Full-Duplex (FD) Integrated Sensing and Communication (ISAC)

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• 5G NR and future 6G networks:
  • Peak data rates
  • Network capacity
  • Number of connected devices
  • Radio access latency & reliability
  • …

• Full-duplex (FD) communication and self-interference cancellation (SIC)
  ➢ Emerging technology initiative (ETI)

• Integrated sensing and communication (ISAC)
  • ”RF convergence”
    • Sharing frequencies, transmit waveforms and even hardware platforms
  ➢ Emerging technology initiative (ETI)
Aim & Scope

- **Aim of the ETI**: To explore and support a wide variety of research directions and industrial opportunities related to ISAC. More importantly, promote our research area here.

- **Scope of the ETI**: Integrate ongoing research efforts and initiatives to become the catalyst and future reference for experts working in different aspects of ISAC, including:
  - **Information Theory** to reveal the fundamental limits and tradeoffs in ISAC
  - **Signal Processing** to design dual-functional waveforms and joint SP frameworks
  - **Mobile Computing** to detect and recognize events and activities via commercial devices
  - **Aerospace & Electronic Systems** (Radar Systems) to embed communication function into radar
  - **Vehicular Technology & Intelligent Transportation Systems** to leverage ISAC in V2X and Autonomous Vehicles
**ISAC Gains**

**Integration Gain**

- Efficiency Improvement:
  - Spectral Efficiency
  - Energy Efficiency
  - Hardware Efficiency
- Cost Reduction:
  - Hardware Cost
  - Signaling Cost

**Fundamental Theory:** ISAC Information Theory, ISAC Signal Processing, ISAC Resource Allocation

Y. Cui, et al. Integrating Sensing and Communications for Ubiquitous IoT: Applications, Trends and Challenges. submitted to IEEE Network

2021-5-13

IEEE ComSoc ISAC-ETI 1st Meeting

https://isac.committees.comsoc.org/
**ISAC Gains**

**Coordination Gain**

**Sensing-Assisted Comms**

Vehicle to Everything
- Key Data Elements
- High-Precision Location
- Vehicle Parking
- Extracted Sensor

Application Scenario:
- V2X

Key Techniques:
- Sensing-Assisted Resource Management
- Sensing-Assisted Platooning
- ...

**Comms-assisted Sensing (Sensing as a Service)**

- Drive Monitoring and Management
- Area Imaging
- Human Localization and Tracking
- Human Authentication and Identification
- Human Counting
- Perceived Sensing Network

Application Scenario:
- Perceptive Cellular Network

Key Techniques:
- Cooperative Sensing
- Beyond LoS Sensing
- Networked Sensing Performance Analysis
- ...

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Research Progress

- 1963 - 2013, 1st 100 IEEE papers on ISAC
- 2013 - 2017, 2nd 100 IEEE papers on ISAC
- 2017 - 2019, 3rd 100 IEEE papers on ISAC
- 2019 - 2020, 4th 100 IEEE papers on ISAC

ISAC research has been **tremendously** accelerated, and **worldwide**!

We witnessed a significant research interest in

- SPS
- AESS
- ComSoc

Several papers published in

- CS
- ITSoC
- ITSS
- VTS

We would like to encourage ISAC activities in these societies.
Industrial Efforts

Huawei identifies ISAC as one of the 3 major scenarios in their vision of 5.5G

Ericsson 6G White Paper

Extreme performance and coverage

The future wireless systems are not only expected to provide high-speed data rates but also to support a wide range of applications such as enhanced mobile broadband, massive machine-type communication, and ultra-reliable low latency communication. Ericsson has been working on 6G technology for several years, focusing on areas such as edge computing, artificial intelligence, and quantum computing.

NTT DOCOMO 6G White Paper

3.6 Extreme-extreme connectivity & mobility

Rapid advancements in technology have enabled significant improvements in wireless communication systems. With the development of 5G, we see a shift towards even more advanced connectivity solutions. NTT DOCOMO’s 6G White Paper highlights the importance of extreme-extreme connectivity and mobility, where devices and users can connect to one another at unprecedented speeds.

Nokia Bell Labs propose a unified mmWave system for combined communication and sensing

ZTE and China Unicom: The integrated communication and sensing is the potential key technology of 6G

ZTE and China Unicom have recently signed a strategic cooperation agreement on 6G. This partnership aims to accelerate the development of 6G technology, focusing on areas such as integrated communication and sensing. The integration of communication and sensing technologies is expected to enable new applications, such as enhanced autonomous driving, smart cities, and more.

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Future 5G/6G wireless indoor systems: A blueprint for joint communication and sensing

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**Industrial Efforts**

**IEEE 802.11bf - WLAN Sensing**

-- The first international standard for sensing

**Definition**

*WLAN sensing is the use of received WLAN signals to detect feature(s) of an intended target(s) in a given environment.*

- **Features**: Range, velocity, angular, motion, presence or proximity, gesture, etc.
- **Target**: Object, human, animal, etc.
- **Environment**: Room, house, car, enterprise, etc.

**Use cases**

1. Smart home
2. Presence and proximity detection (Home/Enterprise/Vehicle)
3. Gesture recognition
4. Gaming control
5. Liveness
6. Location in store
7. Audio with user tracking (Follow-me sound)
8. Sneeze sensing

**KPI**

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (m)</td>
<td>Field of view (°)</td>
<td>Range (m)</td>
</tr>
<tr>
<td>Probability of detection (%)</td>
<td>Latency (ms)</td>
<td>Refresh rate (Hz)</td>
</tr>
</tbody>
</table>

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1. [https://isac.committees.comsoc.org/](https://isac.committees.comsoc.org/)
2. [http://mentor.ieee.org/802.11/www/2017-3-802.11bf-wlan-sensing-use-cases.xlsx](http://mentor.ieee.org/802.11/www/2017-3-802.11bf-wlan-sensing-use-cases.xlsx)

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Full-Duplex Base Station for Sensing

- Using **NR Base Station** (gNB) also as **monostatic radar**, while transmitting the standard downlink signal
- **The receiver must be operating simultaneously while transmitting**
  - no targets within tens of kilometers could be detected otherwise
The receiver must be operating simultaneously while transmitting
- implementation challenge: sufficient transmitter–receiver isolation

Essentially an in-band full-duplex radio:
- direct TX-RX leakage can be interpreted as a strong static target at a very short distance
- powerful SI component can largely mask the true echoes and targets
  - particularly those that are static, but also other slowly moving targets
- efficient isolation/suppression mechanisms needed, though not as high as in two-way communications