Universitat Pompeu Fabra Barcelona

AI-Driven Centralized Multi-AP Joint Scheduling for Wi-Fi

Boris Bellalta
Universitat Pompeu Fabra, Barcelona, Spain

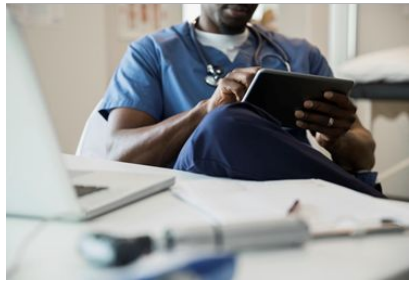
October 28th, 2026
2026 Sixth ITU-T SG15 Workshop on “AI-enhanced Fibre in-premises Network for ION-2030” - Xi’an, China

Today's Wi-Fi "dense" deployments

- Multiple Access Points are deployed together to offer better coverage (higher MCSs), and thus 'better service'.
  - Home, working environments, open spaces.
  - Industrial plants (robots, sensors/actuators).
  - Location Based Entertainment scenarios.
- However: higher contention (more APs sharing the same spectrum).
  - Higher uncertainty.
  - Lower reliability (e.g., worse latency predictability).

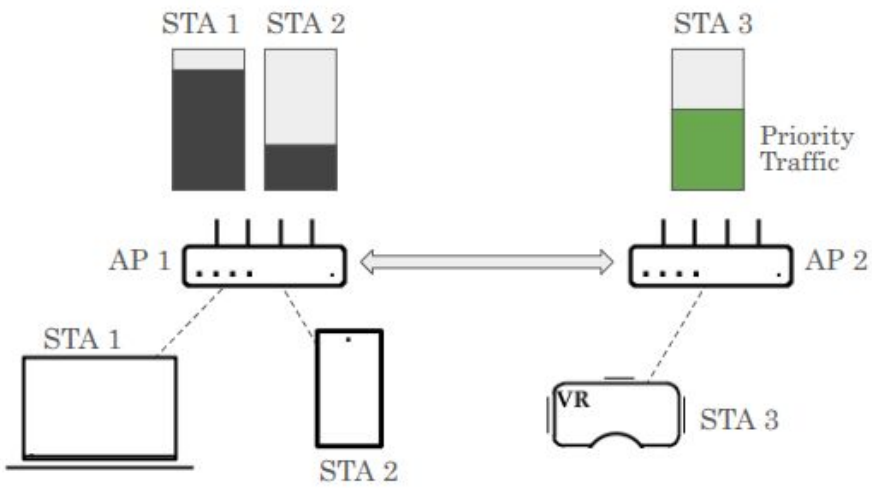


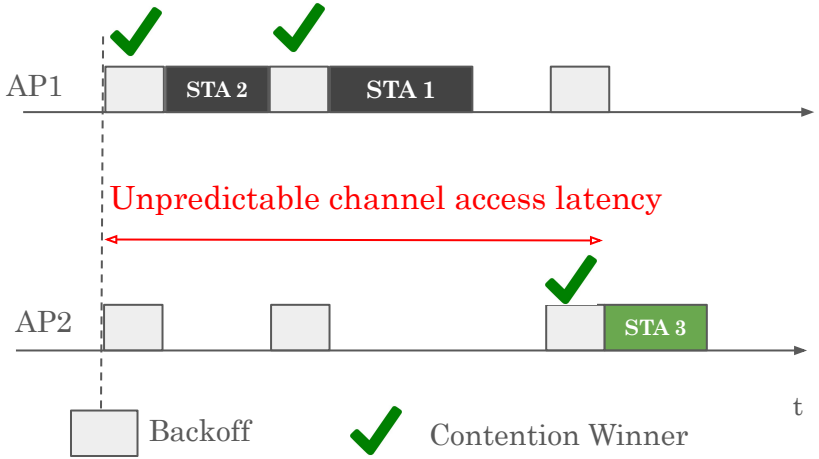




Wi-Fi unreliability

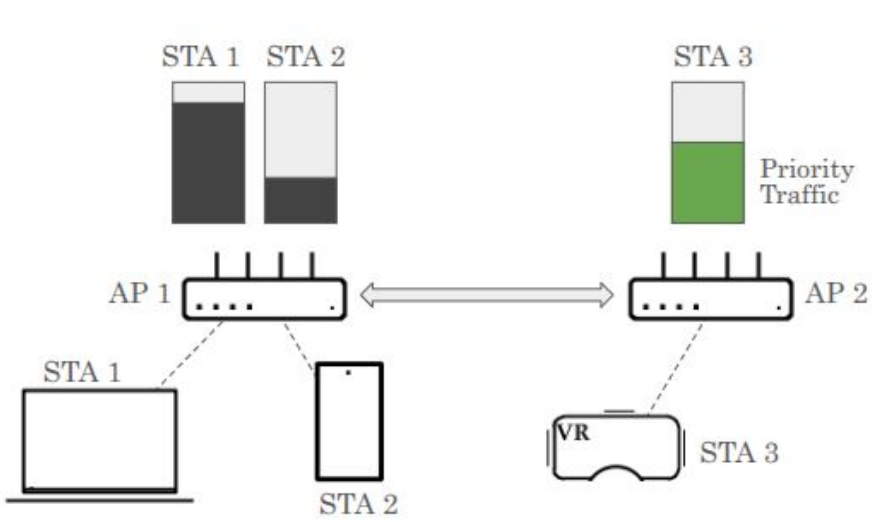
- **Default channel access**: Uncoordinated → No channel access guarantees

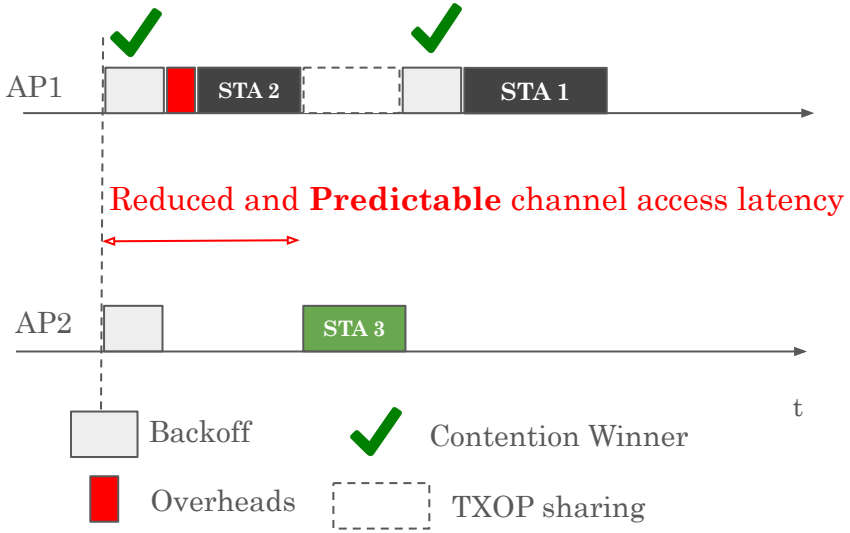




Inter-AP coordination

- **Inter-AP TXOP sharing:** Reduces latency and improves ‘predictability’

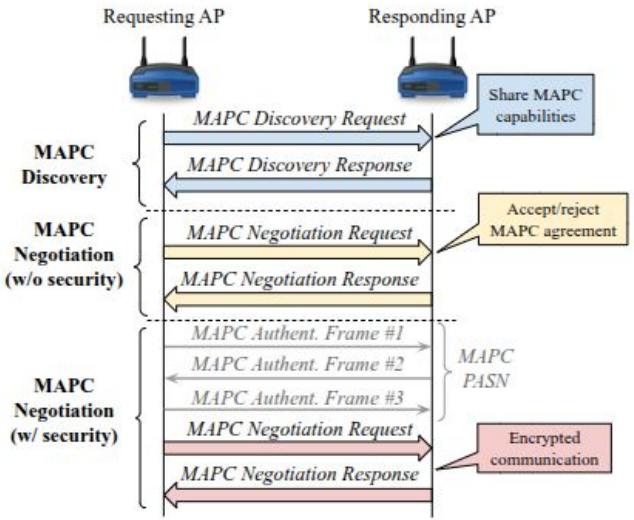




Multi-AP coordination (MAPC)

Nearby APs coordinate TX over the air

- Pros: Reduce ch. contention, improve resource sharing
  - Higher throughput & improved worst-case latency
- Cons: Extra signaling overheads and complexity
  - Discovery / Management; per TXOP signaling



Summary of the main MAPC schemes defined in the IEEE 802.11bn.

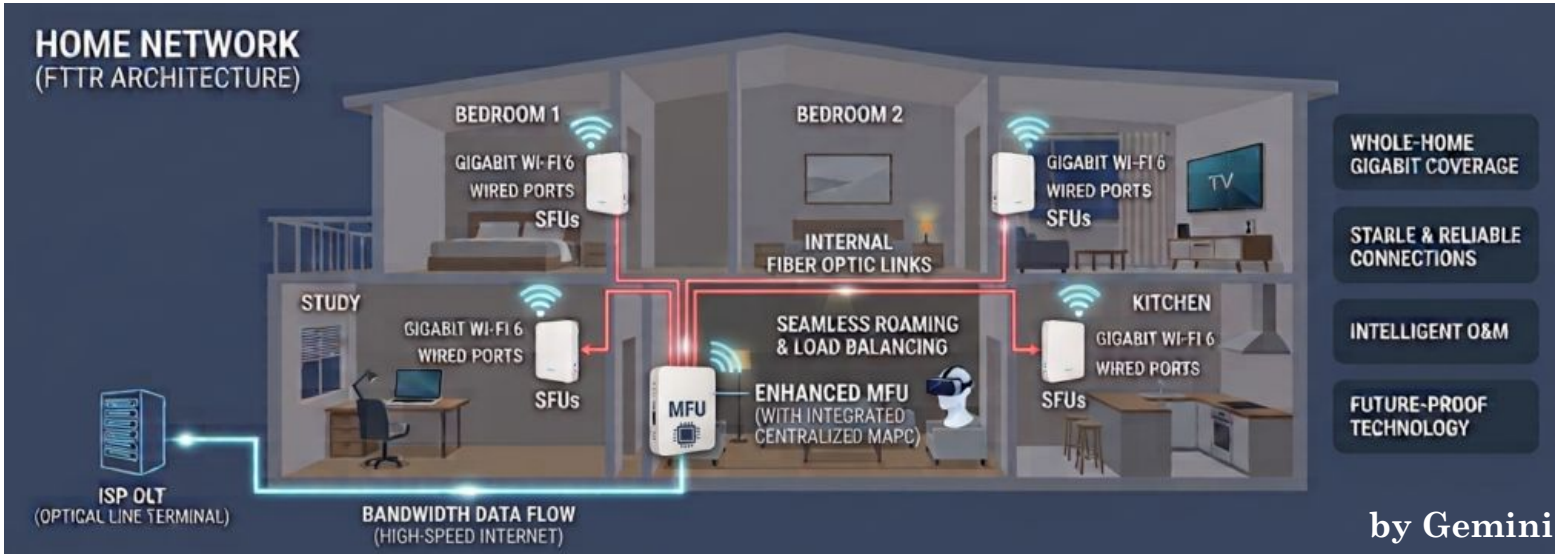
MAPC scheme	Primary objective	Core mechanism	Layer of operation
Co-BF	Enhanced medium utilization	Multi-AP beamforming with null steering for concurrent transmissions	PHY
Co-SR	Enhanced medium utilization	Coordinated concurrent downlink transmission through power control	PHY/MAC
Co-TDMA	Efficient resource sharing	Subdivision of a TXOP and inter-AP scheduling	MAC
Co-RTWT	Protection for scheduled traffic	Coordination of R-TWT schedules between OBSS	MAC
Co-CR	P2P communication enhancement	Recommended channels list for P2P transmissions	MAC

Wilhelmi, Francesc, et al.,. "A **Tutorial on IEEE 802.11 bn Multi-AP Coordination for Wi-Fi 8: From Standardization to Performance Evaluation.**" arXiv preprint arXiv:2606.13759 (2026).

Multi-AP coordination (MAPC)

- **IEEE 802.11bn** (Co-TDMA, Co-SR, Co-BF)**:**
  - Decentralized, only pairwise MAPC agreements between APs.
  - Buffer and CSI state information requested per TXOP (large overheads).
  - Inter-AP sharing decisions based on instantaneous information and/or simple rules.
    - E.g.: Co-TDMA: always share the TXOP 50-50.
- **Centralized MAPC** ('brain' + lightweight APs):
  - APs share information with a central controller via a fast (optical) backhaul.
  - Central controller makes joint decisions (which APs transmit at every TXOP).
  - **Challenge**: Manage latency between central controller decisions and APs.
  - **Opportunity**: Run complex AI/ML models.

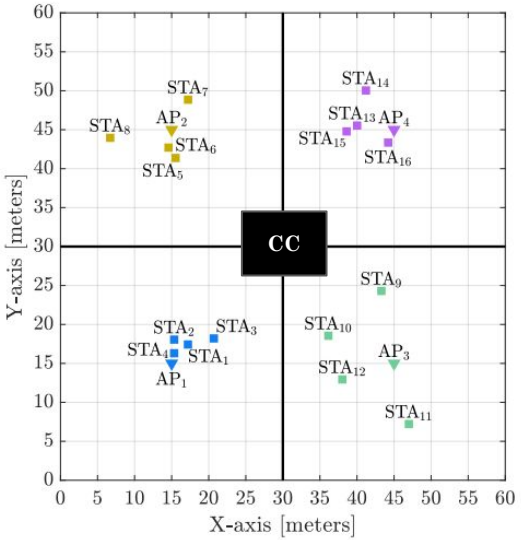
Centralized MAPC and FTTR

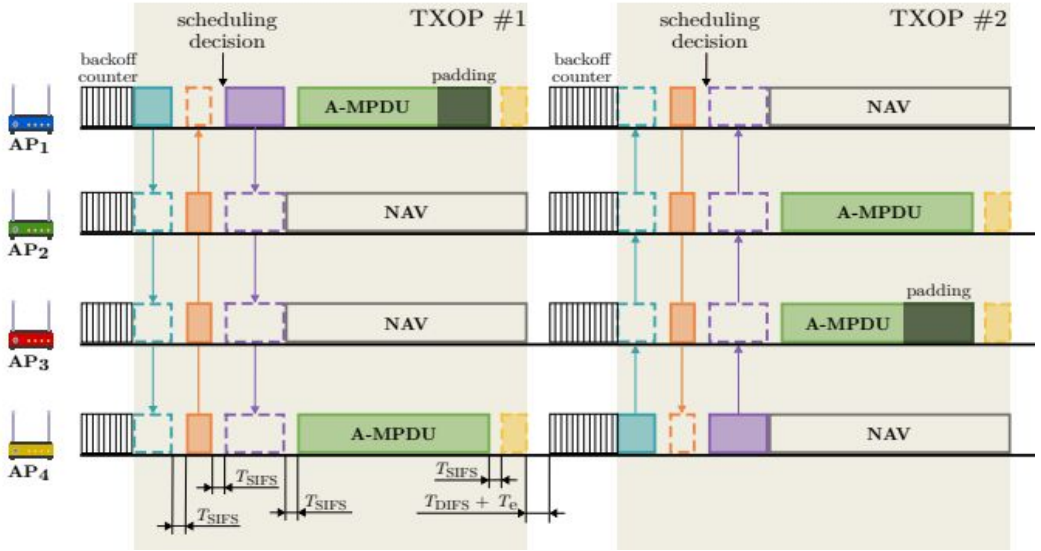


Open challenges: Delivering real-time management commands from the MFU to room SFUs is hampered by optical DBA scheduling delays, protocol encapsulation overhead, and queue contention, which threaten the strict microsecond timing required for seamless Wi-Fi coordination.

Centralized MAPC: DRL-based Scheduling

Scenario: Co-SR, 4 APs (beyond 11bn), only DL traffic. CC Scheduler Goal: Minimize Latency



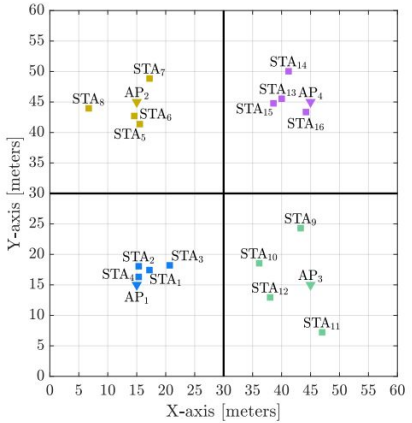


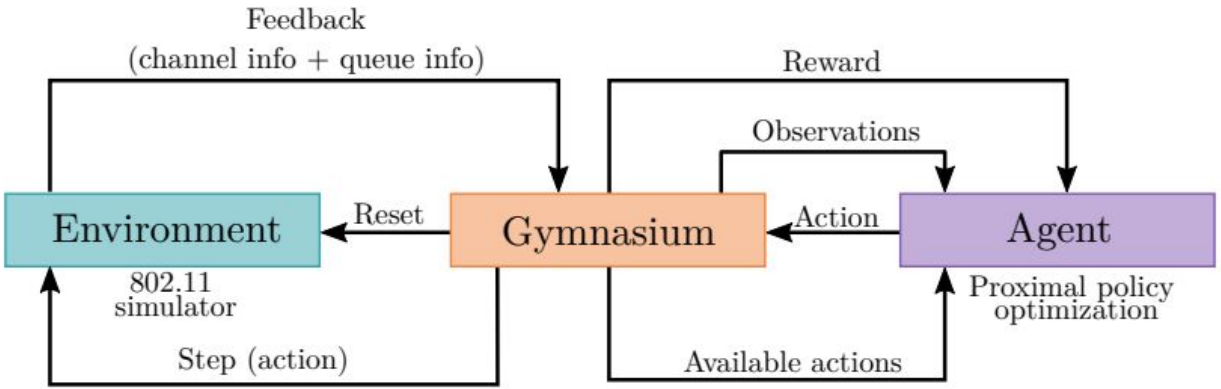
Complex interdependencies between latency and efficiency: Sometimes, it is better to avoid selecting the group of AP-STA pairs with the oldest packet and instead prioritize more efficient transmissions.

Nunez, David, et al., "**Deep Reinforcement Learning-Based Scheduling for Wi-Fi Multi-Access Point Coordination**." IEEE Transactions on Machine Learning in Communications and Networking (2026).

Centralized MAPC: DRL-based Scheduling

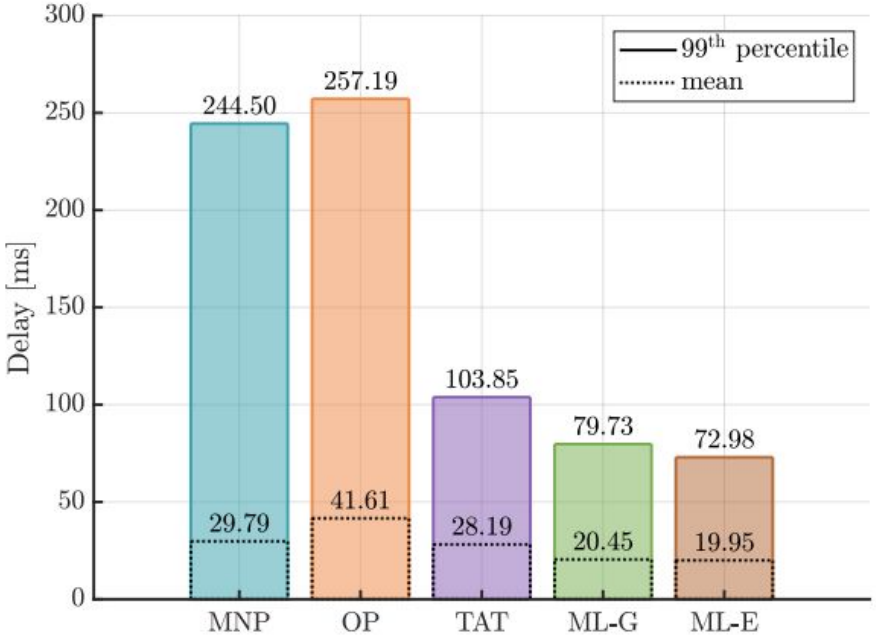
- Can an AI/ML-based scheduler learn how to select the best group of AP-STA pairs so we can minimize the Wi-Fi latency?
  - **Inputs**: Traffic load per AP-STA pair; Buffer state for each AP-STA pair; HoL delay;
  - **Output**: Group of AP-STA pairs that will transmit (Co-SR) in the next TXOP.





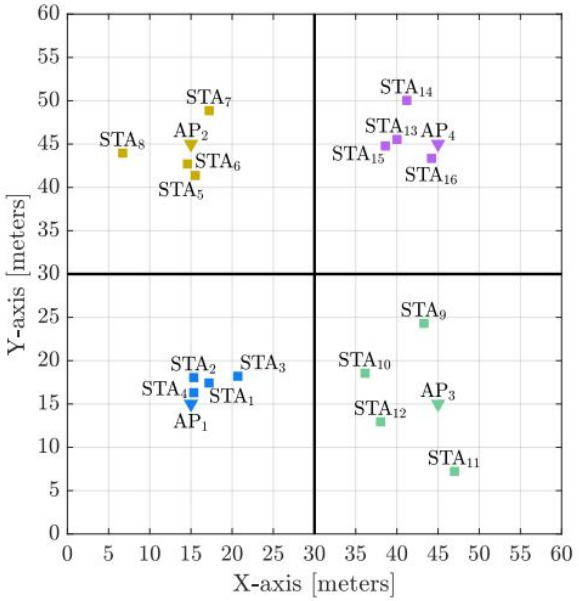
Nunez, David, et al., "**Deep Reinforcement Learning-Based Scheduling for Wi-Fi Multi-Access Point Coordination**." IEEE Transactions on Machine Learning in Communications and Networking (2026).

Results (single deployment)



ML-G: Changing station positions and AP-STA loads.

ML-E: Changing only AP-STA loads

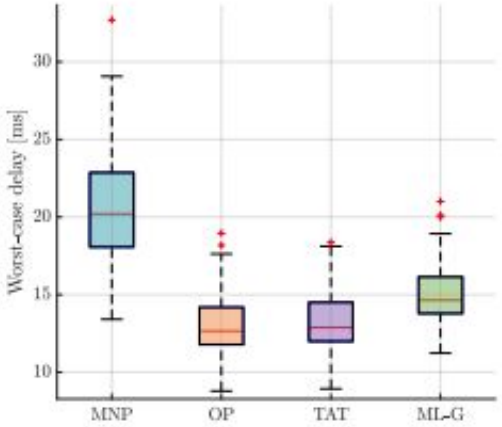


- **MNP – Max Number of Packets:** Selects the group of AP-STA pairs that maximizes the number of packets transmitted.
- **OP – Oldest Packet**: Selects the group of AP-STA pairs that contains the oldest packet while also maximizing the number of packets transmitted in a TXOP.
- **TAT – Traffic Alignment Tracking**: A smart algorithm designed to combine the benefits of MNP and OP.

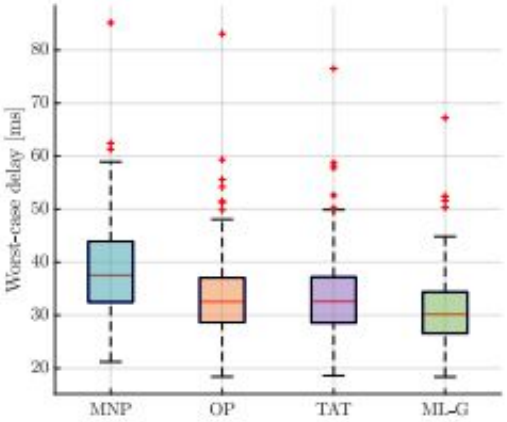
upf. WN

Results (100 deployments)

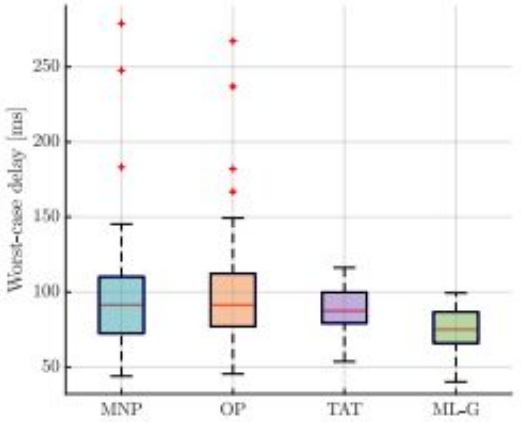
- 4 APs, fixed; 16 stations, randomly placed
- Variable load per AP-STA
  - Low [10 - 30 %], Medium [30 - 50 %], and High [50 - 70 %] of the full-buffer station throughput.



(a) Low load



(b) Medium load



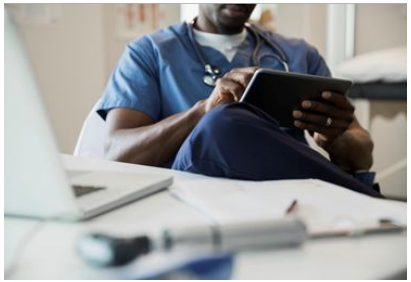
(c) High load

Takeaways, and Ways Forward

- MAPC enables APs to share spectrum resources more efficiently while minimizing channel access contention.
- Centralized MAPC enables better resource allocation through complex AI/ML models.
- Open challenges include the delay between the CC and APs for both decisions and data collection, with the deployment of centralized MAPC over FTTR being of special interest.
- Centralized MAPC can evolve to split MAC/PHY solutions, enabling advanced MAPC functionalities such as Co-OFDMA and Joint Transmission (JT) that require tight synchronization and data sharing.







References

[1] Wilhelmi, Francesc, Boris Bellalta, Giovanni Geraci, Lorenzo Galati-Giordano, Francesca Meneghello, Aleksandra Kijanka, Iñaki Val, and David López-Pérez. "A **Tutorial on IEEE 802.11 bn Multi-AP Coordination for Wi-Fi 8: From Standardization to Performance Evaluation.**" arXiv preprint arXiv:2606.13759 (2026).

[2] Nunez, David, Francesc Wilhelmi, Maksymilian Wojnar, Katarzyna Kosek-Szott, Szymon Szott, and Boris Bellalta. "**Deep Reinforcement Learning-Based Scheduling for Wi-Fi Multi-Access Point Coordination**." IEEE Transactions on Machine Learning in Communications and Networking (2026).

Acknowledgements

This talk and presentation are supported by projects:

TRUE Wi-Fi PID2024-155470NB-I00 funded by MICIU/AEl/10.13039/50110 0011033 and by "ERDF A way of making Europe";

and

MLDR (Chist-ERA WAI 2022) PCI2023-145958-2, financiado por MCIU/AEI/10.13039/501100011033 y cofinanciado por la Unión Europea.



Universitat Pompeu Fabra
Barcelona

Boris Bellalta
boris.bellalta@upf.edu
Universitat Pompeu Fabra, Barcelona, Spain