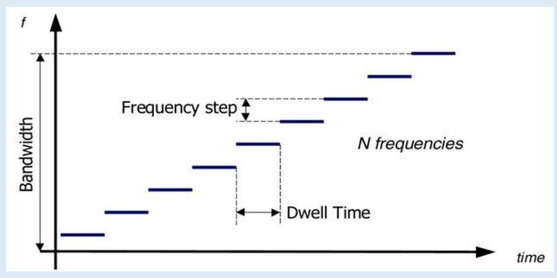
Communication and Sensing for 6G Cellular Networks

CSR Group

OFDM-based Sensing Function

Motivation

- Millimetre wave in both radar sensing and cellular communications
- Similar hardware for sensing and communication
- 'Sensing' brings the new ability of 'see' for 6G
- OFDM is similar to stepped frequency radar

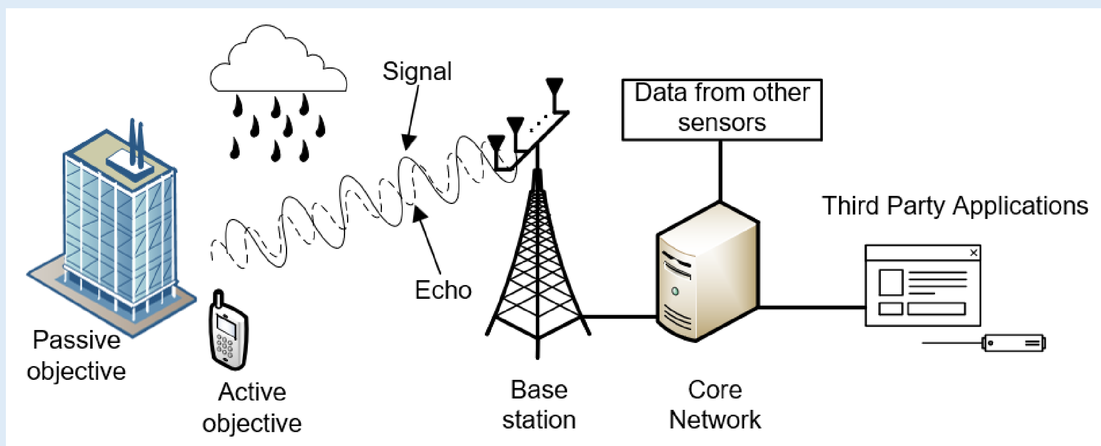


Stepped Frequency Radar

Challenges:

- Interference/collision management
- Resource allocation
- Information abstracting
- Cooperative sensing
- … …

Network Structure



Typical 3GPP Use Cases

Smart Home	Smart City	Smart Factory	Smart Traffic
Intruder detection	Rainfall monitoring	AGV detection and tracking in factories	Pedestrian/animal intrusion detection
Seamless XR streaming	Sensing at crossroads with/without obstacle	AMR collision avoidance	UAV flight trajectory tracing

OFDM-based Sensing

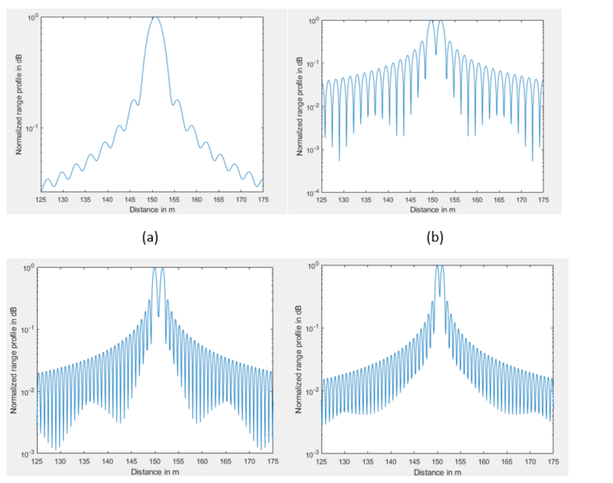


*Figure: Performance of OFDM-based sensing, where (a) bandwidth = 47 MHz, range resolution = 1.5m, **failed sensing**; (b) **bandwidth = 93 MHz**, range resolution = 1.5m, successful sensing; (c) bandwidth = 186 MHz, range resolution = 1.5m, successful sensing; and (d) bandwidth = 186 MHz, **range resolution = 1 m**, successful sensing.*

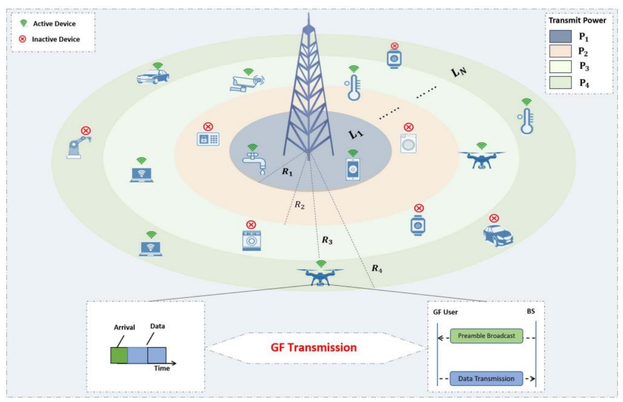
Location-dependent Power Control [1]

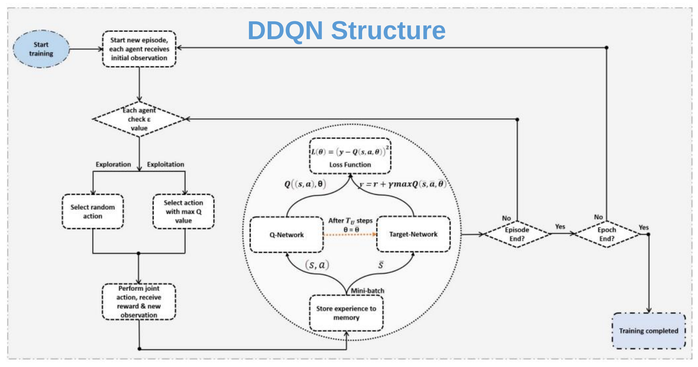
Motivation:

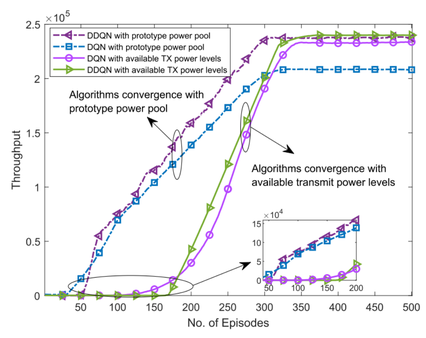
- Echoes/pilot signals arrive like grant-free (GF) transmission
- Average loss is related to communication distance (i.e., locations)
- Closed-loop power control is costly

Our Solution:

- For each location, group multiple transmit power levels in one power pool
- Device chooses one of the power levels to send pilot signals for active sensing
- Successive interference cancellation (SIC) technique is applied at the receiver







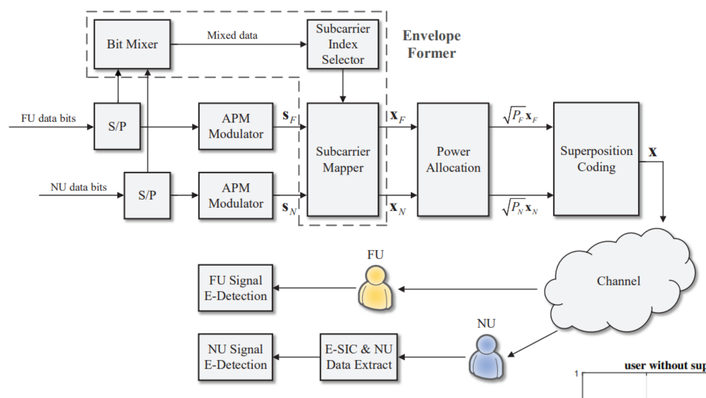
Insight:

- Fast convergence in new environment

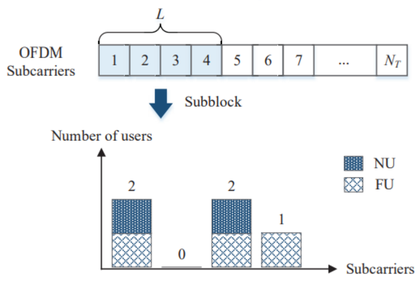
Further Steps:

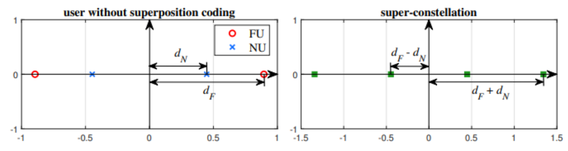
- Location dependent radio frequency map design for both active sensing and passive sensing
- Collision relaxing strategies

Informative Envelope Modulation [2]

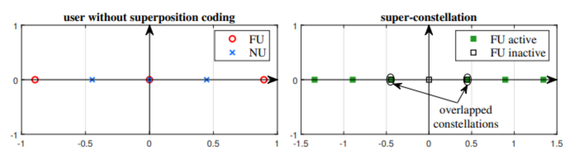


Example

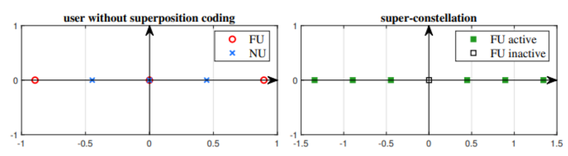




(a) OFDM-NOMA



(b) IM-NOMA



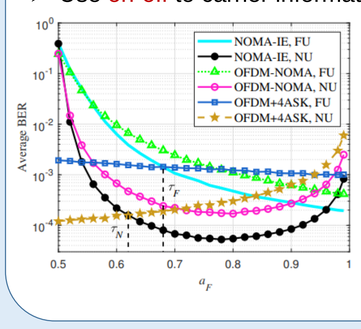
(c) NOMA-IE

Motivation:

- High sensing accuracy needs large bandwidth and long OFDM period
- Sensing waveform needs a constant envelope

Our Solution:

- Feed multiple users in one OFDM subcarrier
- Use on-off to carrier information



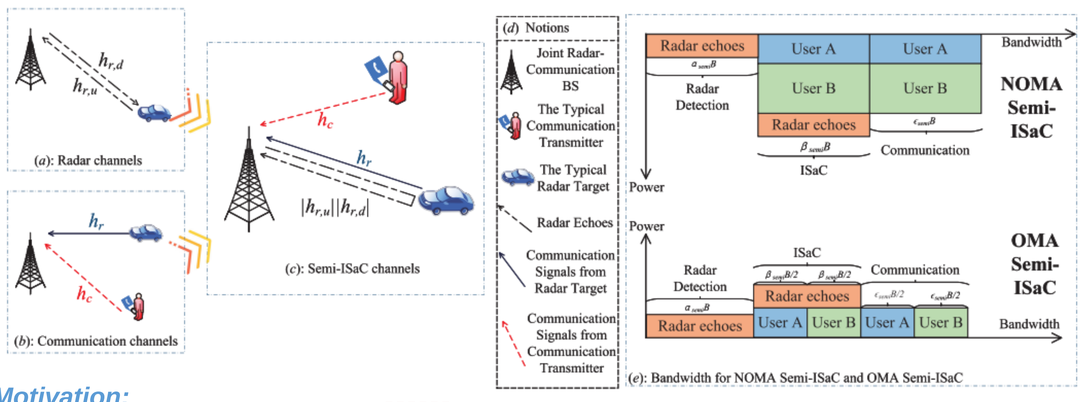
Insight:

- High energy efficiency

Further Steps:

- Waveform-dependent on-off coder design

Joint Power and Bandwidth Management [3]



Motivation:

- For a tracking task:

$$\tilde{z}_{\mathrm{com}}(t) = b\sqrt{P_{\mathrm{com}}}r(t) + n(t)$$
$$+\sqrt{P_{\mathrm{rad}}}\sum_{m=1}^{N} a_m[x(t-\tau_m) - x(t-\tau_{m,\mathrm{pre}})].$$

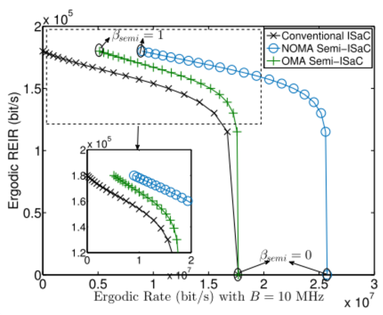
Power Allocation — A Prediction Signal

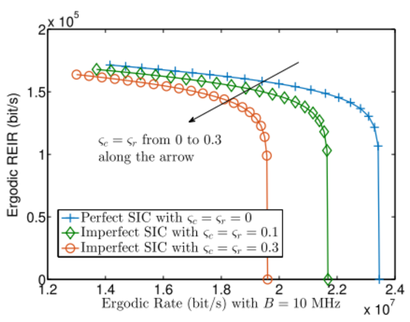
Our Solution:

Integrated sensing and communication (ISaC) ⇄ Non-orthogonal multiple access (NOMA)

Sensing techniques →

← Power allocation techniques





Insight:

- We evaluate the sensing performance bit/s

Further Steps:

- Optimising the joint power and bandwidth allocation
- Robust detection techniques

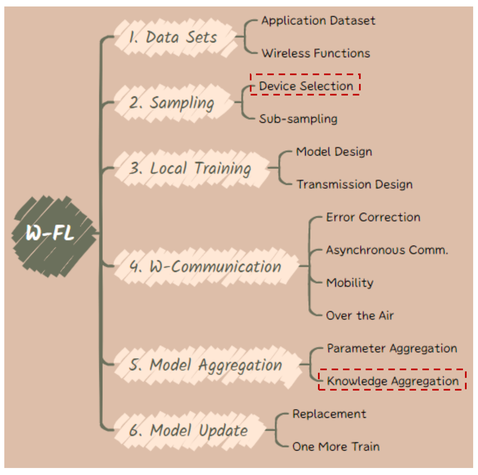
Federated Semantic Information Learning [4]

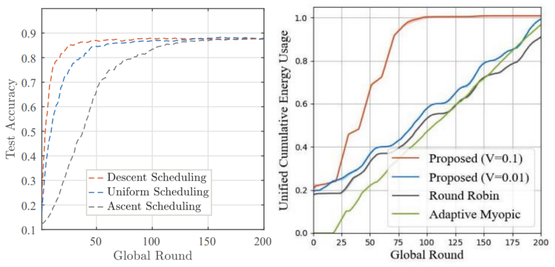
Motivation:

- Millimetre wave sensing has relatively low range resolution (>0.1 m) and no ability of recognition
- Multi-sensor fusion is necessary, sensors have different neural networks

Our Solution:

- Wireless federated learning
- Transmit model-level 'semantic' information
- Schedule different temporal devices



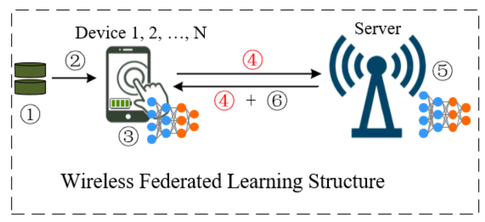


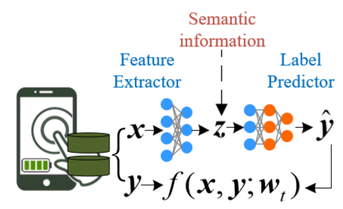
Insight:

- Keep similar performance with less communication overhead and energy consumption

Further Steps:

- Test real sensing tasks
- Design generic semantic information





[1] M. Fayaz, **W. Yi**, Y. Liu and A. Nallanathan, "Transmit Power Pool Design for Grant-Free NOMA-IoT Networks via Deep Reinforcement Learning," in IEEE Transactions on Wireless Communications, vol. 20, no. 11, pp. 7626-7641, Nov. 2021.
[2] Z. Xie, **W. Yi**, X. Wu, Y. Liu and A. Nallanathan, "Is the Envelope Beneficial to Non-Orthogonal Multiple Access?" submitted to IEEE Transactions on Communications. (available: https://arxiv.org/abs/2210.13060)
[3] C. Zhang, **W. Yi**, Y. Liu and L. Hanzo, "Semi-Integrated-Sensing-and-Communication (Semi-ISaC): From OMA to NOMA," in IEEE Transactions on Communications, vol. 71, no. 4, pp. 1878-1893, April 2023.
[4] Z. Chen, **W. Yi**, Y. Liu, and A. Nallanathan, "Communication-efficient federated learning with heterogeneous devices," in Proc. IEEE International Conference on Communication (ICC), Rome, Italy, pp. 1-6, May 2023.