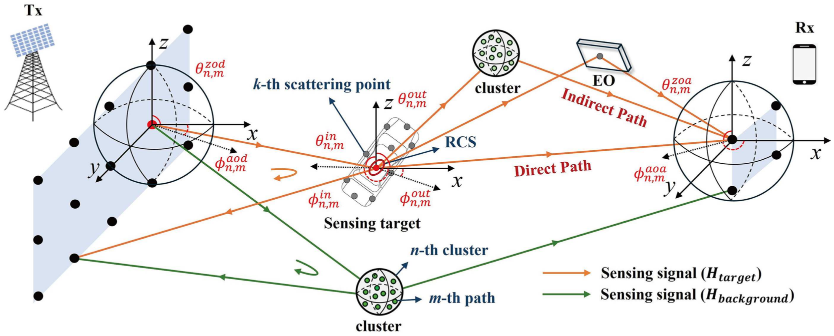

Figure 1 (Color online) Schematic of the 6G ISAC channel model based on extended geometry-based stochastic channel model (GBSM).

unmanned aerial vehicles (UAVs) and humans exhibit similar omnidirectional scattering properties, making the deterministic component angle-independent [9]. However, STs such as vehicles display notably increased RCS values at angles near 0°, 90°, 180°, and 270°, indicating an angle-dependent deterministic component [9]. Moreover, the random component may vary with factors such as frequency and distance, differing across various sensing targets. This variability poses a significant challenge for unified modeling approaches.

• Furthermore, several factors can influence the RCS value. First, the RCS value may vary with the distance between the Tx/Rx and the ST [10]. However, no definitive mathematical formula exists to represent this relationship. The results presented in [9] demonstrate that RCS fluctuations occur with changing distances between Tx/Rx and the ST. While this is initially evident, the fluctuations gradually subside as the distance increases. Second, the RCS value for a given ST may differ depending on whether mono-static or bi-static sensing modes are employed. The results in [9] demonstrate that when the bi-static sensing mode is employed, and the angle between the departing and incident angle waves is small, the RCS value approximates mono-static sensing measurements. However, as this angle increases, the propagation conditions of the target channel may change [11], leading to random RCS value variations. Ultimately, multi-point modeling might characterize the RCS properties more accurately, thereby contributing to the study of ST orientation, posture, and micro-Doppler effects. For example, different ST components, such as UAV bodies and propellers, can be modeled to account for relative motion.

Background channel. In the current discourse on ISAC systems, the prevalent viewpoint is that the background channel should be modeled using the statistical clusters as defined in TR 38.901. However, two critical aspects require immediate attention:

• The first aspect is whether to introduce deterministic components such as EO into the background channel. Including these components could be instrumental in determining interference levels and their influence on sensing performance. For instance, integrating EO into the target channel may be an option, yet the impact of such modeling on current communication channel should be carefully considered.

• The second aspect is whether background and target channels interact. Channel measurements conducted in typical line-of-sight (LoS) and NLoS indoor scenarios [12] indicate that these channels are not independent. This interdependence may result from shared scatterers present in both channels. To measure this interaction, the Sharing Degree metric has been introduced. Nonetheless, further research is necessary to determine whether this characteristic should be expressed in the ISAC channel modeling framework.

Conclusion. Currently, 3GPP TSG RAN1 has held four meetings focused on ISAC technology. These discussions have led to the approval of a common framework for ISAC channel modeling. At the same time, modeling schemes for target and background channels have been proposed. RCS modeling has also been considered, in particular the various factors affecting RCS values. These aspects will be the focus of future discussions as efforts continue to reach a consensus. In addition, further field measurements in typical scenarios are required to support the research and standardization of ISAC channel. Overall, ISAC channel modeling is a challenging and ongoing process.

Acknowledgements This work was supported by Young Scientists Fund of the National Natural Science Foundation of China (Grant No. 62201087), National Science Fund for Distinguished Young Scholars (Grant No. 61925102), Key Program of Beijing Municipal Natural Science Foundation (Grant No. L243002), National Key R&D Program of China (Grant No. 2023YFB2904805), Guangdong Major Project of Basic and Applied Basic Research (Grant No. 2023B0303000001), Key Program of National Natural Science Foundation of China (Grant No. 92167202), and BUPT-CMCC Joint Innovation Center.

References

1 Zhang J H, Wang H, Zhang Y X, et al. Channel characteristics and modeling research for 6G: challenges, progress, and prospects. Sci Sin Inform, 2024, 54: 1114–1143
2 Zhang J H, Wang J L, Zhang Y X, et al. Integrated Sensing and communication channel: measurements, characteristics and modeling. IEEE Commun Mag, 2024, 62: 98–104
3 Study on channel model for frequencies from 0.5 to 100 GHz (Release 16), document 3GPP TR 38.901, 2020
4 Chair Notes, 3GPP TSG RAN WG1 #116, February 26th–March 1st, 2024
5 Chair Notes, 3GPP TSG RAN WG1 #116bis, April 15th–April 19th, 2024
6 Chair Notes, 3GPP TSG RAN WG1 #117, May 20th–May 24th, 2024
7 R1-2404417, Discussion on ISAC channel modeling, 3GPP TSG RAN WG1 #117, May 20th–May 24th, 2024
8 Budge M C, German S R. Basic RADAR analysis. Artech House, 2020
9 R1-2406107, ISAC Channel Measurements and Modeling, 3GPP TSG RAN WG1 #118, Aug 19th–Aug 23th, 2024
10 Chai Z Y, Zhang Y X, Liu G Y, et al. Empirical path loss channel modeling at 28 GHz for integrated sensing and communication system. In: Proceedings of 2023 International Conference on Wireless Communications and Signal Processing (WCSP), 2023. 366–370
11 R1-2406196, Views on Rel-19 ISAC channel modelling, 3GPP TSG RAN WG1 #118, Aug 19th–Aug 23th, 2024
12 Liu Y M, Zhang J H, Zhang Y X, et al. A shared cluster-based stochastic channel model for integrated sensing and communication systems. IEEE Trans Veh Technol, 2024, 73: 6032–6044