Distributed Wireless Systems Laboratory

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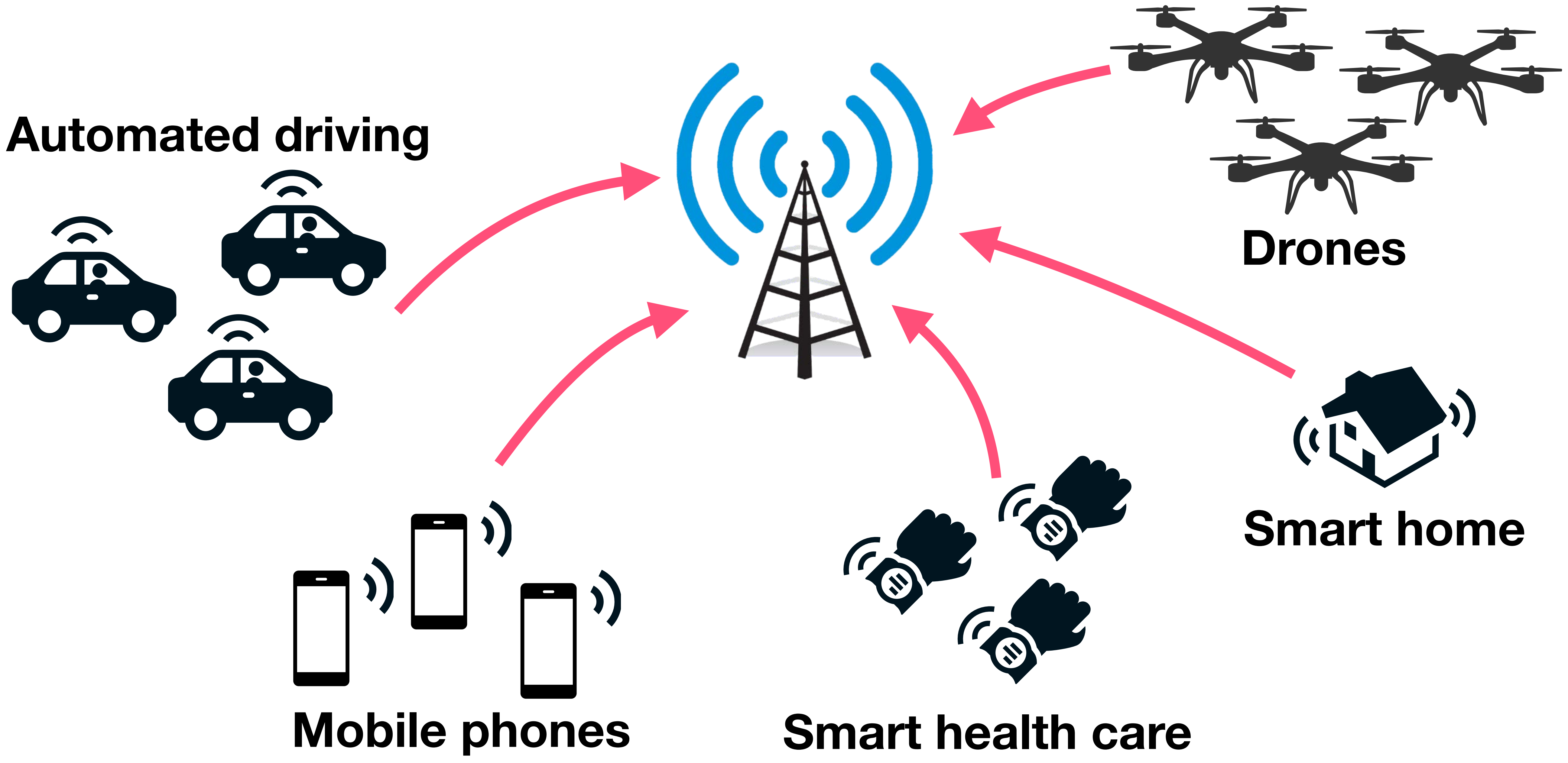
Our Team

- Our team is aiming to realize ultra-reliable and ultra-long-life communications systems and *mainly* focusing on a physical layer.
- We are actively running projects with universities and companies, e.g.,
  - beyond 5G/6G (by MIC),
  - physical-layer security for the post-quantum era (by JST EU-JP Project),
  - ultra-low power communications (by JST) , and more.

- We have:
  2 postdocs
  4 Ph.D. students
  4 master students
  5 undergraduate students

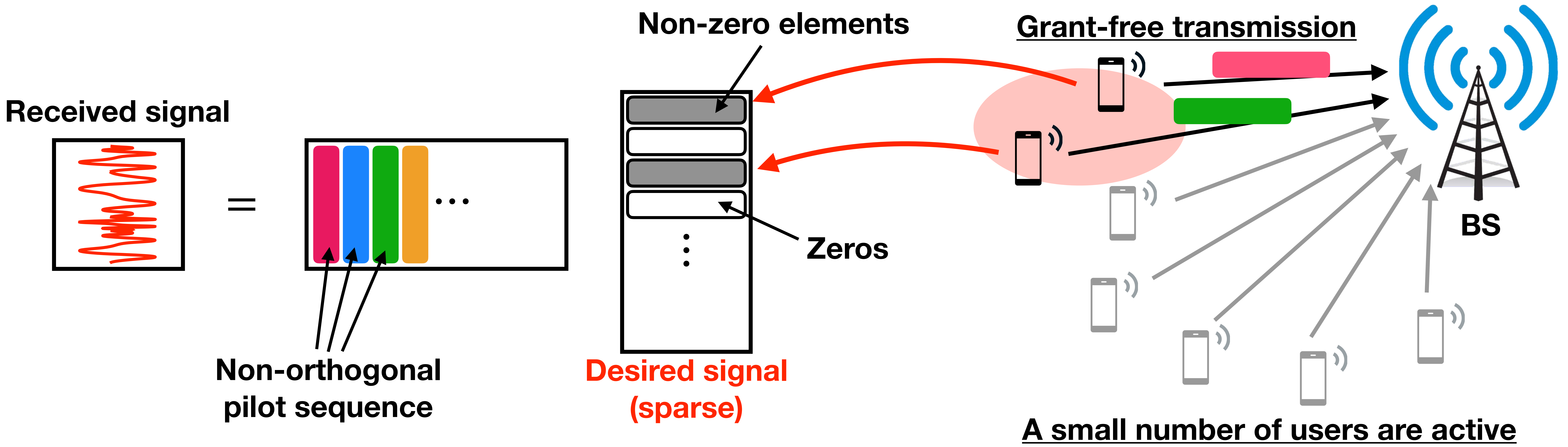
Low-latency Grant-free Massive Access

- With the emergence of advanced applications, future wireless communications systems are demanded to meet massive connectivity and low latency.
- To realize low-latency massive access, we investigate following two approaches.
  - Compressed sensing (CS)-based grant-free non-orthogonal multiple access (GF-NOMA)
  - Graph-based random access protocols



CS-based GF-NOMA

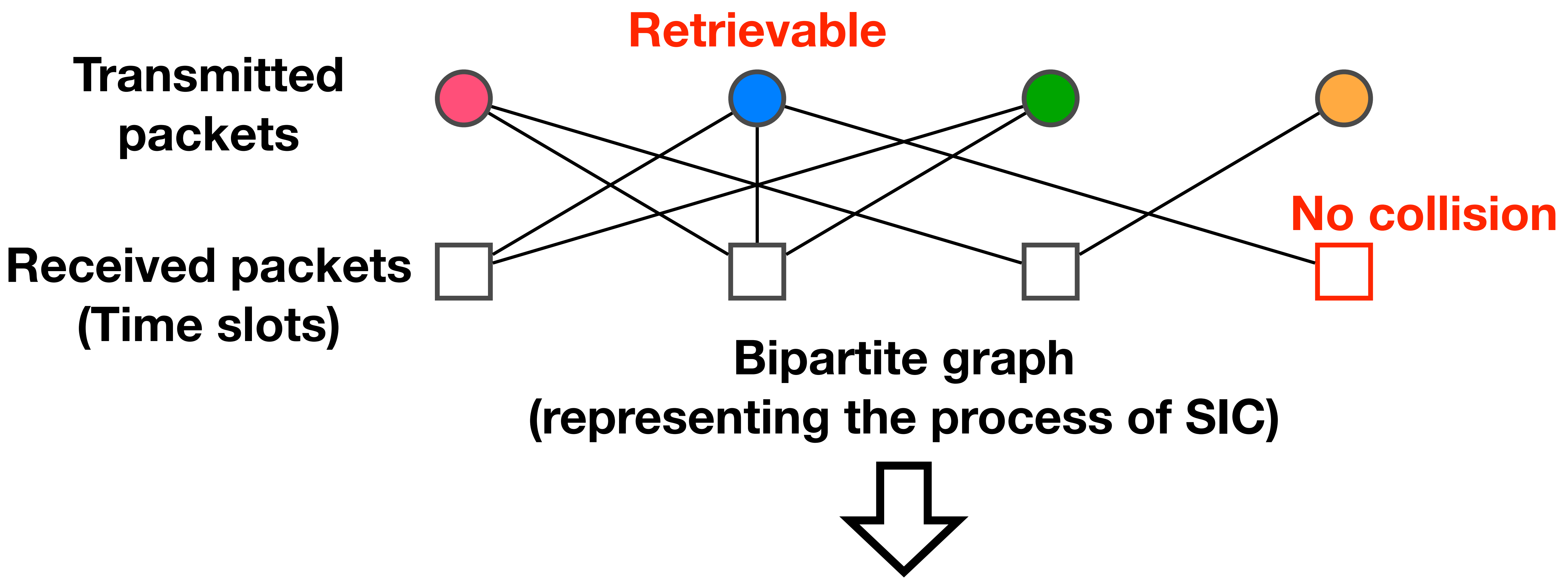
- In GF-NOMA systems, the base station (BS) needs to estimate active users, channel coefficients, and transmitted data efficiently.
- Our proposed schemes enable low-latency massive access based on a bilinear recovery [1], the channel sparsity in the delay domain [2], and the block sparsity due to multiple measurements [3].

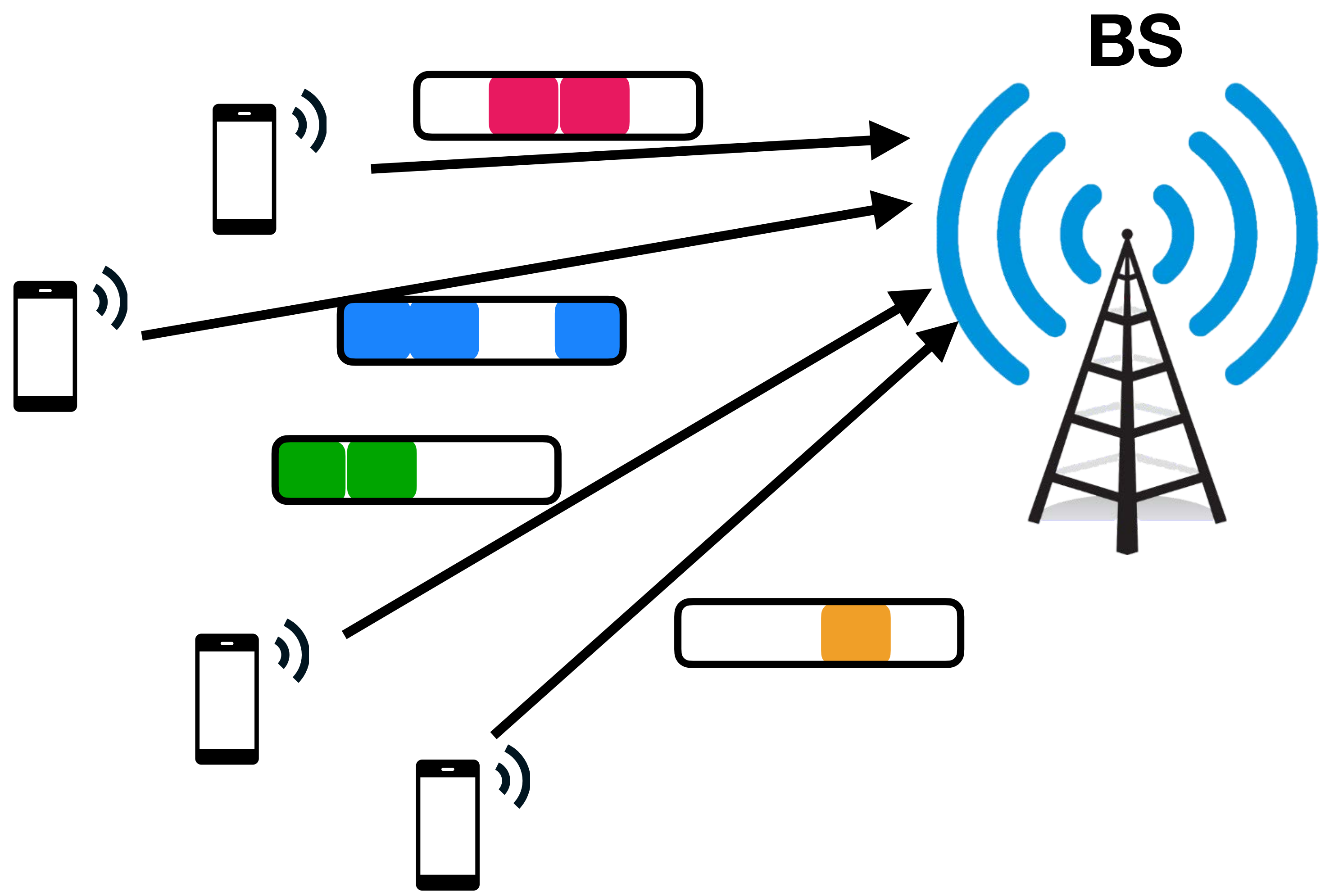


[1] H. Iimori et al., *IEEE Trans. Wireless Commun.*, 2021 (Early Access).
[2] T. Hara, H. Iimori, and K. Ishibashi, *IEEE Wireless Commun. Lett.*, vol. 10, no. 4, pp. 810–814, Apr. 2021.
[3] T. Hara and K. Ishibashi, *IEEE Access*, vol. 7, pp. 175717–175726, Nov. 2019.

Graph-based Random Access Protocols

- The random access protocols, such as coded-slotted ALOHA and frameless ALOHA, utilize probabilistic transmission and successive interference cancellation (SIC).
- Our proposed protocols can achieve higher throughput by incorporating other techniques, e.g., ZigZag decoding[4,5] and multiple BS cooperation[6].



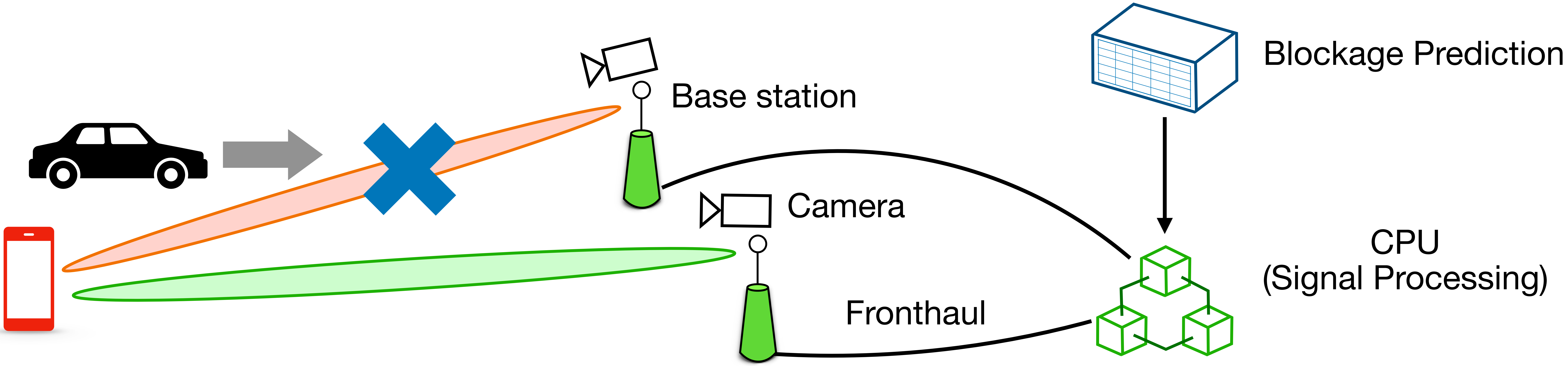


<u>These protocols can be designed based on coding theory.</u>

[4] M. Oinaga, S. Ogata, and K. Ishibashi, *IEEE Access*, vol. 7, pp. 168527–168535, Nov. 2019.
[5] S. Ogata and K. Ishibashi, *IEEE Access*, vol. 7, no. 1, pp. 39528–39538, Mar. 2019.
[6] S. Ogata, K. Ishibashi, and G. T. F. de Abreu, *IEEE Trans. Wireless Commun.*, vol. 17, no. 11, pp. 7486–7499, Nov. 2018.

Robust CoMP with Blockage Prediction

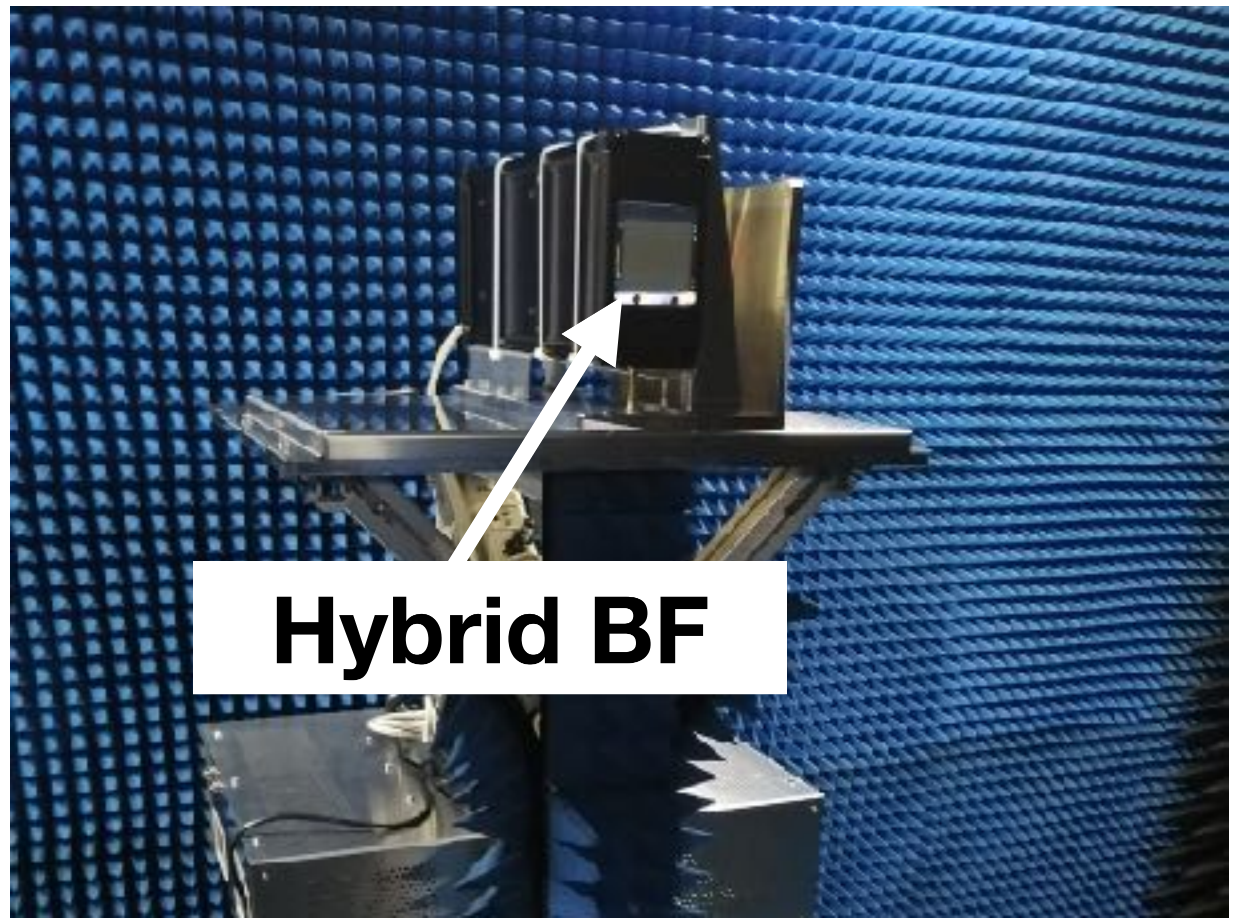
- The increasing demand for high data rates and ultra-high reliability drives future wireless systems to exploit the millimeter wave (mmWave) spectrum. MmWave comprises bands from 24 to 300 [GHz] and is used in Beyond 5G and 6G standards.
- MmWave signals are vulnerable to random blockages caused by obstacles like human bodies and vehicles, resulting in unstable communications.
- To overcome this impediment, we have proposed two coordinated multi-point (CoMP) transmission based on stochastic learning with blockage prediction[8, 9].

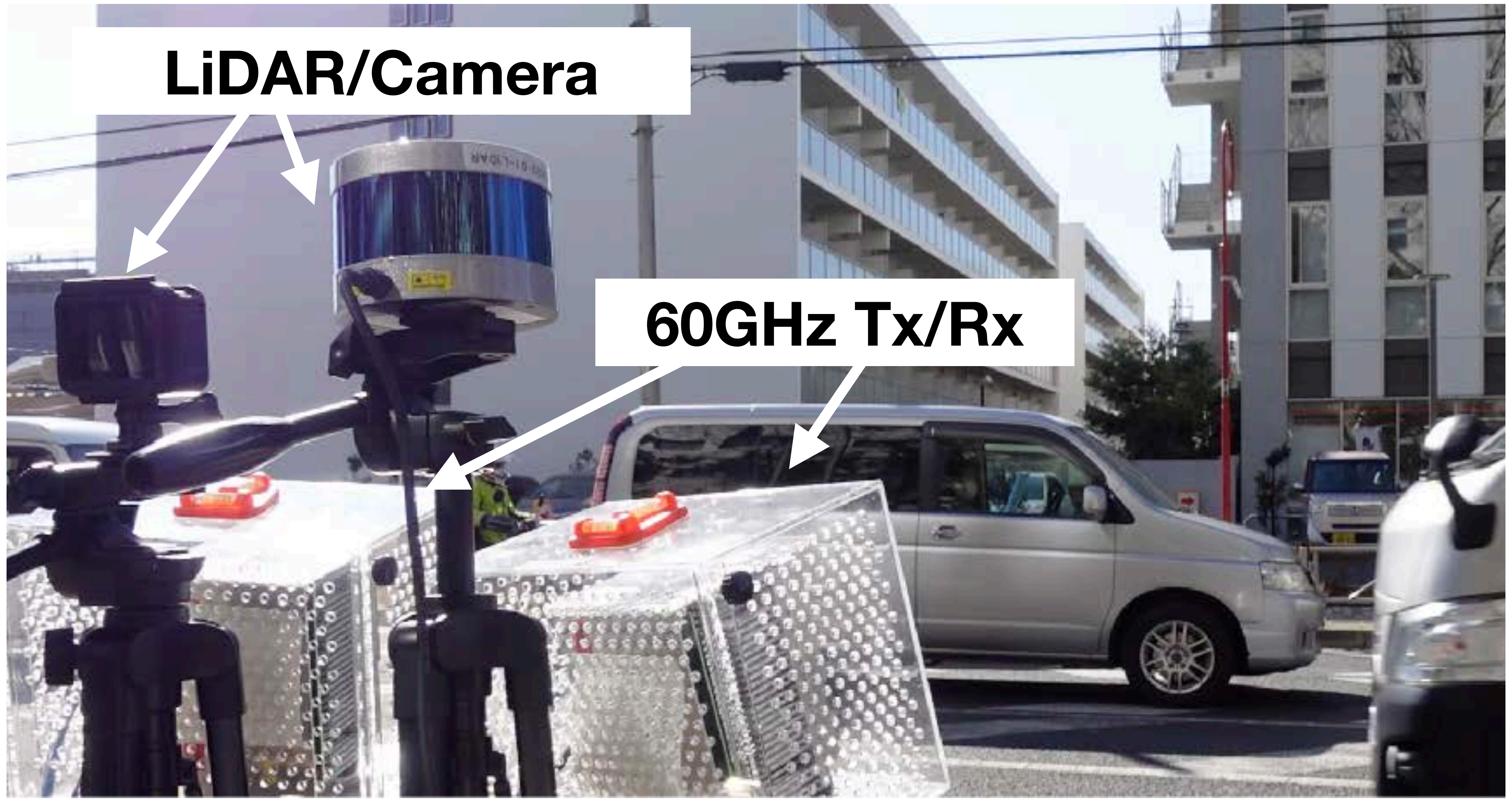


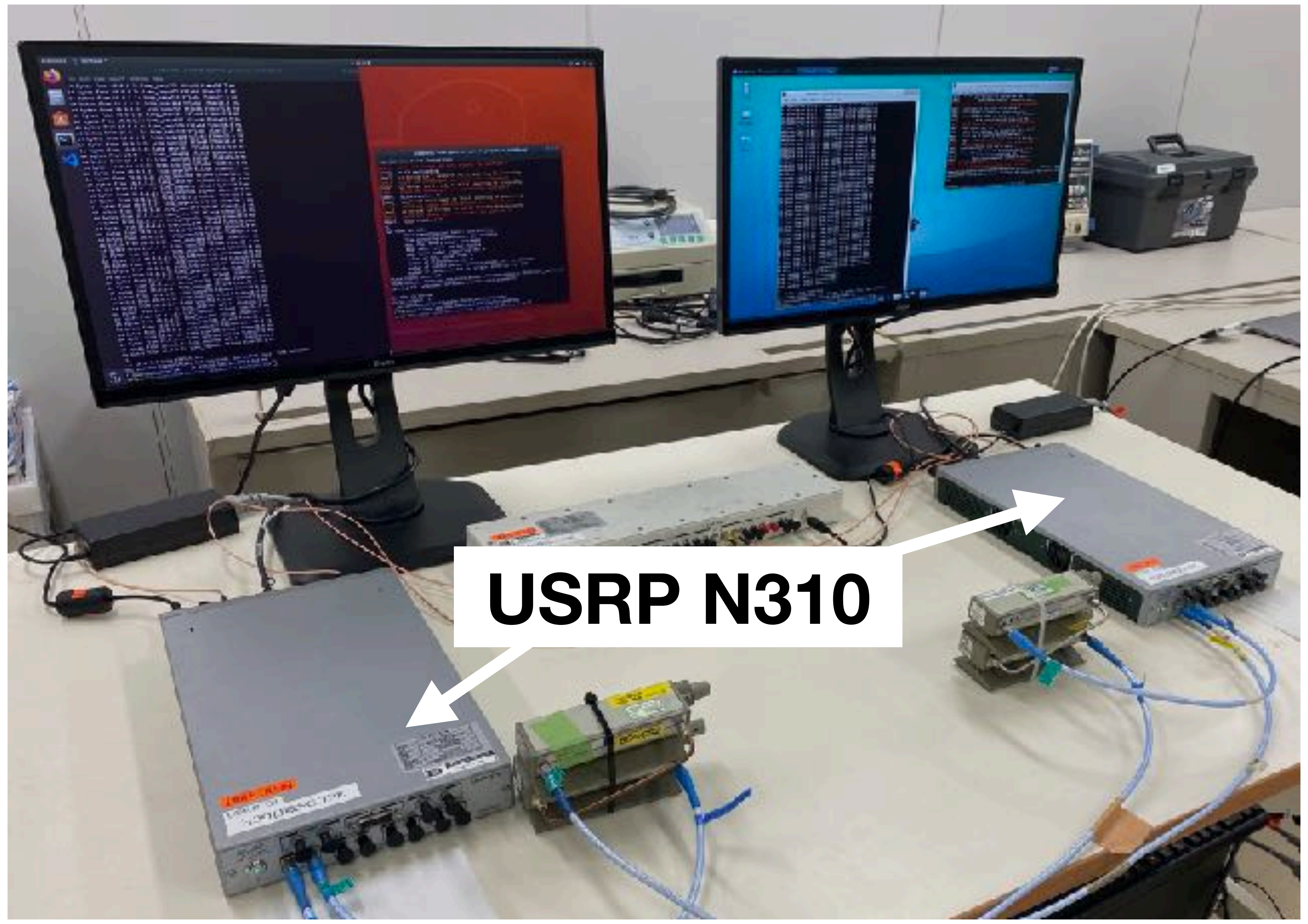
[9] H. Iimori et al., *IEEE Wireless Commun. Lett.*, 2020.
[10] H. Iimori et al, *IEEE Access*, vol. 9, pp. 74471-74487, May, 2021

Experimental Studies w/ KKE and KDDI

- Software-Defined Radio + Open Air Interface (OAI)
  - Robust CoMP over millimeter-wave channels
  - GF-NOMA on 5GNR physical layer
- Blockage modeling over 60GHz channels

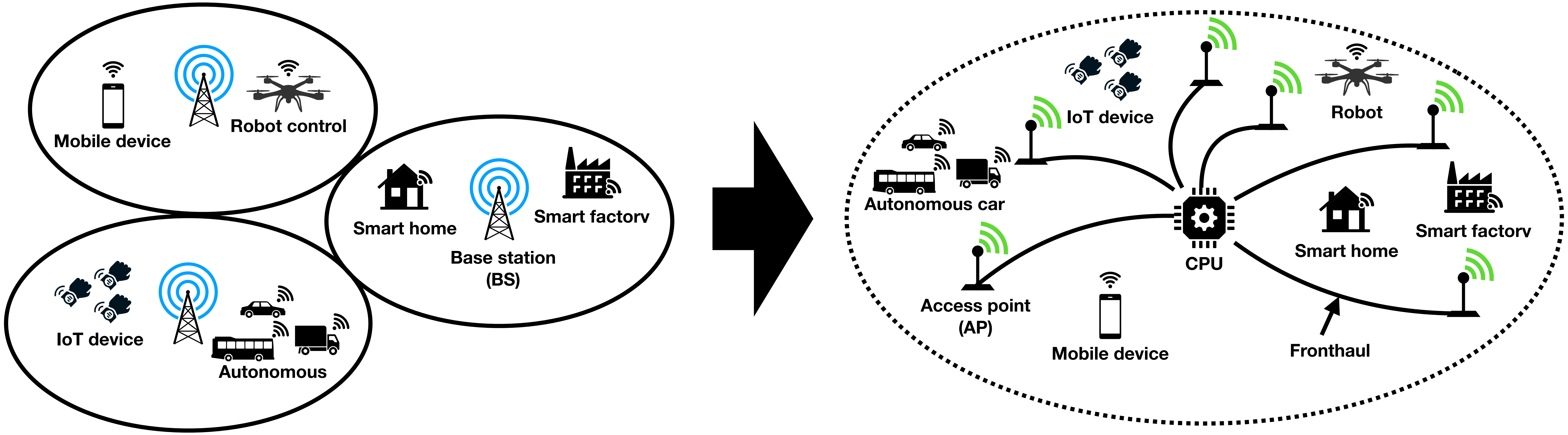






Cell-Free Network Technologies

- Mobile communications remarkably evolved throughout the five generations. However, its architecture is still based on a well-known cellular network that was proposed in 1947. Although higher frequency reuse factor increases the capacity, this leads to stronger inter-cell interference and makes user-centric design difficult.
- Cell-free networks composed of a central processing unit (CPU) and spatially distributed access points (APs) make it possible. Our team proposed grant-free access for cell-free massive MIMO [7] and beam-former designs for more general cell-free networks [8].



[7] H. Iimori, T. Takahashi, K. Ishibashi, G. T. F. de Abreu, and W. Yu, *IEEE Trans. Wireless Commun.*, June 2021.
[8] K. Ando, H. Iimori, T. Takahashi, K. Ishibashi, and G. T. F. de Abreu, *IEEE Access,* vol. 9, pp.102770-102782, July 2021.

Energy Harvesting Wireless Sensor Networks

- To obtain big data from a real world (for digital twin), wireless sensors are essential. Sensor networks must be maintenance-free, scalable, reliable, and secure.
- Our achievements:
  - Energy Neutral Receiver-Initiated MAC [11] [Battery-Free / High Scalability / Low Power Consumption]
    - Based on the instantaneous output power of energy harvester, each sensor node autonomously forms the network.
  - Age of Information (AoI) Minimization [12] [Data Freshness]
    - Theoretical design to guarantee freshness of sensing data over the network.
  - Packet Aggregation / Encryption-then-Compression [13] [Low Power Consumption / Secrecy]
    - The way to reduce transmission data size over the multi-hop network while all data are encrypted by every users.

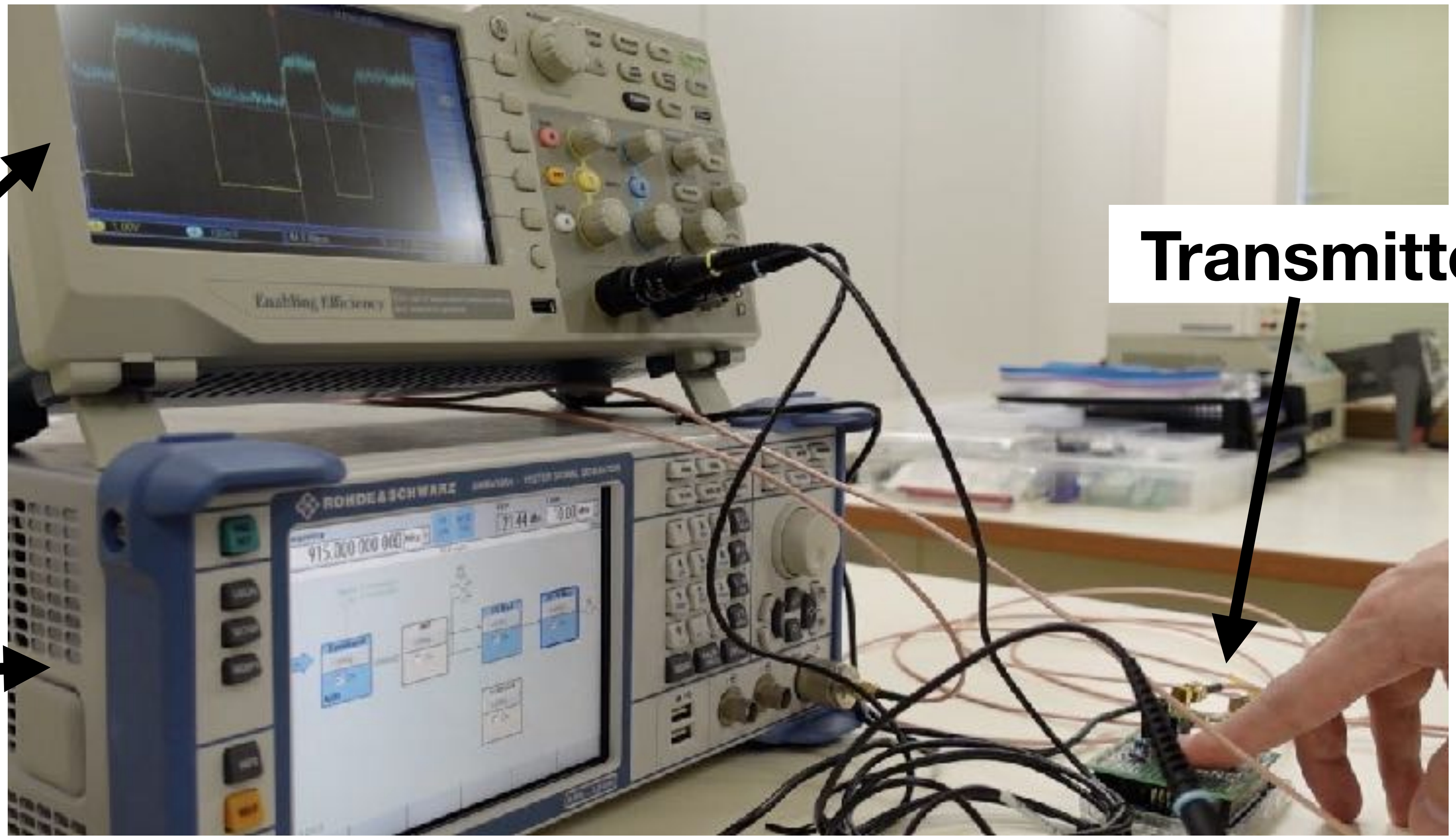
[11] T. Kawaguchi, R. Tanabe, R. Takitoge, K. Ishibashi, and K. Ishibashi, in *Proc. IEEE CCNC 2018*, Las Vegas, NV, Jan. 2018.
[12] N. Hirosawa, H. Iimori, K. Ishibashi, G. T. F. de Abreu, *IEEE Access*, vol. 8, pp. 219934 – 219945, Nov. 2020.
[13] R. Yatsu, T. Hara, K. Ishibashi, S. Tsuchiya, and H. Endo, in *Proc. APSIPA ASC 2020*, Virtual Conference, Dec. 2020.

Ambient Backscatter Communications

- We proposed new transmitter that reflects or absorbs ambient radio-frequency signals using a complex impedance load or delay-circuit based on a SAW/BAW filter.
- This works with off-the-shelf wireless standards, such as IEEE802.11 or TV broadcasting and consumes around 250nW for transmission.
- We further proposed efficient receiver design for the proposed transmitter, which can enlarge communication range.

Received Signal
(Reflected Signals)

Ambient LTE
Signals



Transmitter

[14] T. Hara, R. Takahashi, and K. Ishibashi, *IEEE Access*, vol. 9, pp. 89210 – 89221 June 2021,