Integrated Sensing and Communication with Open RAN Infrastructure

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Abstract

Integrated Sensing and Communication (ISAC) promises to transform every cellular base station into a dual-purpose radar, unlocking pervasive environmental awareness without dedicated sensing hardware. Realizing this vision requires open, reproducible platforms, yet today's prototypes remain locked to custom radios and proprietary stacks. We present the first bistatic ISAC demonstration over an outdoor 5G Open Radio Access Network (O-RAN) network, pairing an unmodified commercial UE with an O-RAN base station consisting of all commercial components. By processing uplink Sounding Reference Signals at the network edge, our system achieves human motion detection and indoor-versus-outdoor sensing comparison with zero hardware modification. Built on Campus5G, a 20-base-station O-RAN testbed, our work opens a direct path from single-link feasibility to large-scale, AI-driven sensing as a native network service.

CCS Concepts

• **Networks** → *Network experimentation*; **Mobile networks**.

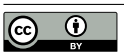
Keywords

Integrated Sensing and Communication, Open RAN, 5G

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1 Introduction

Integrated Sensing and Communication (ISAC) enables mobile networks to jointly use radio spectrum and infrastructure for data transmission and environmental sensing [3]. By capturing the multipath in radio channel impulse response (CIR) and Doppler shifts caused by sensing targets, an ISAC-capable base station (BS) can detect humans, vehicles, and drones without dedicated radar hardware or the privacy concerns of cameras. 3GPP TR 22.837 [1] discusses use cases including intruder detection, vehicle tracking, Unmanned Aerial Vehicle (UAV) monitoring, and infrastructure health sensing, all of which can be realized with today's 5G waveforms.



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However, translating these use cases into working systems remains difficult. Proprietary cellular BSs or user equipments (UE) do not expose the low-level channel measurements needed for sensing purposes. Existing ISAC prototypes therefore rely on Wi-Fi with CIR extraction [8] or Software-Defined Radio (SDR) based cellular testbeds [3]. This limits practical deployment of ISAC in cellular networks and the ability to collect real-world datasets needed for diverse sensing tasks. Open RAN addresses this gap [4]: open-source RAN stacks such as srsRAN [7] provide full access to 5G reference signals and physical-layer internals, enabling commercial-grade ISAC experimentation.

Our work exploits this opportunity by building the first outdoor ISAC testbed that pairs a commercial, unmodified 5G UE with an O-RAN-compliant commercial BS. We focus on *uplink bistatic sensing*, where the UE transmits Sounding Reference Signals (SRS) and the BS as the receiver performs sensing, for two reasons. First, uplink sensing is *network-centric*: the distributed unit (DU) of BS receives SRS from multiple UEs, thereby enabling collaborative sensing and applications. This collaboration can be further extended to multiple DUs to support larger-scale sensing. Second, the DU possesses far greater computing resources than the UE and can be equipped with GPUs [4], making real-time AI-based sensing practical at the network edge. This positions ISAC as an *AI-on-RAN* application under the emerging AI-RAN framework [5]—an AI-enabled service that runs on RAN infrastructure rather than merely optimizing the RAN itself. Note that among uplink reference signals (UL RS), we use SRS because it supports periodic configuration with flexible periods [2], whereas other RSs are tied to UL data transmissions.

To our knowledge, no prior work demonstrates such a commercial-grade, O-RAN-compliant sensing scenario in a *live 5G outdoor network*, which is the primary deployment setting of cellular systems. We present a single-link feasibility study as a first step towards validating ISAC over commercial hardware. Our underlying testbed, Campus5G [4], is a campus-scale outdoor O-RAN deployment with 20 BSs and provides a clear path to multi-link, large-scale ISAC experimentation, such as crowd monitoring and wide-area intrusion detection. In the following, we elaborate on our system setup and present preliminary results on human walking detection and the characterization of indoor versus outdoor sensing.

2 Bistatic ISAC with Open RAN Testbed

System Setup of 5G O-RAN Testbed. Campus5G have 20 O-RAN compliant radio units (O-RU) from two vendors deployed to provide blanket coverage over the campus area. More details are referred to [4]. Figure 1 illustrates our testbed architecture. In this work, a Samsung phone with Quectel 5G modem serves as the ISAC illuminator, transmitting uplink SRS per 320 ms without

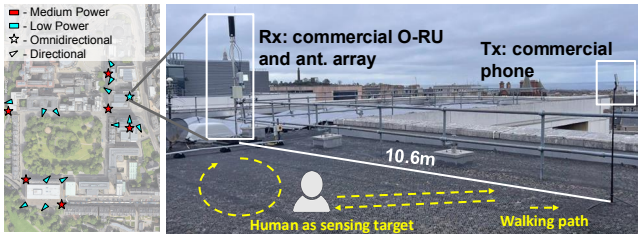


Figure 1: Bistatic ISAC setup with Campus5G Testbed.

any firmware modification. The BS side comprises a Benetel O-RU (100 MHz bandwidth, 3.95 GHz) connected via Open Fronthaul to the srsRAN DU, which extracts per-subcarrier channel estimates from the received SRS. A person as the sensing target exhibits the following behaviors: 1) remaining stationary; 2) walking in straight lines; 3) walking along circular trajectories; 4) and continuously waving their hands near the phone.

Sensing Methodology. An ISAC sensing xApp runs at the network edge (DU) and implements two processing pipelines. For motion detection, we generate a *micro-Doppler spectrogram* from successive SRS channel estimates using a short-time Fourier transform along the slow-time dimension, after aligning the dominant line-of-sight (LOS) path to remove for carrier-frequency offset (CFO) [6]. For indoor–outdoor comparison, we derive a *channel frequency response (CFR) quotient* as the ratio of the raw CFRs from two antenna elements, thereby canceling CFO and phase shifts. We then aggregate this quotient across all subcarriers at each slot and extract its amplitude as the sensing metric.

Human Walking Detection. Figure 2 shows the Doppler spectrograms for three scenarios. In the static case, energy is concentrated near zero Doppler, with small non-zero components due to uncontrollable outdoor effects such as wind. Straight-line walking produces a clear Doppler signature at frequencies consistent with typical walking speeds (~1–1.5 m/s, corresponding to ~15–40 Hz at 3.95 GHz), while circular walking exhibits a clearly different Doppler profile. These results demonstrate that SRS-derived channel estimates from our O-RAN testbed offer sufficient temporal resolution and signal quality to distinguish basic human motion patterns. More complex non-line-of-sight (NLoS) environments or richer activity sets will likely require more advanced sensing algorithms, such as AI-based methods.

Outdoor vs. Indoor Sensing. We compare the same CFR-quotient metric in matched indoor and outdoor experiments, each with a static period followed by a motion period in which a person continuously waves their hands by moving them closer to and farther from the transmitter. As shown in Figure 3, the indoor trace is stable when static and shows a clear periodic pattern during motion. The outdoor trace fluctuates more even in the static period and shows a weaker periodic pattern during motion. This suggests that outdoor sensing is more difficult, because environmental clutter and other small uncontrolled motions can obscure the periodic signature of the target activity.

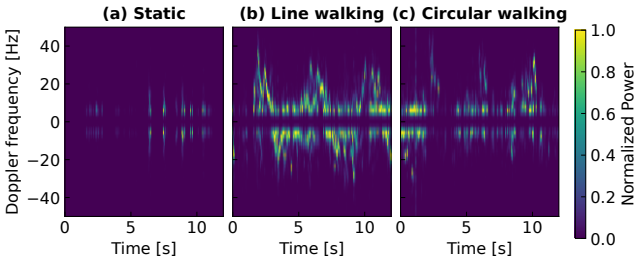


Figure 2: Doppler spectrograms for (a) static, (b) straight-line walking, and (c) circular walking.

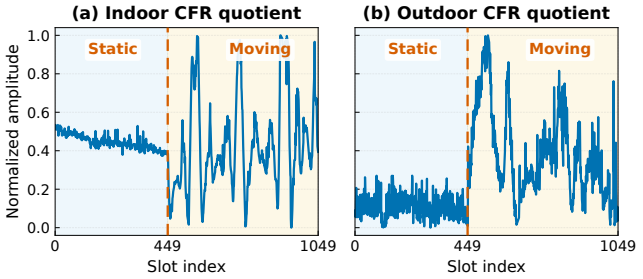


Figure 3: CFR quotient amplitude aggregated across subcarriers over time for (a) indoor (b) outdoor.

3 Concluding Remarks and Future Work

We present a bistatic ISAC feasibility study that pairs a commercial, unmodified 5G UE with an O-RAN-compliant BS, demonstrating human walking detection and indoor-versus-outdoor sensing characterization using uplink SRS. Our immediate next step is to conduct systematic cross-environment (indoor, outdoor, and varying weather) and cross-device (multiple UE models, O-RU vendors, SDR baselines, and 5G vs. Wi-Fi) benchmarking campaigns. To our knowledge, this would be a unique contribution that has not been thoroughly explored before. We then plan to extend the testbed toward network-centric, large-scale sensing applications involving multiple BSs and UEs and combining multiple types of reference signals, enabling novel use cases such as crowd density estimation. Finally, we will explore AI-based sensing for complicated environments, thereby moving toward ISAC as an AI-on-RAN service.

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